# WP 1.6 Whole-State Network Impact Assessment: Final Report

**Milestone Report 4: 14/03/2025**

**Report for C4NET**

# Project Consortium


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# Executive Summary

This report corresponds to Milestone 4 “Final Report” for Work Package 1.6 (WP1.6) "Whole-State Network Impact Assessment" as part of the Centre for New Energy Technologies (C4NET)'s Enhanced System Planning (ESP) project.

The project assesses the impact of electrification on 6 subtransmission networks and extrapolates MV-LV network assessments for different types of MV feeders (carried out in WP1.5) to the entire state of Victoria considering a baseline scenario without DOEs and scenario with a progressive adoption of DOEs by residential customers. The following considerations are used for the scenarios:

- <u>Without DOEs</u>: all PV inverters have 5kVA rated capacity and their functions (Volt-Watt and Volt-Var, following AS/NZS4777.2:2020 Australia A settings) are enabled, and DOEs are not implemented.
- <u>With DOEs</u>: PV inverter functions are still enabled, and DOEs (both exports and imports) are implemented on the following adoption rates:
  - ✓ Export DOEs (and upgrade to 10kVA PV inverter)
    - 2028 - apply to new PV customers.
    - 2033 - apply to 50% of existing PV customers.
    - 2038 - apply to 100% of existing PV customers.
  - ✓ Import DOEs
    - 2033 - apply to new EV customers.
    - 2038 - apply to 100% of existing level-2 EV customers.
    - Only level-2 EV demand will be managed

**Key findings** from the simulations are presented below, along with **Recommendations** to advise Victorian distribution companies on network planning beyond 2030. These recommendations will ultimately help accelerate the electrification of distribution networks in alignment with Victoria’s goal of achieving net-zero emissions.

## Key Findings

## Whole-State Extrapolation

### MV-LV Voltage Assessment

1. In the next decade (starting from 2023), PV penetration is expected to grow steadily, and voltage issues can emerge as a limiting factor for further PV uptake. Typically for those ZSS with MV-LV networks less robust to voltage changes (i.e., ZSS with many urban and short-rural feeders).
2. From 2033, the PV uptake slows down and net demand rises significantly due to the presence of increasing EV adoption and residential electrification (i.e., heating/cooling and hot water systems), which further exacerbate voltage issues. Note that since the voltage regulation devices in this study are operated to ensure equal voltage headroom and footroom, more voltage drop issues have emerged as a result of managing PV-related voltage rise issues. This indicates that voltage

regulation devices (i.e., tap positions) have been exhausted to maintain customer voltages within both upper and lower limits.

3. The adoption of export DOEs by residential customers effectively mitigate voltage rise issues caused by PV export once applied to all residential PV customers (by 2038). However, since PV inverters functions (i.e., Volt-Watt and Volt-Var) already enforce PV curtailment to help regulate voltages in the scenario without DOEs, the additional benefits of export DOEs may be limited.

4. Since import DOEs are applied only to Level-2 EV charging, only a small fraction of the demand is managed (up to 30%). Over time, the demand from residential electrification (i.e., heating/cooling and hot water systems) becomes significant, resulting in more voltage drops and heavy asset utilisation. Consequently, managing Level-2 EV demand alone is insufficient to resolve both voltage and thermal l issues.

### MV-LV Thermal Assessment

1. By 2028, about 4% (~6,800, out of the estimated 170, 000) of state distribution transformers are expected to experience overloading, escalating to 14% (~23,800) by 2033, and 24% (~40,800) by 2038. This rapid increase in overloaded transformers could severely limit further DER uptake without network augmentation.

2. The adoption of import DOEs by residential customers shows positive impacts on thermal performance of distribution transformer from 2033 onwards. The number of overloaded transformers decreases by 1% (~1,700) to 5% (~8,500) annually between 2033 and 2053, with 2% (~3,400) to 5% (~8,500) fewer transformers experiencing extreme overloading (>150%). These improvements will significantly reduce required network augmentation investments across the state.

### PV Curtailment Assessment

1. For the scenario without DOEs, PV curtailment increases from 410 GWh (6%) in 2023 to 3,878 GWh (24%) in 2053 as PV penetration grows from 27% to 47%. This curtailment is mainly due to 5 kVA inverter capacity limits and Volt-Watt function constraints, limiting renewable energy penetration across MV-LV networks.

2. For the scenario with DOEs, initially, export DOEs reduce curtailment slightly (8% or 983 GWh in 2028, compared to 9% or 793 GWh without DOEs). However, as export DOE adoption increases, curtailment surpasses the without-DOEs scenario due to additional constraints and the "Equal Allocation" strategy. By 2033, curtailment reaches 1,865 GWh (13%), and by 2053, it reaches 7,872 GWh (34%). Note that PV inverters are upgraded to 10 kVA in the DOEs scenario, unlocking greater PV potential but also increasing curtailment.

### EV Management Assessment

1. With residential customers adopting import DOEs for Level-2 EVs from 2033, Victorian residential customers should expect some EV charging delays. Analysis shows these delays average around 5 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

## Impact Assessment of Subtransmission Networks

### Terminal Station Assessment

1. Terminal stations are expected to face severe overloading issues between 2033 and 2048, with 2033 peak utilization rates of 119-146% and overutilization periods of 8-14 hours during peak demand days. ERTS and TTS are the earliest to face significant overloading by 2033, reaching 133% and 146% utilization respectively. By 2053, the situation worsens across all networks, with overloading reaching 131-345% and overutilization periods extending to 14-24 hours. ERTS and TTS show the most severe projections, potentially exceeding 340% utilization, while GNTS shows the least severe overloading at 131% by 2053, though still critical.
2. Terminal stations are expected to have diverse power factor performance from 2023 to 2053. Three stations (MBTS, SMTS, and TSTS) maintain power factors higher than the 0.9 statutory limit throughout the entire period. Four others face challenges: ERTS and GNTS drop below 0.9 by 2038, TTS by 2043, and CBTS by 2048. These power factor issues are projected to worsen over time for these four stations.
3. The adoption of import DOEs by residential customers consistently reduces load across all terminal stations, with impacts ranging from less than 1% in 2023 to 14% by 2053. ERTS shows the most significant reduction (14%, 318 MVA) by 2053. However, despite these reductions, all six terminal stations continue to exceed their thermal limits in the same years as in the scenario without DOEs. TSTS experiences a brief respite in 2033, with load reduction bringing it within thermal capacity (531 MVA) and potentially delaying upgrades by 5 years, but this benefit is short-lived. While import DOEs provide some load relief, they are insufficient to resolve the long-term thermal capacity issues or significantly delay the need for upgrades at these terminal stations.
4. The adoption of import DOEs by residential customers results in slight power factor improvements at terminal stations. GNTS shows improvement from 2043, while CBTS, ERTS, and TTS improve from 2048 onward. However, compared to the scenario without DOEs, these improvements are insufficient to bring any station into compliance with the statutory power factor limit (≥0.9).

### Subtransmission Voltage Assessment

1. Subtransmission networks are expected to face varying degrees of undervoltage issues projected to occur between 2033 and 2048, with TSTS being the only exception, showing no voltage issues throughout the assessment period (2023-2053). The percentage of affected buses ranges from 7% in GNTS-MBTS by 2033 to 39% in SMTS by 2038. These undervoltage problems primarily affect the 66kV networks, but some 22kV networks (secondary of ZSSs) are also impacted, indicating that OLTCs at both terminal stations and ZSSs, as well as capacitor banks, have reached their operational limits in maintaining voltage levels. The issues generally occur during early morning and peak periods (morning and evening) of the worst day (winter peak), attributed to high loading conditions caused by electrified heating systems, increased adoption of cooling systems, and rising EV usage by residential customers.
2. The adoption of import DOEs by residential customers generally results in slight improvements to subtransmission voltages, with effects becoming noticeable between 2038 and 2053, depending on the network. However, these improvements are largely insufficient to bring voltages within

statutory limits for most networks, when compared to the scenario without DOEs. The TTS subtransmission network stands out as an exception, where the small voltage improvement in 2038 is enough to eliminate voltage issues for that year, potentially delaying necessary upgrades by 5 years. Nevertheless, even for TTS, the improvements are not sufficient to maintain voltages within statutory limits after 2043.

**Subtransmission Thermal Assessment**

1. ZSS transformers across all subtransmission networks are expected to face escalating overloading issues. ERTS, SMTS, and TTS encounter concerning problems by 2033, CBTS and GNTS-MBTS by 2038, and TSTS by 2048. By 2053, overloading becomes critical, with 36% (GNTS-MBTS) to 100% (TTS) of transformers exceeding 150% utilization. Peak rates reach up to 441% (SMTS), with some networks experiencing overloads for an average of 11 hours during peak demand days.

2. Subtransmission networks are expected to face varying degrees of 66kV line overloading issues between 2038 and 2053. Four networks (CBTS, ERTS, SMTS, and TTS) face significant challenges, while GNTS-MBTS and TSTS are expected to remain without issues throughout the assessment period (2023-2053). By 2038, the affected networks show 10-23% of lines experiencing significant overload (110-150%) for 5-7 hours on average, with some lines in TTS already facing extreme overload (>150%). The situation worsens by 2053, with CBTS experiencing the most severe issues (62% of lines exceeding 150% utilization for over 8 hours), followed by TTS (40% of lines exceeding 150%). Peak utilization rates reach up to 241% in ERTS and 244% in TTS.

3. The adoption of import DOEs by residential customers across all six subtransmission networks results in slight loading reductions on ZSS transformers, observed from as early as 2028 in GNTS-MBTS to 2038 in TSTS. These reductions decrease both the intensity and duration of overloads, but upgrades remain necessary for all networks as the number of overutilized transformers has not significantly decreased, and capacity issues persist.

4. The adoption of import DOEs by residential customers reduces the intensity and duration of 66kV line overloads in CBTS, ERTS, SMTS, and TTS networks from 2033-2038. However, while providing some relief, these reductions are insufficient to eliminate the need for network upgrades as capacity issues persist.

## Recommendations

### Whole-State Extrapolation

1. **Continue implementing export DOEs** to enable larger export limits (greater than 5 kVA) where/when network conditions allow. This approach should allow some customers to generate more renewable energy and make a more efficient use of the network infrastructure, while mitigating both voltage and thermal issues.

2. **DOEs should not stop in exports, import DOEs should also be implemented** to mitigate high power flows, which is expected to be driven by widespread EV adoption and electrification of loads. However, **import DOEs should be extended to most if not all controllable loads** (e.g.,

heating/cooling) where possible, given that this study shows that implementing import DOEs only to level-2 EVs is not enough to solve voltage issues.

3. **Upgrade voltage regulation devices on MV-LV networks** across the state by expanding the tap range of zone substation OLTCs or by upgrading distribution transformers with additional tap positions. This will enable better voltage management and facilitate further DER uptake. Implement these upgrades starting with networks already experiencing problems, followed by those prone to future voltage issues.
4. **Upgrade distribution transformers facing significant (110%-150%) overload for long periods, and extreme (>150%) overload** to increase network capacity. Any upgrades should account for expected future loads to ensure sufficient capacity in the medium to long term, minimizing the need for frequent reinforcements.

## Subtransmission Networks

1. **Take measures to address the expected high loading conditions** at ERTS and TTS by 2033, at CBTS and TSTS by 2038, at SMTS by 2043, and at GNTS-MBTS by 2048. Options may include upgrading the substation's capacity, implementing demand management strategies, or exploring alternative power supply configurations (e.g., use interconnection with other subtransmission networks).
2. **Take measures to correct the expected low inductive power factor** at ERTS by 2038, at TTS by 2043, and at CBTS and GNTS by 2048. Options may include upgrading existing capacitor banks or installing additional ones.
3. **Conduct further studies with detailed modelling of the terminal stations of CBTS, SMTS, TTS**, including its transformers and OLTCs, since the current models do not include them. This would provide a more accurate assessment of voltage profiles under load electrification scenarios during peak demand days, potentially eliminating voltage issues on these networks.
4. **Upgrade ZSSs facing significant (110%-150%) overload for long periods, and extreme (>150%) overload** to increase network capacity. Any upgrades should account for expected future loads to ensure sufficient capacity in the medium to long term, minimizing the need for frequent reinforcements.
5. **Take measures to reduce the loading on subtransmission lines facing significant (110%-150%) overload for long periods, and extreme (>150%) overload** to increase network capacity. Options may include constructing new subtransmission lines, implementing demand management strategies, or exploring alternative power supply configurations (e.g., use interconnection with other subtransmission networks).
6. **Expand import DOEs** to cater for all controllable loads, given that this study shows that implementing import DOEs only to level-2 EVs already alleviate the demand on subtransmission networks, but it is not substantial. This will mitigate the expected surge in demand over the next 30 years. This strategy should reduce augmentation investments in both MV-LV and subtransmission networks.

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# Abbreviations and Acronyms

| | |
|---|---|
| AEMO | Australian Energy Market Operator |
| C4NET | Centre for New Energy Technologies |
| DER | Distributed Energy Resource |
| DNSP | Distribution Network Service Provider |
| ESP | Enhanced System Planning |
| EV | Electric Vehicle |
| LV | Low Voltage |
| MV | Medium Voltage |
| PV | Photovoltaics |
| ZSS | Zone Substation |

# List of Considerations and Assumptions

## Impact Assessment Stage

1. In cases where the provided OpenDSS model, which was provided by WP 1.4, lacked zone substation peak demand data, the information provided by the DNSPs was used instead.
2. For zone substations containing urban MV feeder type, it was assumed that half of these feeders are urban, while the other half are suburban.
3. For zone substations containing rural MV feeder type, it was assumed that half of these feeders are short rural, while the other half are long rural.
4. Network augmentation or planned connections/expansions are not considered in this study, i.e., distribution networks (both subtransmission and MV-LV) are assumed to remain unchanged throughout the assessment period (2023-2053).
5. Even though daily simulations are carried out, the voltage at the terminal station is assumed to be fixed to a certain value, which will depend on the subtransmission network being studied.
6. Thermal assessments are for normal operational conditions (i.e., no contingency).
7. Some large loads (e.g., interconnection to another DNSP), which do not represent zone substations, are assumed to have the same peak load throughout the simulation (e.g., if the peak load of this large load is 50MVA, it will be repeated for every half hour of the day).
8. Any generator connected to the subtransmission networks are assumed always ON and with the generation set with the value received from WP 1.4 (e.g., if the generation given on the OpenDSS file is 2MVA, it will be repeated for every half hour of the day).
9. Only peak demand days and shoulder days are considered in the impact assessment, while minimum demand days are out of the scope.
10. Battery storage is assumed to be unavailable in this study.
11. Any assumption made by WP 1.4 (distribution network models) and WP 1.5 (MV-LV network impact assessment) will also impact the results of this project. For their list of assumptions, please refer to their reports.

## Whole-State Extrapolation Stage

1. The CBD MV feeder type is not considered in this project. This means that in the whole-state extrapolation any zone substation containing CDB MV feeder type was excluded from the studies.
2. For zone substations containing urban MV feeder type, it was assumed that half of these feeders are urban, while the other half are suburban.
3. For zone substations containing rural MV feeder type, it was assumed that half of these feeders are short rural, while the other half are long rural.
4. Power flow simulations are not performed at this stage. Instead, metrics calculated by WP1.5 for four representative MV feeder types are extrapolated to the state level using weighted averages based on the number and types of MV feeders connected to each zone substation.
5. Any assumption made by WP 1.4 (distribution network models) and WP 1.5 (MV-LV network impact assessment) will also impact the results of this project. For their list of assumptions, please refer to their reports.

# 1. Project Overview

This report corresponds to "Milestone 4: Final Report" of Work Package 1.6 (WP1.6) "Whole-State Network Impact Assessment". It will ultimately provide recommendations to Victorian Distribution Network Service Providers (DNSPs, aka distribution companies) about the subtransmission (i.e., 66kV line-to-line) network planning beyond 2030 as part of the Centre for New Energy Technologies (C4NET)'s Enhanced System Planning (ESP) project. This section presents the Victorian context in terms of the uptake of Distributed Energy Resources (DERs), the challenges it brings to distribution networks along with the objectives of WP1.6.

## The Victorian Context

Hundreds of thousands of Australians (including Victorians) are embracing the use of DERs – seizing the opportunity to generate, store, manage or sell their own energy. These DERs include rooftop solar photovoltaics (PVs), electric vehicles (EVs), residential batteries as well as gas electrification (e.g., heat pumps). As shown in Figure 1, which is based on AEMO's forecast of DER installed capacity by 2050[1], solar PVs will continue to be the prominent DER technology adopted in Australia. Additionally, while the uptake of batteries will also rise steadily, it will not grow as rapidly as solar PV. However, EVs is the highlight of the forecast since they are expected to become a major DER in the coming years, surpassing the installed capacity of both solar PV and batteries.

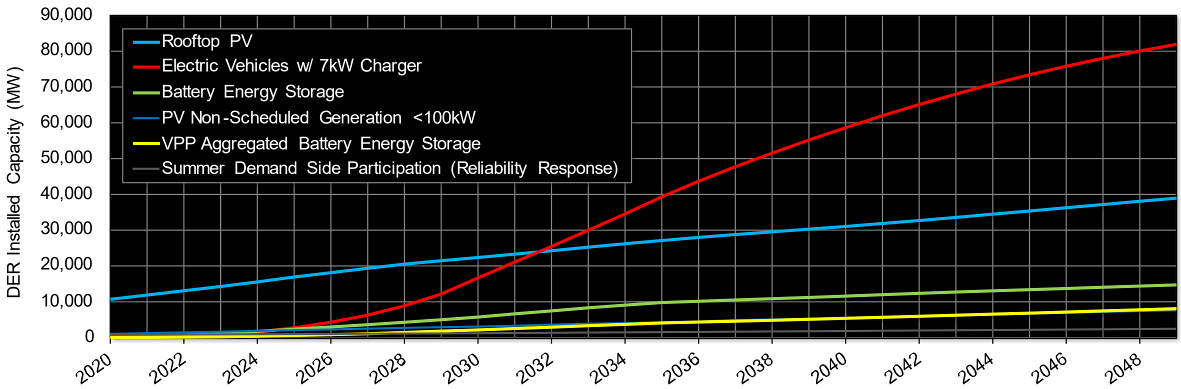



***Figure 1. DER Installed Capacity Forecast[2].***

In the context of Victoria, according to the State Government's vision[3], 1 in 3 households will have solar PVs installed by 2025, which can deliver up to 60% of our energy demand at times. Additionally, a total of 740MWh of residential batteries will be available by 2025, which is equivalent to the capacity

[1] AEMO. "2022 ISP Inputs, Assumptions and Scenarios." https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/2022-isp-inputs-assumptions-and-scenarios

[2] L. N. Ochoa, A. G. Givisiez, D. Jaglal, M. Z. Liu, and W. Nacmanson, "CSIRO Australian Research Planning forGlobal Power Systems Transformation: Topic 8 "Distributed Energy Resources"," The University of Melbourne, 2021.

[3] L. The State of Victoria Department of Environment, Water and Planning,, "Harnessing Victoria's Distributed Energy Resources," 2022.

of 25 Ballarat Energy Storage Systems[4]. Furthermore, 50% of all new light-duty vehicle sales are projected to be EVs by 2030. Moreover, a gas substitution roadmap was released in 2022 to speed up the home electrification. This rapid uptake of various DER technologies simultaneously is expected to help Victoria in achieving its legislative renewable energy targets of 40% by 2025, 50% by 2030, and the ultimate goal of reaching net-zero emissions by 2050.

From the technical perspective, the combination of all these new DERs being added to the lower voltage levels of distribution networks is expected to considerably change the demand profiles on Medium-Voltage (MV) feeders (e.g., 22kV). Inevitably, this change on demand profiles on lower voltage levels will be reflected in subtransmission networks. This could make parts of the subtransmission network reach its thermal limits during normal operational conditions (i.e., no contingency), or even create voltage issues. In fact, according to the forecast daily load profile on minimum demand day from the Victorian Annual Planning Report[5], shown in Figure 2, a significant increase in both the reverse power flow during midday (11am-1pm) and peak demand during the night (6pm-8pm) is expected in Victoria from the massive PV generation and EV demand, respectively. This forecast makes clear that DERs are bringing big challenges for DNSPs to deal with. However, these challenges can be potentially further exacerbated by the initiative of gas electrification in Victoria that will result in increased electricity demand, which requires further investigation for the network impacts.

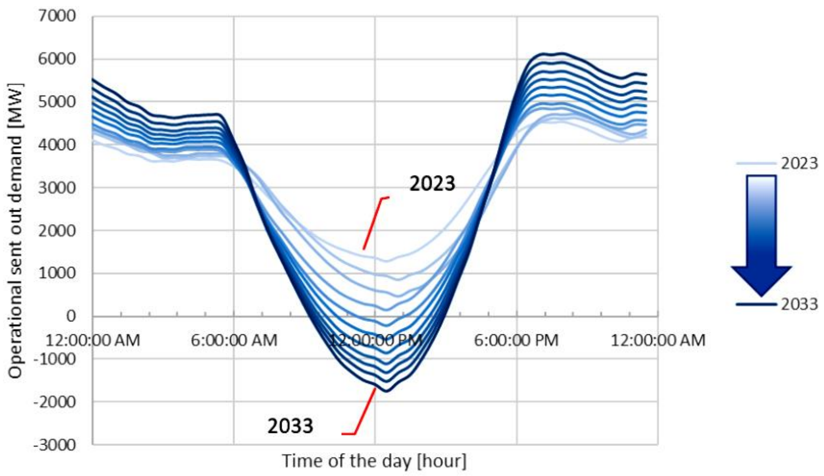



***Figure 2.Victorian Daily Load Profile Forecast (2023-33) - Minimum Demand Day[5].***

Consequently, to accommodate more DERs within Victorian distribution networks, it is critical for DNSPs to understand the potential challenges posed by different scenarios (i.e., mix of DER technologies and different penetrations) in the current electrical infrastructure of the whole state, considering both subtransmission and MV-LV networks.

[4] AusNet Services, "Ballarat Battery Energy Storage System," 2021.
[5] AEMO Victorian Planning, "Victorian Annual Planning Report," 2023.

## Scope and Objectives

WP1.6 "Whole-State Network Impact Assessment" is a key component of C4NET's Enhanced System Planning project. Its scope is to assess the impacts of electrification on Victorian subtransmission networks (66kV line-to-line), utilizing data provided by Work Packages 1.1 to 1.5 as inputs. The study analyses various scenarios incorporating different mixes of Distributed Energy Resources (DERs), including Electric Vehicles (EVs) and residential gas electrification.

The primary objectives are to conduct comprehensive impact assessments of electrification trends on the subtransmission network performance between 2023 and 2053, identify potential infrastructure limitations, and formulate strategic recommendations for Victorian Distribution Network Service Providers (DNSPs). These recommendations aim to guide the planning of subtransmission network as well as MV-LV networks, support DER adoption, and align with Victoria's net-zero emissions goals.

Ultimately, WP1.6 seeks to provide actionable insights that will help DNSPs make their subtransmission and MV-LV networks ready for a future characterized by increased electrification and diverse DER integration, supporting Victoria's transition to a low-carbon energy system.

# 2. Methodology

This section presents the full methodology for the impact assessment of electrification on the whole state of Victoria, which is done in two stages: the Impact Assessment and the Whole-State Extrapolation. Within the Impact Assessment stage, power flow simulations are carried out on the subtransmission networks modelled by WP1.4 (including improvements made by this work package when necessary) considering the aggregated demand profiles produced by WP1.5. Within the Whole-State Extrapolation stage, the impact metrics from WP1.5 are extrapolated to the whole state of Victoria using only limited information associated with zone substations.

Detailed explanations for the two stages are presented in the subsections below.

## Impact Assessment Stage

The Impact Assessment stage relies on detailed models of the subtransmission network, along with demand data for zone substations (ZSSs), demand profiles for non-ZSS loads, and generation profiles of network-connected generators to conduct comprehensive power flow simulations. An overview of the Impact Assessment stage is given in Figure 3, and detailed explanation of input data and steps are provided next.

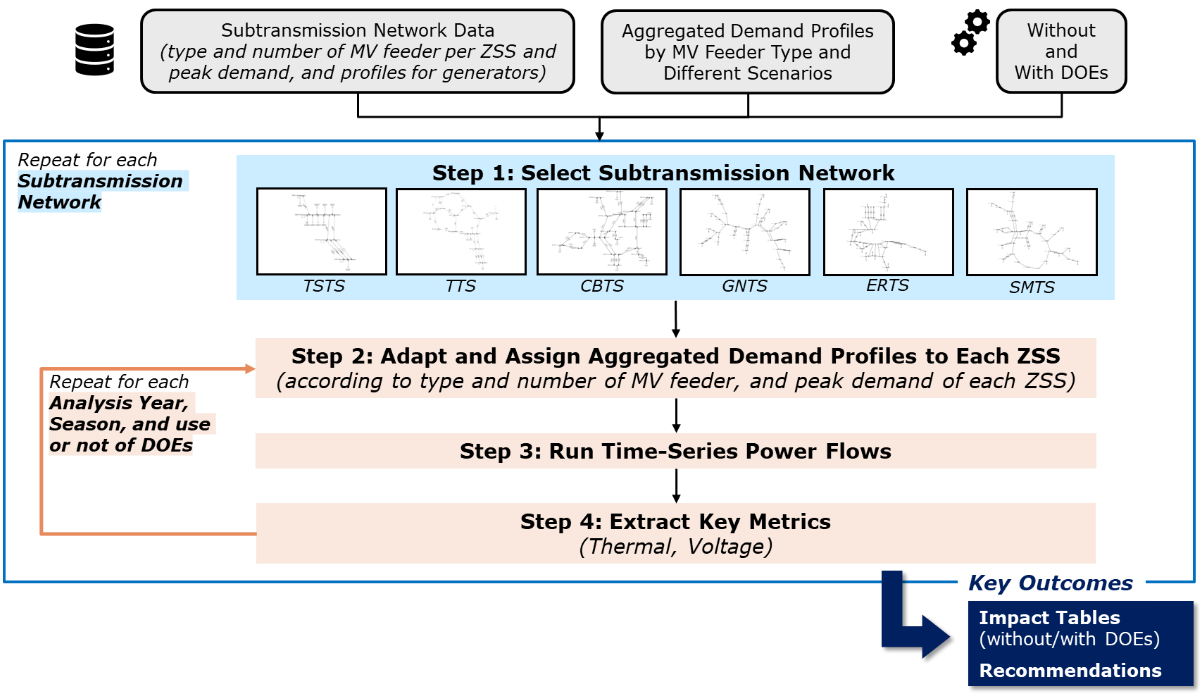



*Figure 3. Overview on the Impact Assessment stage.*

This assessment approach requires the following input data.

## Subtransmission Network

The subtransmission network data includes network models, information on the type and number of MV feeders connected to each ZSS along with their corresponding peak demand, and the active and reactive power values at the peak demand snapshot for non-ZSS loads and generators connected to the subtransmission networks.

Six subtransmission network models were created by WP1.4 in OpenDSS from the original DNSPs' network data (modelled in PSSE). This work package improved four of these models (CBTS, ERTS, TSTS, and TTS) to better align with the original PSSE files. Consequently, this work package uses the four improved OpenDSS subtransmission network models and two (GNTS-MBTS and SMTS) directly from WP1.4. WP1.4 also provided the type and number of MV feeders connected to each ZSS and their corresponding peak demand.

Ideally, each non-ZSS load and generator connected to the subtransmission network would require a demand/generation profile. However, as these were not provided, this work package assumes that flat demand/generation profiles based on the values provided in the peak demand snapshot.

## Demand Profiles by MV Feeder Type, Year, Seasons and Use of DOEs

WP 1.5 provided 24h aggregated demand profiles with 30-minute resolution for four types of MV feeders, three peak demand days, seven analysis years, and scenarios with and without Dynamic Operating Envelopes (DOEs). Examples of these aggregated demand profiles are illustrated in Figure 4 for active power and Figure 5 for reactive power.

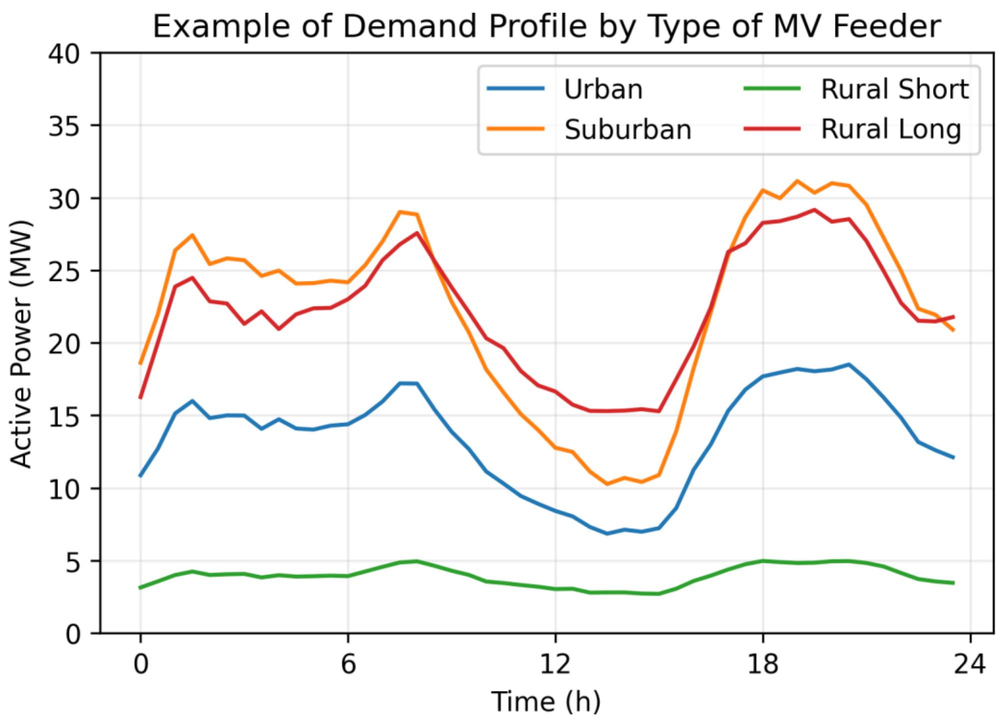



*Figure 4. Example of active power demand profile for the four types of MV feeders without DOEs.*

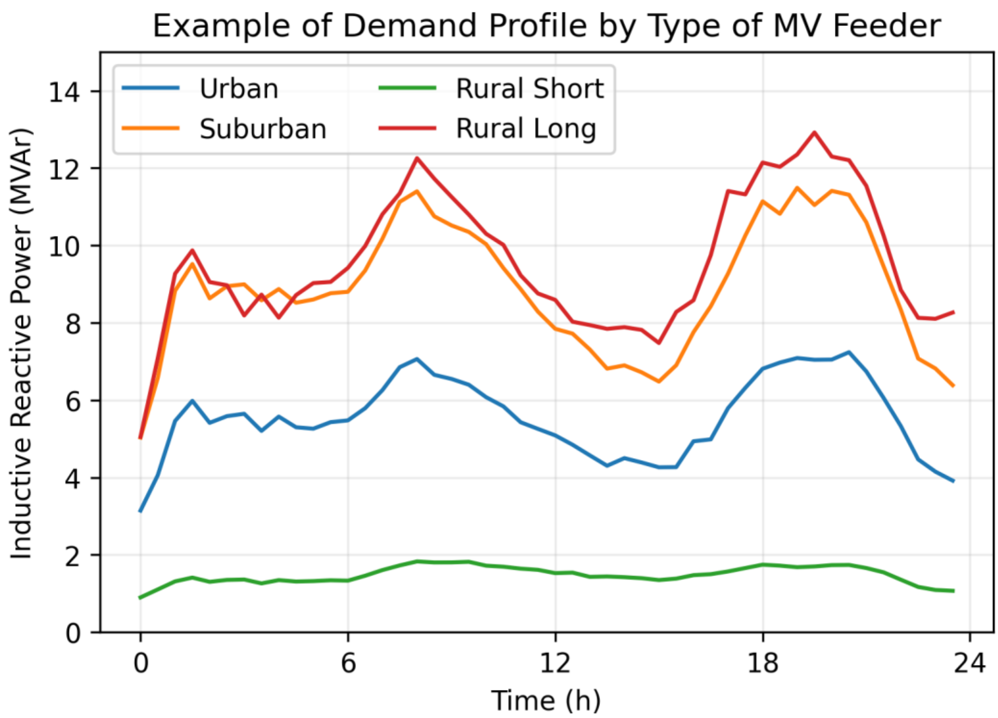



***Figure 5. Example of reactive power demand profile for the four types of MV feeders without DOEs.***

Once the input data is available, this assessment approach follows the steps below:

### Step 1: Subtransmission Network Selection

This initial step involves selecting a specific subtransmission network and loading its OpenDSS model. The model is then prepared with demand data for the Zone Substations (ZSS) to enable power flow simulations in step 4.

### Step 2: Assign and Adapt Net Demand Profiles to Each ZSS

Considering the demand profiles for the for four types of MV feeders, three peak demand days, seven analysis years, and scenarios with and without DOEs, and using the type and number of MV feeders connected to each ZSS, this step builds an initial demand profile for each ZSS by summing the relevant MV feeder profiles. For example, if a ZSS has two urban MV feeders (which profile is shown in Figure 4), their sum creates the initial ZSS demand profile for a given day and year without DOEs (orange line in Figure 6).

Then, using the known original peak demand for each ZSS, the initial ZSS demand profiles are adapted to match the corresponding peak demands, ensuring accurate representation of loading conditions. For instance, if a ZSS has the original peak active power demand of 27 MW, but its initial demand profile peaks at 17 MW, 10 MW is added to each time step of the initial profile (illustrated in Figure 6).

This process is repeated for every ZSS of the selected subtransmission network, and it is done for both active and reactive power.

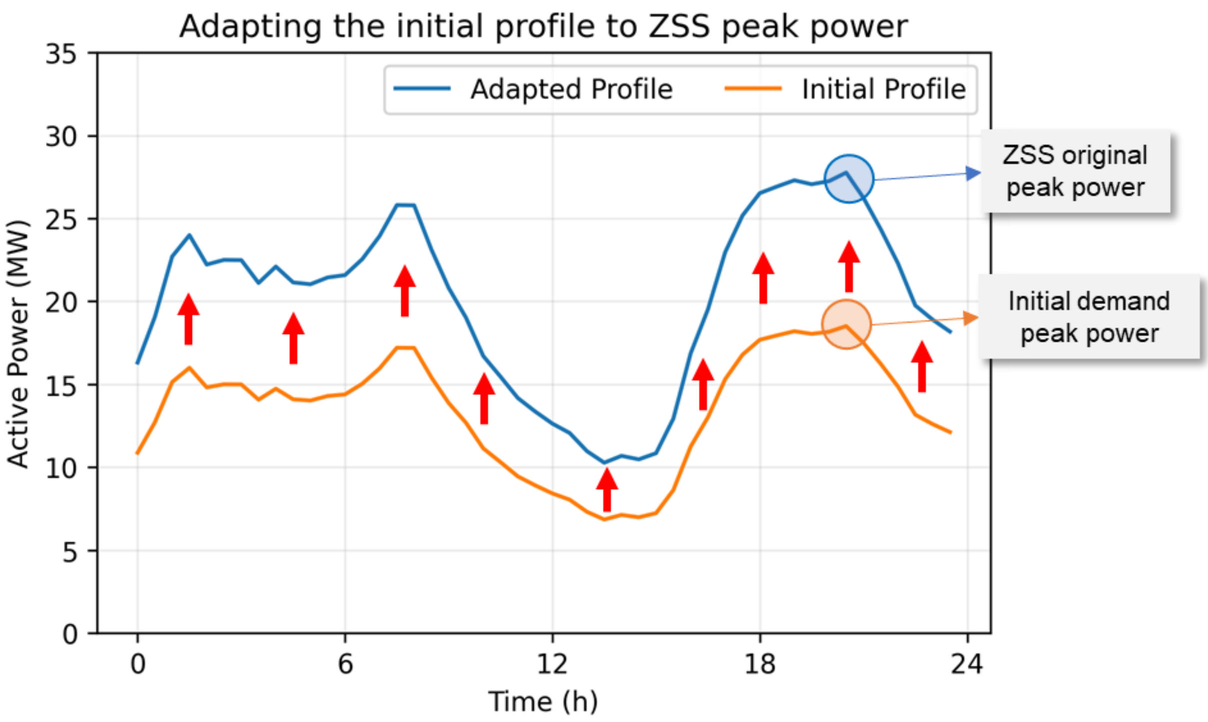



**Figure 6. Illustration of the adaptation of the initial ZSS profile to its peak power.**

### Step 3: Run Time-Series Power Flows

Using the subtransmission network model (from step 1), the adjusted ZSS demand profiles (from step 2), and the profiles of non-ZSS loads and generators directly connected to the subtransmission network, OpenDSS is configured to run time-series power flows. The simulation results are then recorded for further analysis. It's important to note that all loads in this process are considered balanced.

### Step 4: Extract Key Metrics

The impact assessment considers the following key metrics, among others:

#### Transformer Utilization

The total apparent power (MVA) passing through the transformer divided by its rated capacity. This is done for every transformer of the subtransmission network, considering ZSSs and terminal stations (when data is available). The following criteria is used to classify the different loading conditions:

- *Ideal load*: below 100%
- *Acceptable overload*: between 100% and 110%
- *Significant overload*: between 110% and 150%
- *Extreme overload*: above 150%

## Line Utilization

The total apparent power (MVA) passing through the line divided by its rated capacity. This is done for every line (when data is available) of the subtransmission network. The following criteria is used to classify the different loading conditions:

- *Ideal load*: below 100%
- *Acceptable overload*: between 100% and 110%
- *Significant overload*: between 110% and 150%
- *Extreme overload*: above 150%

## Voltages

The voltage in per unit for every bus of the subtransmission network. The main voltage levels considered are of 220kV, 66kV, and 22kV, depending on the subtransmission network being studied. The Electricity Distribution Code of Practice[6] is used to assess voltages, as follow.

For 220kV and 66kV areas:

- *Good*: between 0.9 pu and 1.1 pu
- *Concerning*: below 0.9 pu or above 1.1 pu

For 22kV and 6.6kV areas:

- *Good*: between 0.94 pu and 1.06 pu
- *Concerning*: below 0.94 pu or above 1.06 pu

For areas below 1kV:

- *Good*: between 0.94 pu and 1.1 pu
- *Concerning*: below 0.94 pu or above 1.1 pu

Step 4 uses the recorded time-series power flow results to extract metrics related to the utilisation of transformers and lines, and voltages at all buses of the network.

Once these metrics are calculated, the impact assessment is carried out (following the metrics definition aforementioned) and a summary table (the impact tables) is created. This impact tables can be used by DNSPs as a guide for their planning considering the electrification of loads.

Finally, from the impact assessment, it is possible to know which lines or transformers are passing the limits and by how much (e.g., MVA). Thus, it is possible to create high-level recommendations on the needed augmentation for ZSSs and lines for each day, analysis year, and scenario. These suggested solutions can be used by DNSPs as a guide for their planning considering the electrification of loads.

Note that all these analyses and results are done for the scenario with DOEs and without them.

[6] Electricity Distribution Code of Practice, Essential Service Commission, Version 2, May 2023

## Whole-State Extrapolation Stage

The Whole-State Extrapolation stage relies on the impact metrics from WP1.5 to extrapolate the impact assessment to the whole state of Victoria using only limited information associated with zone substations. An overview of the Extrapolation stage is given in Figure 7, and detailed explanation of input data and steps are provided next.

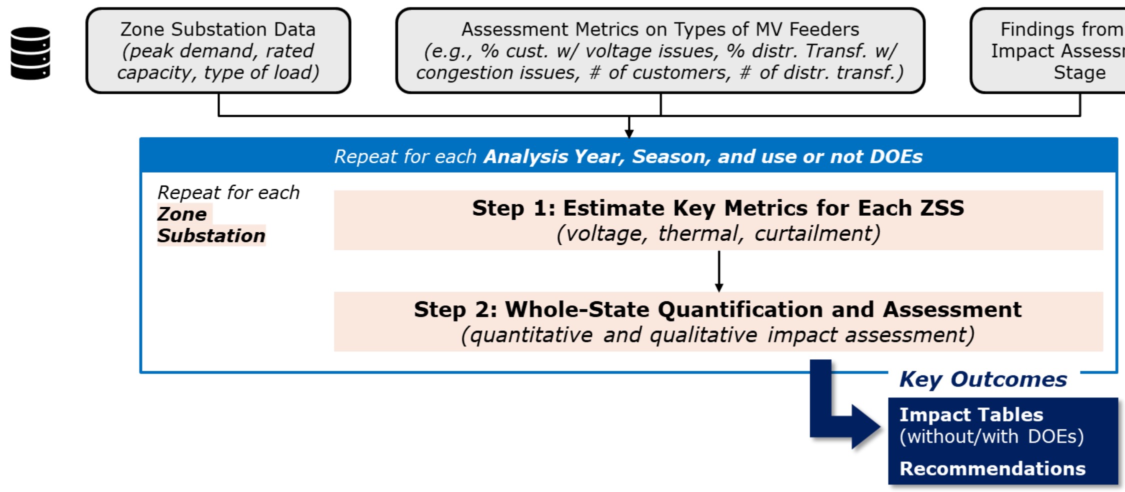



**Figure 7. Overview of the Whole-State Extrapolation stage.**

This assessment approach requires the following input data.

### Zone Substation Data

Victorian DNSPs provided key info about all their ZSSs, which is used to extrapolate the impact assessment to the entire state. These data are ZSSs peak demand, rated capacity, and quantity and type of MV feeder, which are exemplified in Table 1.

**Table 1. Example of zone substation data received from DNSPs**

| Name of ZSS 1 | | | Name of ZSS 2 | | |
|---|---|---|---|---|---|
| Peak Demand (MW) | Rated Capacity (MVA) | Quantity and Type of MV Feeder | Peak Demand (MW) | Rated Capacity (MW) | Quantity and Type of MV Feeder |
| 92 | 150 | 1 urban | 58 | 100 | 5 rural-short |

### Assessment Metrics on Types of MV Feeders

WP1.5 provided multiple assessment metrics for four types of MV feeders, three peak demand days, seven analysis years, and scenarios with and without DOEs, which is used to extrapolate the impact assessment to the entire state. Some of these metrics are presented in Table 2.

### Step 1: Estimate Key Metrics for Each ZSS

In this step, and extrapolation of the impact assessment metrics from WP1.5 for each type of MV feeder (Table 2) is carried out to the whole state of Victoria, using ZSS data provided by DNSPs (Table 1). This extrapolation employs simple weighted averages to correlate the assessment metrics from WP1.5 with the key ZSS data from DNSPs.

**Table 2. Example of the assessment metrics from WP 1.5.**

| 2023 | | | | | |
|---|---|---|---|---|---|
| Metrics | MV Feeder Type | | | | |
| | CBD | Urban | Suburban | Short-Rural | Long-Rural |
| Peak Demand (MW) | 48 | 58 | 58 | 9 | 58 |
| Number of Customers | 1,001 | 2,536 | 10,678 | 3,378 | 8,691 |
| Number of Distribution Transformers | 12 | 10 | 52 | 24 | 133 |
| Feeder Length (km) | 4 | 5 | 13 | 18 | 55 |
| Customers w/ Voltage Issues (%) | 0% | 10% | 12% | 15% | 20% |
| Distr. Transf. w/ Congestion Issues (%) | 0% | 5% | 3% | 2% | 1% |
| Lines w/ Congestion Issues (%) | 0% | 5% | 3% | 2% | 1% |
| Customers w/ PV Curtailment (%) | 0% | 10% | 12% | 15% | 20% |
| Yearlong Curtailed per Customers (MW) | 0 | 2 | 2 | 3 | 4 |

Once the input data is available, this assessment approach follows the steps below:

For example, consider ZSS 1, which has 1 urban MV feeder connected to it (Table 1). To estimate the number of customers with voltage issues in ZSS 1, it is first needed to estimate the number of customers connected to ZSS 1, then multiply the estimated number of customers by the percentage of customers with voltage issues in urban MV feeders (Table 2). In turn, to estimate the number of customers in ZSS 1, the number of customers in urban MV feeders, which is 2,536 (Table 2), is divided by the corresponding peak demand, which is 58 MW (Table 2), then, the result is multiplied by the peak demand at ZSS 1, which is 92 MW (Table 1), resulting in 4,023 customers connected to ZSS 1 (Table 3). Finally, the estimated number of customers connected to ZSS 1, which is 4,023, is multiplied by the percentage of customers with voltage issues in urban MV feeders, which is 10% (Table 2), resulting in 402 customers with voltage problems in ZSS 1 (Table 3). This process is repeated for every assessment metric given in Table 2. A full example of this estimation for ZSS 1 and ZSS 2 is given in Table 3.

## Step 2: Whole-State Quantification and Assessment

The assessment metrics estimated for each ZSS (step 1) can be used to quantify the impact assessment in the entire state of Victoria. Thus, the whole-state impact assessment is carried out and a summary table (the impact tables) is created. This impact tables can be used by DNSPs as a guide for their planning considering the electrification of loads.

In addition, using the quantified Whole-State Extrapolation metrics together with learnings from WP1.5 and from the Impact Assessment stage, it is possible to carry out a qualitative analysis so to create high-level recommendations for each analysis year and scenario. These recommendations can be used by DNSPs as a guide for their planning considering the electrification of loads.

**Table 3.Example for the extrapolation of MV feeders' metrics to ZSSs**

| Example of Extrapolation | | |
|---|---|---|
| **Estimated Metrics** | **Name of ZSS 1** | **Name of ZSS 2** |
| **Number of Customers** | 4,023 | 2,627 |
| **Number of Distr. Transf.** | 16 | 19 |
| **Feeder Length (km)** | 7.93 | 14.00 |
| **Number of Customers w/ Voltage Issues** | 402 | 394 |
| **Distr. Transf. w/ Congestion Issues** | 2 | 3 |
| **Lines w/ congestion Issues (km)** | 0.397 | 0.280 |
| **Number of Customers w/ PV Curtailment** | 402 | 394 |
| **Yearlong Curtailment per Customer (MW)** | 8,045 | 7,882 |

Note that all these analyses and results are carried out for the scenarios with and without DOEs.

# 3. Project Results

This section presents and assesses the results of our two-stage study: "Impact Assessment " and "Whole-State Extrapolation". The Impact Assessment stage evaluates 6 Victorian subtransmission networks (66kV) using power flow simulations to assess their performance under increased load electrification. The Whole-State Extrapolation stage assess MV-LV networks (22kV-0.4kV) across Victoria by extrapolating from representative MV feeder types, using metrics provided by WP1.5. Both stages evaluate two scenarios: a baseline without DOEs, and one with DOEs adoption for residential customers. By analysing these two stages and scenarios, we provide a comprehensive evaluation of potential network voltage and thermal challenges at different voltage levels and assess the effectiveness of DOEs in mitigating these issues across Victoria's distribution networks. The DOEs scenarios are the following.

- **Without DOE**: In this scenario, PV inverter functions (Volt-Watt and Volt-Var, following AS/NZS4777.2:2020 Australia A settings) are enabled, but DOEs are not implemented.
- **With DOE**: In this scenario, PV inverter functions are still enabled, and DOEs are implemented based on the following adoption rates:
  - ✓ Export OE (and upgrade to 10kVA PV inverter)
    - 2028 - apply to new PV customers.
    - 2033 - apply to 50% of existing PV customers.
    - 2038 - apply to 100% of existing PV customers.
  - ✓ Import OE
    - 2033 - apply to new EV customers.
    - 2038 - apply to 100% of existing EV customers.
    - Only EV demand will be managed

## Impact Assessment (Without DOEs)

This section presents the results of the electrification impact assessment on the 6 Victorian subtransmission networks (66kV) without the use of DOEs by residential customers. To complement the analysis, an assessment of MV-LV networks connected to each subtransmission network's ZSSs is presented, using extrapolated metrics from WP1.5. This approach provides a comprehensive view of effects of the increasing load electrification across different network levels.

Before the results, it is essential to understand the key assumptions and limitations of this study:

1. Network Models: Subtransmission networks are assumed to remain the same throughout the assessment period (2023-2053), i.e., network augmentation or planned connections/expansions are not considered in this study.
2. Voltage at Terminal Stations: Voltage at terminal stations is set to a fixed value, which is specified individually for each subtransmission network.

3. Operational Conditions: Capacitor banks and On Load Tap Changers (OLTCs) are operated as needed to keep voltages within the required limits.

4. Thermal Limits: Thermal assessments are conducted for normal operational ratings.

5. Large Loads: Certain large loads, such as interconnections to other DNSPs, are assumed to maintain a constant load (as per the received models) throughout the simulated days.

6. Generation: Any generator connected to the subtransmission network is assumed to be continuously operating, with generation levels set according to the data received from WP1.4.

7. Network Model Simplifications: Subtransmission network models received from WP1.4 have simplifications – transformers and OLTCs of terminal stations were not modelled – that will affect the ability to manage voltages in the 66kV level.

Given these assumptions and limitations, it is crucial to interpret all results within this context.

## CBTS Subtransmission Network

Cranbourne Terminal Station (CBTS) supplies a 66kV subtransmission network loop that spans from Narre Warren in the north to Clyde in the south, and from Pakenham in the east to Carrum and Frankston in the west. The electricity distribution networks for this area are the responsibility of both AusNet Electricity Services (61%) and United Energy (39%). With an operational capacity of 553 MVA and a 2023 peak load of 482 MVA, CBTS supplies over 100,000 customers through 7 zone substations (ZSSs).

As shown in Table ***4***, the results indicate that this network may experience the following technical issued during the analysis period (if no network augmentation or planned connections/expansions are considered):

- The terminal station is expected to face minor overload by 2033, escalating to a significant overload by 2038. Low power factor will start being an issue by 2048.
- The subtransmission network is expected to face voltage drop issues at the 66kV level by 2043, which escalates in the subsequent years.
- Some ZSS transformers reach unacceptable overload levels by 2033, which escalates in the subsequent years.
- Some subtransmission lines (66kV) reach unacceptable overload levels by 2038, which escalates in the subsequent years.
- The MV-LV networks connected to the CBTS subtransmission loop face minor voltage issues from 2023, escalating to moderate by 2028 and severe after 2033.
- The MV-LV networks connected to the CBTS subtransmission loop face minor overload on several distribution transformers in 2028, affecting 14% of distribution transformers by 2033 and a quarter by 2038.

*Table 4. Impact assessment for the CBTS subtransmission network without DOEs.*

| Subtransmission Network – CBTS (Without DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 483 | 543 | 625 | 732 | 861 | 1027 | 1145 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 12% | 15% | 17% | 18% | 19% | 11% |
| Power Factor at Terminal Station for Max. Demand | | | 0.98 | 0.98 | 0.96 | 0.94 | 0.91 | 0.85 | 0.8 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 37% | 42% | 63% |
| Maximum Voltage (pu) | | | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 |
| Minimum Voltage (pu) | | | 0.97 | 0.96 | 0.93 | 0.90 | 0.84 | 0.75 | 0.67 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 83% | 75% | 8% | 8% | 8% | 8% | 8% |
| | | 100%-110% | 17% | 8% | 50% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 1.5 | 5 | 2.2 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 17% | 42% | 58% | 42% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 2.5 | 5.5 | 5.9 | 9.7 | 0 | 0 |
| | | > 150% | 0% | 0% | 0% | 33% | 50% | 92% | 92% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 2.6 | 6.2 | 8.4 | 10.7 |
| | Max. Utilisation of the Worst Performing Transformer | | 106% | 119% | 138% | 158% | 195% | 219% | 228% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 85% | 77% | 38% | 38% | 38% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 15% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 1.8 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 15% | 23% | 31% | 31% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 3.3 | 7.2 | 4.9 | 6.6 | 0 |
| | | > 150% | 0% | 0% | 0% | 0% | 15% | 31% | 62% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 7 | 9.8 | 8.6 |
| | Max. Utilisation of the Worst Performing Line | | 82% | 98% | 119% | 148% | 187% | 245% | 280% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0% | 2% | 6% | 9% | 12% | 14% | 18% |
| Residential Voltage Drop Non-Compliance | | | 2% | 5.3% | 10% | 14% | 18% | 23% | 27% |
| % of LV Networks with Voltage Rise Issues | | | 1% | 9% | 15% | 18% | 19% | 21% | 22% |
| % of LV Networks with Voltage Drop Issues | | | 9% | 17% | 20% | 23% | 28% | 33% | 39% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 1% | 9% | 15% | 18% | 19% | 21% | 22% |

| MV-LV Thermal Assessment (extrapolation of metrics) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % of Distribution Transformers with Maximum Utilisation | | <= 100% | 100% | 97% | 86% | 75% | 70% | 64% | 62% |
| | | 100%-110% | 0.1% | 2% | 5% | 4% | 3% | 3% | 2% |
| | | 110%-150% | 0.3% | 0.5% | 8% | 16% | 14% | 10% | 10% |
| | | > 150% | 0% | 0.3% | 0.8% | 5% | 14% | 23% | 26% |
| PV Curtailment Assessment (extrapolation of metrics) | | | | | | | | | |
| % of PV Customers Curtailed | | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 15 | 29 | 45 | 70 | 86 | 114 | 142 |
| | % of PV Curtailment | | 6% | 9% | 12% | 15% | 18% | 21% | 24% |

- Considerable aggregate PV curtailment occurs from 2028 (9%), constantly increasing around 3% every year.

Detailed analysis is provided below.

## Terminal Station Assessment

By 2033, Cranbourne terminal station is expected to exceed its normal operational limit by up to 13% during the worst day (winter peak) and remain above 100% utilization for 6h, which should be manageable. However, in 2038, CBTS is expected to experience considerable overload, reaching up to 32% above capacity and operating over 100% for at least 14h during the worst day (winter peak). This overload is expected to intensify in subsequent years, reaching extreme levels in 2053 with up to 207% overload and staying below 100% for only 4h on the worst day (winter peak). Additionally, the terminal station is expected to face power factors below the code requirements of 0.9 from 2048, with this issue worsening over subsequent years.

- In 2038, overload occurs in the early morning hours (1am-6am), intensifies during peak morning hours (6am-9am), subsides in the late morning and afternoon, and resurges during the peak evening hours (5pm-10pm). In subsequent years, the period with loads below 100% shrinks drastically, from 9h in 2038 to only 4h in 2053.
- This increasing overload is primarily driven by residential adoption of electrified heating/cooling systems and EVs. From 2023 to 2038, demand surges approximately 4-fold in early mornings and 2.5-fold during peak hours. By 2053, the increase intensifies further, with loads rising around 7-fold in early mornings and 4-fold during peak hours compared to 2023.
- Note that these calculations assume CBTS and its corresponding subtransmission loop to be isolated from the rest of the grid, disregarding potential interconnections that could be used to alleviate loading.
- Also note that this terminal station model is simplified and does not include capacitor banks, which are likely available in reality, meaning that the power factor could be better managed.

### Subtransmission Voltage Assessment

By 2043, approximately 37% of the buses may experience undervoltage issues, falling below the code requirement of 0.9 pu for 66kV, during peak periods (both morning and evening) of the worst day (winter peak). This trend persists in subsequent years, with low voltage issues intensifying over time and extending to the early morning hours as well.

- In 2048, all 7 buses experiencing undervoltage issues are on the 66kV network. While the 22kV (secondary of ZSSs) are within the required limits due to the use of capacitor banks and OLTCs at ZSSs.
- These low voltages result from expected high demands driven by residential adoption of electrified heating/cooling systems and EVs.
- Note that the terminal station is assumed to provide fixed voltages at 1.01 pu (as per received model), with its transformers not being modelled. If CBTS transformers were modelled, their OLTCs could potentially mitigate this voltage drop issues on the subtransmission network.

### Subtransmission Thermal Assessment

Since the base year (2023), 17% (2) of ZSS transformers already face acceptable overload. This issue is expected to escalate rapidly if network augmentation is not considered, reaching unacceptable levels by 2033. While 66kV lines are expected to remain robust enough to accommodate the increasing demand until 2033.

- By 2033, 42% (5) of ZSS transformers are expected to face significant overload (110%-150%) during peak hours for an average of 5.5h. Only 8% (1) of ZSS transformers are expected to remain within capacity limits (below 100%) throughout the entire day. The situation deteriorates in subsequent years, with 92% (11) of ZSS transformers expected to experience extreme overutilization (>150%) by 2053, reaching up to 228% utilization.
- By 2033, 15% (2) of 66kV lines are expected to face significant overload (110%-150%) during peak hours for an average of 3.3h, which may still be manageable as the peak overload is around 119%. However, by 2038, 23% (3) of 66kV lines are expected to face significant overload for an average of 7.2h, becoming unmanageable with peak overutilization around 148% and extended duration. The situation deteriorates rapidly in subsequent years, with 62% (8) of 66kV lines expected to experience extreme overutilization (>150%) by 2053, reaching up to 280% utilization.
- In 2033, overload occurs during peak hours (both morning and evening) for both ZSS transformers and 66kV lines. By 2038, it expands to include early morning hours (1am-6am) and intensifies peak hours. In subsequent years, the overload extends into part of the afternoon, while further intensifying in the early morning and peak hours.

## MV-LV Voltage Assessment

By 2028, the MV-LV networks connected to the CBTS subtransmission loop reaches 33% PV penetration, triggering moderate voltage issues that starts limiting further PV uptake.

- As voltage regulation devices in the MV-LV networks are operated to balance voltage headroom and footroom, more voltage drop issues emerge while managing PV-related voltage rise. This indicates that voltage regulation devices (i.e., tap positions) have reached their limits in maintaining customer voltages within both upper and lower boundaries.
- In 2028, of the estimated 96,092 residential customers, 2% (~1,922) are expected to face voltage rise issues and 5.3% (~5,093) voltage drop issues, slightly exceeding the code requirement that voltage non-compliance should remain below 5%.

From 2028 to 2038, the MV-LV networks experience heating electrification and a surge in EV uptake, from 14% to 86%, while PV uptake grows modestly, from 33% to 39%. Consequently, rising the net demand, which exacerbates voltage issues.

- More specifically, from 2028 to 2038, voltage rise non-compliance increases by 7% and voltage drop non-compliance by 9%. Again, voltage regulation devices (i.e. tap positions) reach their limits in maintaining customers voltages within both upper and lower boundaries. Consequently, efforts to address demand-related voltage drop issues further exacerbate voltage rise problems.

## MV-LV Thermal Assessment

By 2028, only 3% (~298) of the distribution transformers in the MV-LV networks connected to the CBTS subtransmission loop experience overloading, with 2% (~198) facing minor overloading (100%-110%). However, without network augmentation, this issue can escalate rapidly in subsequent years.

- Without network augmentation, by 2033, 14% (~1,389) of distribution transformers may be overloaded, with 8% (~794) facing significant (110%-150%) and 1% (~99) extreme (>150%) overloading. By 2038, overloaded transformers increase to 25% (~2,480), with 16% (~1,587) experiencing significant and 5% (~496) extreme overloading, potentially severely limiting further DER uptake.

## PV Curtailment Assessment

In 2028, with 33% PV penetration, some PV customers may face significant curtailment due to network-wide voltage rise issues. Simulations assume residential PV systems have 5 kVA inverters, which can limit export opportunities and reduce overall renewable energy penetration across the MV-LV networks.

- All PV customers may experience varying degrees of curtailment. The aggregated PV curtailment increases dramatically from 15 GWh (6%) in 2023 to 142 GWh (24%) in 2053.

This curtailment is mainly due to the 5 kVA capacity limit of residential PV inverters, with further curtailment resulting from the PV Volt-Watt inverter function.

## ERTS Subtransmission Network

East Rowville Terminal Station (ERTS) is the main supply of a 66kV subtransmission network that serves part of the outer south-eastern corridor of Melbourne. It spans from Scoresby in the north to Lyndhurst in the south, and from Belgrave in the east to Mulgrave in the west. The electricity supply network for this large region is split between United Energy (74%) and AusNet Electricity Services (26%). With an operational capacity of 680 MVA and a 2023 peak load of 436 MVA, ERTS supplies power to at least 7 zone substations (ZSSs).

As shown in Table 5, the results indicate that this network may experience the following technical issued during the analysis period (if no network augmentation or planned connections/expansions are considered):

- The terminal station is expected to face significant overload by 2033, which escalates in the subsequent years. Low power factor will start being an issue by 2038.
- The subtransmission network is expected to face voltage drop issues at the 66kV level by 2048, which escalates in the subsequent years.
- Some ZSS transformers reach unacceptable overload levels by 2033, which escalates in the subsequent years.
- Some subtransmission lines (66kV) reach unacceptable overload levels by 2038, which escalates in the subsequent years.
- The MV-LV networks connected to the ERTS subtransmission network face minor voltage issues by 2028, escalating to significant by 2033, and worsening in the subsequent years.
- The MV-LV networks connected to the ERTS subtransmission network face minor overload on several distribution transformers in 2028, reaching 18% of distribution transformers by 2033, a third by 2038, and worsening in the subsequent years.
- Considerable aggregate PV curtailment occurs from 2028 (9%), constantly increasing around 3% every year.

Detailed analysis is provided below.

### Terminal Station Assessment

By 2033, East Rowville terminal station is expected to exceed its normal operational limit by up to 33% during the worst day (winter peak) and stay above 100% utilization for 8h, which can be considered a severe overload. This overload is expected to intensify in subsequent years, reaching extreme levels by 2053 with up to 345% overload and continuous overutilization for nearly 24h. Additionally, the terminal station is expected to face power factors below the code requirements of 0.9 from 2038, with this issue worsening over subsequent years.

*Table 5. Impact assessment for the ERTS subtransmission network without DOEs.*

| Subtransmission Network – ERTS (Without DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 504 | 653 | 906 | 1254 | 1631 | 2049 | 2350 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 30% | 39% | 38% | 30% | 26% | 15% |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 0.97 | 0.91 | 0.83 | 0.77 | 0.69 | 0.64 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 0% | 26% | 43% |
| Maximum Voltage (pu) | | | 1.06 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 |
| Minimum Voltage (pu) | | | 0.98 | 0.98 | 0.98 | 0.97 | 0.94 | 0.75 | 0.71 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 88% | 88% | 65% | 47% | 47% | 47% | 47% |
| | | 100%-110% | 12% | 0% | 12% | 6% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 3 | 0 | 3.3 | 4 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 12% | 12% | 24% | 29% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 5.5 | 5 | 6.6 | 13.5 | 0 | 0 |
| | | > 150% | 0% | 0% | 12% | 24% | 24% | 53% | 53% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 4.5 | 6 | 13.9 | 10.2 | 14.2 |
| | Max. Utilisation of the Worst Performing Transformer | | 110% | 150% | 187% | 282% | 302% | 307% | 318% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 94% | 75% | 75% | 62% | 44% |
| | | 100%-110% | 0% | 0% | 6% | 6% | 0% | 12% | 12% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 4 | 2.5 | 0 | 1 | 0.5 |
| | | 110%-150% | 0% | 0% | 0% | 19% | 12% | 0% | 19% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 5.8 | 6.8 | 0 | 1.2 |
| | | > 150% | 0% | 0% | 0% | 0% | 12% | 25% | 25% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 4.3 | 9 | 12.1 |
| | Max. Utilisation of the Worst Performing Line | | 66% | 81% | 108% | 133% | 168% | 205% | 241% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0% | 1% | 3% | 5.3% | 9% | 12% | 14% |
| Residential Voltage Drop Non-Compliance | | | 1% | 3% | 9% | 14% | 19% | 23% | 26% |
| % of LV Networks with Voltage Rise Issues | | | 1% | 12% | 20% | 24% | 26% | 28% | 28% |
| % of LV Networks with Voltage Drop Issues | | | 12% | 22% | 26% | 30% | 34% | 41% | 45% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 1% | 12% | 20% | 24% | 25% | 28% | 28% |

| MV-LV Thermal Assessment (extrapolation of metrics) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| % of Distribution Transformers with Maximum Utilisation | <= 100% | 100% | 97% | 82% | 67% | 61% | 56% | 54% |
| | 100%-110% | 0% | 3% | 7% | 4% | 4% | 3% | 2% |
| | 110%-150% | 0.2% | 0.2% | 11% | 22% | 17% | 11% | 11% |
| | > 150% | 0% | 0.2% | 0.3% | 6% | 18% | 30% | 33% |
| **PV Curtailment Assessment (extrapolation of metrics)** | | | | | | | | |
| % of PV Customers Curtailed | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | 28 | 55 | 84 | 120 | 163 | 216 | 268 |
| | % of PV Curtailment | 6% | 9% | 12% | 15% | 18% | 21% | 24% |

- In 2033, overload occurs for nearly 3h during peak morning hours (6am-9am) and 5h during peak evening hours (5pm-10pm). By 2038, overloading extends to early mornings (1am-6am), while intensifying during peak hours. In subsequent years, it progressively spreads to late morning and afternoon periods, ultimately reaching near 24h overload by 2053.
- This increasing overload is primarily driven by residential adoption of electrified heating/cooling systems and EVs. From 2023 to 2038, demand surges 4-fold in early mornings and 2.5-fold during peak hours. By 2053, the increase intensifies further, with loads rising 7-fold in early mornings and 4-fold during peak hours compared to 2023.
- Note that these calculations assume ERTS and its corresponding subtransmission loop to be isolated from the rest of the grid, disregarding potential interconnections that could be used to alleviate loading.

## Subtransmission Voltage Assessment

By 2048, approximately 26% of the buses may experience undervoltage issues, falling below the code requirement of 0.9 pu for 66kV and/or below 0.94 pu for 22kV, mainly during peak periods (both morning and evening) of the worst day (winter peak). This trend persists in subsequent years, with low voltage issues intensifying over time and extending to the early morning hours as well.

- In 2048, five out of six buses experiencing undervoltage issues are on the 66kV network, with one on the 22kV (secondary of ZSSs). This indicates that both terminal station and ZSSs OLTCs, as well as capacitor banks, have reached their operational limits in maintaining voltage levels.
- These low voltages result from expected high demands driven by residential adoption of electrified heating/cooling systems and EVs.
- Note that the primary side (220kV) of the terminal station is assumed to provide fixed voltages at 1.036 pu, as per received model.

## Subtransmission Thermal Assessment

Since the base year (2023), 12% (1) of ZSS transformers already face acceptable overload. This issue is expected to escalate rapidly if network augmentation is not considered, reaching unacceptable levels by 2033. While 66kV lines are expected to remain robust enough to accommodate the increasing demand until 2038.

- By 2033, 12% (1) of ZSS transformers are expected to face extreme overload (>150%) during peak hours for an average of 4.5h, while another 12% (1) are expected to experience significant overload (110%-150%) for an average of 5h. The situation worsen in subsequent years, with 53% (6) of ZSS transformers expected to undergo extreme overutilization (>150%) by 2053, reaching up to 318% utilization.
- By 2038, 19% (3) of 66kV lines are expected to face significant overload (110%-150%) during peak hours for an average of 5.8h, which is likely to be unmanageable with peak overutilization around 133% and extended duration. The situation deteriorates rapidly in subsequent years, with 25% (5) of 66kV lines expected to experience extreme overutilization (>150%) by 2053, reaching up to 241% utilization.
- In 2033, overload occurs during peak hours (both morning and evening) for both ZSS transformers and 66kV lines. By 2038, it expands to include early morning hours (1am-6am) and intensifies peak hours. In subsequent years, the overload extends into the afternoon, while further intensifying in the early morning and peak hours.

## MV-LV Voltage Assessment

By 2028, the MV-LV networks connected to the ERTS subtransmission loop reaches 33% PV penetration, triggering minor voltage issues that start limiting further PV uptake.

- As voltage regulation devices in the MV-LV networks are operated to balance voltage headroom and footroom, more voltage drop issues emerge while managing PV-related voltage rise. This indicates that voltage regulation devices (i.e., tap positions) have reached their limits in maintaining customer voltages within both upper and lower boundaries.
- In 2028, of the estimated 117,999 residential customers, 1% (~1,180) are expected to face voltage rise issues and 3% (~3,540) voltage drop issues, which still does not exceed the code requirement that voltage non-compliance should remain below 5%.

From 2028 to 2033, the MV-LV networks experience heating electrification and a surge in EV uptake, from 14% to 50%, while PV uptake grows modestly, from 33% to 36%. Consequently, rising the net demand, which exacerbates voltage issues.

- More specifically, from 2028 to 2033, voltage rise non-compliance increases by 2% and voltage drop non-compliance by 6%, bringing the voltage non-compliance outside the code requirements. Again, voltage regulation devices (i.e. tap positions) reach their limits in maintaining customer voltages within both upper and lower boundaries. Consequently, efforts to address demand-related voltage drop issues further exacerbate voltage rise problems.

### MV-LV Thermal Assessment

By 2028, only 3% (~124) of the distribution transformers in the MV-LV networks connected to the ERTS subtransmission network experience minor overload (100%-110%). However, without network augmentation, this issue can escalate rapidly in subsequent years.

- Without network augmentation, by 2033, 18% (~744) of distribution transformers may be overloaded, with 11% (~455) facing significant (110%-150%) and 0.3% (~12) extreme (>150%) overload. By 2038, overloaded transformers increase to 33% (~1,365), with 22% (~910) experiencing significant and 6% (~248) extreme overload, which would severely limit further DER uptake.

### PV Curtailment Assessment

In 2028, with 33% PV penetration, some PV customers may face curtailment due to network-wide voltage rise issues. Simulations assume residential PV systems have 5 kVA inverters, which can limit export opportunities and reduce overall renewable energy penetration across the MV-LV networks.

- All PV customers may experience varying degrees of curtailment. The aggregated PV curtailment increases dramatically from 28 GWh (6%) in 2023 to 268 GWh (24%) in 2053. This curtailment is mainly due to the 5 kVA capacity limit of residential PV inverters, with further curtailment resulting from the PV Volt-Watt inverter function.

## GNTS-MBTS Subtransmission Network

Glenrowan Terminal Station (GNTS) is the main supply of a 66kV subtransmission network serving a major part of north-eastern Victoria. It spans from Wangaratta in the north to Euroa in the south, to Mansfield and Mt Buller in the east, and Benalla centrally. Mount Beauty Terminal Station (MBTS) serves the kiewa hydro generation resources and supplies the alpine areas of Mt Hotham and Falls Creek, along with the townships of Bright, Myrtleford, and Mount Beauty. Ausnet Electricity Services is responsible for all these areas. GNTS has an operational capacity of 290 MVA with a 2022 peak load of 105 MVA, while MBTS has an operational capacity of around 75 MVA with a 2022 peak load of 40.3 MVA. Combined, these terminal stations supply power to at least 8 zone substations (ZSSs).

As shown in Table 6, the results indicate that this network may experience the following technical issued during the analysis period (if no network augmentation or planned connections/expansions are considered):

- The <u>terminal station</u> is expected to face significant <u>overload</u> by 2048, which escalates in the subsequent years. <u>Low power factor</u> will start being an issue by 2038.
- The <u>subtransmission network</u> is expected to face <u>voltage drop issues</u> at the 66kV level by 2033, which escalates in the subsequent years.

- Some ZSS transformers reach unacceptable overload levels by 2038, which escalates in the subsequent years.

*Table 6. Impact assessment for the GNTS-MBTS subtransmission network without DOEs.*

| Subtransmission Network – GNTS + MBTS (Without DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Stations Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at GN Terminal Station (MVA) | | | 104 | 136 | 184 | 239 | 287 | 344 | 380 |
| Maximum Demand at MB Terminal Station (MVA) | | | 23 | 28 | 36 | 44 | 52 | 62 | 70 |
| Increase of Max. Demand at Terminal Stations (MVA) | | | - | 29% | 34% | 29% | 20% | 20% | 11% |
| Power Factor at GN Terminal Station for Max. Demand | | | 0.97 | 0.93 | 0.91 | 0.87 | 0.85 | 0.82 | 0.80 |
| Power Factor at MB Terminal Station for Max. Demand | | | 1.00 | 1.00 | 0.98 | 0.97 | 0.97 | 0.95 | 0.94 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 7% | 13% | 13% | 20% | 20% |
| Maximum Voltage (pu) | | | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 |
| Minimum Voltage (pu) | | | 0.99 | 0.95 | 0.86 | 0.76 | 0.71 | 0.66 | 0.63 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 95% | 91% | 64% | 50% | 45% | 45% | 45% |
| | | 100%-110% | 0% | 5% | 18% | 0% | 9% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0.5 | 0.9 | 0 | 0.5 | 0 | 0 |
| | | 110%-150% | 5% | 0% | 14% | 41% | 18% | 18% | 18% |
| | | Avg. Overloading Duration (hr) | 1.1 | 0 | 0.7 | 4.2 | 3 | 3.1 | 3.4 |
| | | > 150% | 0% | 5% | 5% | 9% | 27% | 36% | 36% |
| | | Avg. Overloading Duration (hr) | 0 | 0.3 | 0.9 | 1.3 | 2.6 | 4.9 | 5.8 |
| | Max. Utilisation of the Worst Performing Transformer | | 123% | 156% | 171% | 211% | 223% | 268% | 286% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 100% | 100% | 95% | 95% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 0% | 5% | 5% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0.2 | 0.7 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Max. Utilisation of the Worst Performing Line | | 47% | 55% | 68% | 81% | 93% | 111% | 124% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | |
| **Residential Voltage Rise Non-Compliance** | | **0%** | **2%** | **5%** | **8%** | **10%** | **12%** | **22%** |
| **Residential Voltage Drop Non-Compliance** | | **1%** | **4%** | **6%** | **8%** | **12%** | **15%** | **26%** |
| **% of LV Networks with Voltage Rise Issues** | | **0.5%** | **4%** | **6%** | **7%** | **8%** | **9%** | **15%** |
| **% of LV Networks with Voltage Drop Issues** | | **4%** | **7%** | **8%** | **10%** | **14%** | **16%** | **28%** |
| **% of LV Networks with Both Voltage Rise & Drop Issues** | | **0.5%** | **4%** | **6%** | **6%** | **7%** | **9%** | **13%** |
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of Distribution Transformers with Maximum Utilisation** | **<= 100%** | **98%** | **95%** | **90%** | **84%** | **78%** | **72%** | **70%** |
| | **100%-110%** | **0.9%** | **1%** | **2%** | **3%** | **3%** | **3%** | **3%** |
| | **110%-150%** | **0.7%** | **3%** | **5%** | **8%** | **9%** | **11%** | **11%** |
| | **> 150%** | **0%** | **0.8%** | **3%** | **5%** | **9%** | **14%** | **16%** |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of PV Customers Curtailed** | | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |
| **Aggregate Export** | **Total PV Curtailment (GWh)** | **5** | **9** | **14** | **20** | **27** | **35** | **44** |
| | **% of PV Curtailment** | **6%** | **9%** | **12%** | **15%** | **18%** | **21%** | **23%** |

- Subtransmission lines (66kV) should stay within acceptable overload levels throughout the entire assessment period (2023-2053).
- The MV-LV networks connected to the GNTS-MBTS subtransmission network face minor voltage issues by 2028, escalating to significant by 2033, and worsening in the subsequent years.
- The MV-LV networks connected to the GNTS-MBTS subtransmission network face minor overload on several distribution transformers in 2028, reaching 10% of distribution transformers by 2033, and a third by 2053.
- Considerable aggregate PV curtailment occurs from 2028 (9%), constantly increasing around 3% every year.

Detailed analysis is provided below.

### Terminal Station Assessment

By 2038, GNTS is expected to experience power factors below the code requirements of 0.9. By 2048, GNTS is expected to exceed its normal operational limit by up to 19% during the worst day (winter peak), remaining above 100% utilization for 9h, which can be considered a severe overload. Both issues are expected to worsen in subsequent years, with power factor dropping as low as 0.8 (inductive) and overload reaching up to 131% with utilization above 100% for 14h by 2053. In contrast, MBTS is not expected to face any overload or power factor issues throughout the assessment period (2023-2053).

- In 2048, GNTS experiences overload for 2h during early morning (1am-3am), briefly subsides, then overloads again for 2h during peak morning hours (6am-9am). It normalises during late morning and afternoon before overloading for 5h during peak evening hours (5pm-

10pm). By 2053, the overload pattern intensifies, extending throughout the early morning (1am-6am) and further intensifying during peak hours.

- This increasing overload is primarily driven by residential adoption of electrified heating/cooling systems and EVs. Between 2023 and 2048, demand increases drastically, surging almost 5-fold in early morning hours and 3-fold during peak periods.
- Note that these calculations assume GNTS-MBTS subtransmission network operates in isolation from the rest of the grid, disregarding potential interconnections that could alleviate loading. Furthermore, any hydro generation that may actually be connected to this network was not included in the model.

### Subtransmission Voltage Assessment

By 2033, initial undervoltage issues may emerge on some buses, falling below the code requirement of 0.9 pu for 66kV networks during peak periods (both morning and evening) of the worst day (winter peak). In subsequent years, these low voltage issues are expected to intensify and expand, first extending to early morning hours and later into the afternoon.

- By 2033, 2 buses (7%) on the 66kV level experience undervoltage issues, indicating that the OLTCs in both terminal stations have reached their operational limits in maintaining voltage levels. In 2038, an additional 2 buses on the 22kV level start experiencing low voltage issues, indicating that OLTCs from these ZSSs have also reached their operational limits in maintaining voltage levels.
- These low voltages result from expected high demands driven by residential adoption of electrified heating/cooling systems and EVs.
- Note that the primary side (220kV) of GNTS is assumed to provide fixed voltages at 1.021 pu and MBTS is assumed to provide fixed voltages at 1 pu, as per received model.

### Subtransmission Thermal Assessment

Since the base year (2023), 5% (1) of ZSS transformers already face acceptable overload. This issue is expected to escalate if network augmentation is not considered, reaching unacceptable levels by 2038 when 50% (9) of ZSS transformers are expected to operate above 110% capacity for several hours during peak demand days. In contrast, 66kV lines are expected to remain robust enough to accommodate the increasing demand throughout the entire assessment period (2023-2053).

- By 2038, 9% (1) of ZSS transformers are expected to face extreme overload (>150%) during peak hours for an average of 1.3h, while another 41% (8) are expected to experience significant overload (110%-150%) for an average of 4.2h. The situation worsens in subsequent years, with 36% (6) of ZSS transformers expected to undergo extreme overutilization (>150%) by 2053, reaching up to 286% utilization.

- In 2038, overload occurs during early morning hours (1am-6am) and peak periods (both morning and evening). By 2053, this overload extends throughout the entire day, intensifying during early morning and peak hours.

### MV-LV Voltage Assessment

By 2028, the MV-LV networks connected to the ERTS subtransmission loop reaches 33% PV penetration, triggering minor voltage issues that start limiting further PV uptake.

- As voltage regulation devices in the MV-LV networks are operated to balance voltage headroom and footroom, more voltage drop issues emerge while managing PV-related voltage rise. This indicates that voltage regulation devices (i.e., tap positions) have reached their limits in maintaining customer voltages within both upper and lower boundaries.
- In 2028, of the estimated 37,113 residential customers, 2% (~742) are expected to face voltage rise issues and 4% (~1484) voltage drop issues, which still does not exceed the code requirement that voltage non-compliance should remain below 5%.

From 2028 to 2033, the MV-LV networks experience heating electrification and a surge in EV uptake, from 14% to 50%, while PV uptake grows modestly, from 33% to 36%. Consequently, rising the net demand, which exacerbates voltage issues.

- More specifically, from 2028 to 2033, both voltage rise and voltage drop non-compliance increases around 2%, bringing the voltage non-compliance outside the code requirements. Again, voltage regulation devices (i.e. tap positions) reach their limits in maintaining customer voltages within both upper and lower boundaries. Consequently, efforts to address demand-related voltage drop issues further exacerbate voltage rise problems.

### MV-LV Thermal Assessment

By 2028, only 5% (~396) of the distribution transformers in the MV-LV networks connected to the GNTS-MBTS subtransmission network experience overload. However, without network augmentation, this issue can escalate rapidly in subsequent years.

- Without network augmentation, by 2033, 10% (~791) of distribution transformers may be overloaded, with 5% (~396) facing significant (110%-150%) and 3% (~237) extreme (>150%) overload. By 2038, overloaded transformers increase to 16% (~1,266), with 8% (~633) experiencing significant and 5% (~396) extreme overload. This trend keeps up until reaching overload for 30% (~2,374) of distribution transformers by 2053, with 11% (~870) experiencing significant and 16% (~1,266) extreme overload.

### PV Curtailment Assessment

In 2028, with 33% PV penetration, some PV customers may face curtailment due to network-wide voltage rise issues. Simulations assume residential PV systems have 5 kVA inverters, which can limit export opportunities and reduce overall renewable energy penetration across the MV-LV networks.

- All PV customers may experience varying degrees of curtailment. The aggregated PV curtailment increases dramatically from 5 GWh (6%) in 2023 to 44 GWh (23%) in 2053. This curtailment is mainly due to the 5 kVA capacity limit of residential PV inverters, with further curtailment resulting from the PV Volt-Watt inverter function.

## SMTS Subtransmission Network

South Morang Terminal Station (SMTS) supplies a 66kV subtransmission network that spans from Seymour, Kilmore, Kalkallo, Kinglake and Rubicon in the north to Mill Park in the south and from Doreen and Mernda in the east to Somerton and Craigieburn in the west. The electricity distribution networks for this area are the responsibility of both AusNet Electricity Services (72%) and Jemena Electricity Networks (28%). With an operational capacity of 530 MVA and a 2023 peak load of 356 MVA, SMTS supplies power to at least 9 zone substations (ZSSs).

As shown in Table 7, the results indicate that this network may experience the following technical issued during the analysis period (if no network augmentation or planned connections/expansions are considered):

- The terminal station is expected to face minor overload by 2038, escalating to a significant overload by 2043.
- The subtransmission network is expected to face voltage drop issues at the 66kV level by 2033, which escalates in the subsequent years.
- Some ZSS transformers reach unacceptable overload levels by 2033, which escalates in the subsequent years.
- Some subtransmission lines (66kV) reach unacceptable overload levels by 2038, which escalates in the subsequent years.
- The MV-LV networks connected to the SMTS subtransmission loop face minor voltage issues from 2023, escalating to moderate by 2028 and significant after 2033.
- The MV-LV networks connected to the SMTS subtransmission loop face minor overload on several distribution transformers in 2028, affecting 12% of distribution transformers by 2033, and a third by 2053.
- Considerable aggregate PV curtailment occurs after 2028, constantly increasing around 3% every year.

Detailed analysis is provided below.

## Terminal Station Assessment

By 2038, South Morang terminal station is expected to exceed its normal operational limit by up to 3% during the worst day (winter peak) and remain above 100% utilization for 4h, which is manageable. However, in 2043, SMTS is expected to experience considerable overload, reaching up to 22% above capacity and operating over 100% for at least 8h during the worst day (winter peak). This overloading is expected to intensify in subsequent years, reaching extreme levels by 2053 with up to 157% overload and continuous overutilization for 17h.

*Table 7. Impact assessment for the SMTS subtransmission network without DOEs.*

| Subtransmission Network – SMTS (Without DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 274 | 338 | 430 | 546 | 646 | 756 | 832 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 23% | 27% | 27% | 18% | 17% | 10% |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 0.99 | 0.98 | 0.96 | 0.94 | 0.92 | 0.91 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 21% | 39% | 45% | 48% | 48% |
| Maximum Voltage (pu) | | | 1.04 | 1.04 | 1.05 | 1.06 | 1.05 | 1.06 | 1.06 |
| Minimum Voltage (pu) | | | 0.93 | 0.90 | 0.86 | 0.75 | 0.70 | 0.65 | 0.62 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 95% | 85% | 65% | 60% | 60% | 50% | 50% |
| HV Transformers | % of Transformers with Maximum Utilisation | 100%-110% | 5% | 5% | 0% | 0% | 0% | 0% | 0% |
| HV Transformers | % of Transformers with Maximum Utilisation | Avg. Overloading Duration (hr) | 1.5 | 3 | 0 | 0 | 0 | 0 | 0 |
| HV Transformers | % of Transformers with Maximum Utilisation | 110%-150% | 0% | 10% | 30% | 30% | 5% | 15% | 10% |
| HV Transformers | % of Transformers with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 2 | 3.3 | 10 | 7 | 5 | 4.5 |
| HV Transformers | % of Transformers with Maximum Utilisation | > 150% | 0% | 0% | 5% | 10% | 35% | 35% | 40% |
| HV Transformers | % of Transformers with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 13.5 | 12 | 7.9 | 13.5 | 14.1 |
| HV Transformers | Max. Utilisation of the Worst Performing Transformer | | 104% | 118% | 209% | 306% | 383% | 422% | 441% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 96% | 84% | 84% | 64% | 60% |
| HV Lines | % of Lines with Maximum Utilisation | 100%-110% | 0% | 0% | 4% | 4% | 0% | 8% | 4% |
| HV Lines | % of Lines with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 3 | 5.5 | 0 | 5 | 5 |
| HV Lines | % of Lines with Maximum Utilisation | 110%-150% | 0% | 0% | 0% | 12% | 8% | 20% | 24% |
| HV Lines | % of Lines with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 6.2 | 8.5 | 6.9 | 7.3 |
| HV Lines | % of Lines with Maximum Utilisation | > 150% | 0% | 0% | 0% | 0% | 8% | 8% | 12% |
| HV Lines | % of Lines with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 3.3 | 10 | 10.5 |
| HV Lines | Max. Utilisation of the Worst Performing Line | | 66% | 81% | 106% | 138% | 158% | 172% | 181% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0% | 2% | 5% | 8% | 11% | 13% | 18% |
| Residential Voltage Drop Non-Compliance | | | 2% | 4% | 8% | 12% | 16% | 20% | 26% |
| % of LV Networks with Voltage Rise Issues | | | 0.5% | 5% | 9% | 10% | 11% | 13% | 17% |
| % of LV Networks with Voltage Drop Issues | | | 5% | 10% | 12% | 14% | 18% | 22% | 32% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 0.5% | 5% | 9% | 10% | 11% | 12% | 16% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of Distribution Transformers with Maximum Utilisation** | **<= 100%** | **99%** | **96%** | **88%** | **80%** | **75%** | **69%** | **67%** |
| | **100%-110%** | **0.6%** | **1%** | **4%** | **3%** | **3%** | **3%** | **3%** |
| | **110%-150%** | **0.6%** | **2%** | **6%** | **12%** | **11%** | **11%** | **10%** |
| | **> 150%** | **0%** | **0.6%** | **2%** | **5%** | **11%** | **18%** | **20%** |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of PV Customers Curtailed** | | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |
| **Aggregate Export** | **Total PV Curtailment (GWh)** | **12** | **24** | **37** | **52** | **71** | **94** | **117** |
| | **% of PV Curtailment** | **6%** | **9%** | **12%** | **15%** | **18%** | **21%** | **24%** |

- In 2038, overloading occurs for 1h during peak morning hours (6am-9am) and 3h during peak evening hours (5pm-10pm). By 2043, overloading extends into part of the early morning (1am-6am) while intensifying during peak hours. In subsequent years, it progressively spreads to the remainder of the early morning, parts of the late morning, and afternoon periods, ultimately reaching 17h of overload by 2053.
- This increasing overload is primarily driven by residential adoption of electrified heating/cooling systems and EVs. From 2023 to 2043, demand surges 6-fold in early mornings and 2.2-fold during peak hours. By 2053, the increase intensifies further, with loads rising 10-fold in early mornings and just over 3-fold during peak hours compared to 2023.
- Note that these calculations assume SMTS and its corresponding subtransmission loop to be isolated from the rest of the grid, disregarding potential interconnections that could be used to alleviate loading.

## Subtransmission Voltage Assessment

By 2033, approximately 21% (6) of the buses may experience undervoltage issues, falling below the code requirement of 0.9 pu for 66kV networks, during peak periods (both morning and evening) of the worst day (winter peak). By 2038, an additional 2 66kV buses and 5 22kV buses fall below their respective low voltage limits of 0.9 pu and 0.94 pu. This trend continues in subsequent years, with low voltage issues intensifying and extending to early morning and late morning hours as well.

- By 2038, 8 out of 13 buses experiencing undervoltage issues are on the 66kV network, with 5 on the 22kV (secondary of ZSSs). This indicates that OLTCs and capacitor banks at these ZSSs have reached their operational limits in maintaining voltage levels.
- These low voltages result from expected high demands driven by residential adoption of electrified heating/cooling systems and EVs.
- Note that the terminal station is assumed to provide fixed voltages at 1.03 pu (as per received model), with its transformers not being modelled. If SMTS transformers were modelled, their OLTCs could potentially mitigate this voltage drop issues on the subtransmission network.

### Subtransmission Thermal Assessment

Since the base year (2023), 5% (1) of ZSS transformers already face acceptable overload. This issue is expected to escalate rapidly if network augmentation is not considered, reaching unacceptable levels by 2033. While 66kV lines are expected to remain robust enough to accommodate the increasing demand until 2038.

- By 2033, 5% (1) of ZSS transformers are expected to face extreme overload (>150%) for around 13.5h, while another 30% (5) are expected to experience significant overload (110%-150%) for an average of 3.3h. The situation worsens in subsequent years, with 40% (7) of ZSS transformers expected to undergo extreme overutilization (>150%) by 2053, reaching up to 441% utilization.
- By 2038, 12% (2) of 66kV lines are expected to face significant overload (110%-150%) during peak hours for an average of 6.2h, which is likely to be unmanageable with peak overutilization around 138% and extended duration. The situation deteriorates rapidly in subsequent years, with 12% (2) of 66kV lines expected to experience extreme overutilization (>150%) by 2053, reaching up to 181% utilization.

### MV-LV Voltage Assessment

By 2028, the MV-LV networks connected to the SMTS subtransmission loop reaches 33% PV penetration, triggering moderate voltage issues that starts limiting further PV uptake.

- As voltage regulation devices in the MV-LV networks are operated to balance voltage headroom and footroom, more voltage drop issues emerge while managing PV-related voltage rise. This indicates that voltage regulation devices (i.e., tap positions) have reached their limits in maintaining customer voltages within both upper and lower boundaries.
- In 2028, of the estimated 81,421 residential customers, 2% (~1,628) are expected to face voltage rise issues and 4% (~3,257) voltage drop issues, which still does not exceed the code requirement that voltage non-compliance should remain below 5%.

From 2028 to 2033, the MV-LV networks experience heating electrification and a surge in EV uptake, from 14% to 50%, while PV uptake grows modestly, from 33% to 36%. Consequently, rising the net demand, which exacerbates voltage issues

- More specifically, from 2028 to 2033, voltage rise non-compliance increases by nearly 3% and voltage drop non-compliance by 4%, bringing the voltage non-compliance outside the code requirements. Again, voltage regulation devices (i.e. tap positions) reach their limits in maintaining customers voltages within both upper and lower boundaries. Thus, efforts to address demand-related voltage drop issues further exacerbate voltage rise problems.

### MV-LV Thermal Assessment

By 2028, only 4% (~392) of the distribution transformers in the MV-LV networks connected to the SMTS subtransmission loop experience overloading, with 2% (~196) facing significant overload

(110%-150%). However, without network augmentation, this issue can escalate rapidly in subsequent years.

- Without network augmentation, by 2033, 12% (~1,177) of distribution transformers may be overloaded, with 6% (~589) facing significant (110%-150%) and 2% (~196) extreme (>150%) overload. By 2038, overloaded transformers increase to 20% (~1,962), with 12% (~1,177) experiencing significant and 5% (~490) extreme overload. This trend keeps up until reaching overload for 33% (~3,237) of distribution transformers by 2053, with 10% (~981) experiencing significant and 20% (~1,962) extreme overload.

### PV Curtailment Assessment

In 2028, with 33% PV penetration, some PV customers may face curtailment due to network-wide voltage rise issues. Simulations assume residential PV systems have 5 kVA inverters, which can limit export opportunities and reduce overall renewable energy penetration across the MV-LV networks.

- All PV customers may experience varying degrees of curtailment. The aggregated PV curtailment increases dramatically from 12 GWh (6%) in 2023 to 117 GWh (24%) in 2053. This curtailment is mainly due to the 5 kVA capacity limit of residential PV inverters, with further curtailment resulting from the PV Volt-Watt inverter function.

## TSTS Subtransmission Network

Templestowe Terminal Station (TSTS) is the main supply of a 66kV subtransmission network that serves major part of the north-eastern metropolitan area. It spans from Eltham in the north to Canterbury in the south, and from Donvale in the east to Kew in the west. The electricity supply network for this large region is split between United Energy (42%), CitiPower (30%), AusNet Electricity Services (20%), and Jemena Electricity Networks (8%). With an operational capacity of 531 MVA and a 2023 peak load of 301 MVA, TSTS supplies power to at least 5 zone substations (ZSSs).

As shown in Table 8, the results indicate that this network may experience the following technical issued during the analysis period (if no network augmentation or planned connections/expansions are considered):

- The terminal station is expected to face minor overload by 2033, escalating to a significant overloading by 2038.
- The subtransmission network is not expected to experience any voltage issues during peak demand days throughout the entire assessment period (2023-2053).
- Some ZSS transformers reach unacceptable overload levels by 2048, which escalates in the subsequent years.
- Subtransmission lines (66kV) should stay within acceptable overload levels throughout the entire assessment period (2023-2053).
- The MV-LV networks connected to the TSTS subtransmission network face minor voltage issues from 2023, escalating to moderate by 2028, and severe after 2033.

- The MV-LV networks connected to the TSTS subtransmission network face minor overload on several distribution transformers in 2028, affecting 16% of distribution transformers by 2033, and 34% by 2043.
- Considerable aggregate PV curtailment occurs after 2028, constantly increasing around 3% every year.

Detailed analysis is provided below.

***Table 8. Impact assessment for the TSTS subtransmission network without DOEs.***

| Subtransmission Network – TSTS (Without DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 359 | 433 | 538 | 659 | 781 | 912 | 1002 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 20% | 24% | 22% | 19% | 17% | 10% |
| Power Factor at Terminal Station for Max. Demand | | | 0.99 | 0.99 | 0.98 | 0.97 | 0.96 | 0.96 | 0.95 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Maximum Voltage (pu) | | | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| Minimum Voltage (pu) | | | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 0% | 0% | 0% | 0% |
| HV Transformers | % of Transformers with Maximum Utilisation | 100%-110% | 0% | 0% | 0% | 100% | 0% | 0% | 0% |
| HV Transformers | % of Transformers with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 3.5 | 0 | 0 | 0 |
| HV Transformers | % of Transformers with Maximum Utilisation | 110%-150% | 0% | 0% | 0% | 0% | 100% | 100% | 100% |
| HV Transformers | % of Transformers with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 4.3 | 7 | 10.8 |
| HV Transformers | % of Transformers with Maximum Utilisation | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HV Transformers | % of Transformers with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HV Transformers | Max. Utilisation of the Worst Performing Transformer | | 77% | 86% | 97% | 110% | 122% | 134% | 143% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 100% | 100% | 100% | 67% |
| HV Lines | % of Lines with Maximum Utilisation | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 33% |
| HV Lines | % of Lines with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| HV Lines | % of Lines with Maximum Utilisation | 110%-150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HV Lines | % of Lines with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HV Lines | % of Lines with Maximum Utilisation | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HV Lines | % of Lines with Maximum Utilisation | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HV Lines | Max. Utilisation of the Worst Performing Line | | 52% | 59% | 67% | 77% | 85% | 96% | 103% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | |
| **Residential Voltage Rise Non-Compliance** | | 0% | 1% | 4% | 6% | 10% | 12% | 15% |
| **Residential Voltage Drop Non-Compliance** | | 2% | 4% | 9% | 14% | 18% | 23% | 26% |
| **% of LV Networks with Voltage Rise Issues** | | 0.8% | 10% | 16% | 18% | 20% | 22% | 23% |
| **% of LV Networks with Voltage Drop Issues** | | 10% | 18% | 21% | 24% | 30% | 36% | 41% |
| **% of LV Networks with Both Voltage Rise & Drop Issues** | | 0.8% | 10% | 16% | 18% | 20% | 22% | 23% |
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of Distribution Transformers with Maximum Utilisation** | **<= 100%** | 100% | 97% | 84% | 72% | 66% | 61% | 59% |
| | **100%-110%** | 0% | 2% | 6% | 4% | 3% | 3% | 2% |
| | **110%-150%** | 0.2% | 0.2% | 9% | 19% | 15% | 11% | 10% |
| | **> 150%** | 0% | 0.2% | 0.5% | 5% | 15% | 26% | 29% |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of PV Customers Curtailed** | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Aggregate Export** | **Total PV Curtailment (GWh)** | 12 | 23 | 35 | 50 | 69 | 91 | 113 |
| | **% of PV Curtailment** | 6% | 9% | 12% | 15% | 18% | 21% | 24% |

## Terminal Station Assessment

By 2033, TSTS is expected to exceed is expected to marginally exceed its normal operational limit by 1% during the worst day (winter peak), which is well within manageable levels. However, in 2038, TSTS is expected to experience considerable overload, reaching up to 24% above capacity and operating over 100% for 13h during the worst day (winter peak). This overloading is expected to intensify in subsequent years, reaching extreme levels by 2053 with up to 189% overload and continuous overutilization for 20h.

- In 2038, mild overload occurs for 5h during early morning (1am-6am), intensifies for 3h during peak morning hours (6am-9am), subsides during late morning and afternoon, then resurges heavily for 5h during peak evening hours (5pm-10pm). By 2043, overload intensifies during morning hours and peak demand periods, extending into part of late morning. In subsequent years, it progressively spreads to more parts of late morning and afternoon periods, ultimately resulting in 20 hours of overload by 2053.
- This increasing overload is primarily driven by residential adoption of electrified heating/cooling systems and EVs. From 2023 to 2038, demand surges 3.5-fold in early mornings and just over 2-fold during peak hours. By 2053, the increase intensifies further, with loads rising 6.5-fold in early mornings and just over 3-fold during peak hours compared to 2023.
- Note that these calculations assume TSTS and its corresponding subtransmission network to be isolated from the rest of the grid, disregarding potential interconnections that could be used to alleviate loading.

## Subtransmission Voltage Assessment

The TSTS subtransmission network is not expected to experience any voltage issues during peak demand days throughout the entire assessment period (2023-2053).

- Despite the surge on demand driven by residential adoption of electrified heating/cooling systems and EVs, voltages are expected to remain very close to the voltage at the secondary of the terminal station. This happens because in the received model most of the loads are connected directly to the terminal station.
- Note that the terminal station is assumed to provide fixed voltages at 1.008 pu (as per received model). In addition, the terminal station is not modelled in detail, meaning its transformers are not included in the simulation.

## Subtransmission Thermal Assessment

ZSS transformers is expected to start facing some overloading by 2038, but it is at acceptable levels (100%-110%) and for only 3.5h. This issue is expected to escalate rapidly if network augmentation is not considered, reaching almost unmanageable levels by 2043, and unmanageable levels by 2048. In contrast, 66kV lines are expected to remain robust enough to accommodate the increasing demand throughout the entire assessment period (2023-2053).

- By 2043, all 3 (100%) ZSS transformers are expected to face significant overload (110%-150%) during peak hours for an average of 4.3h. The situation is expected to worsen in subsequent years, with these same transformers expected to undergo significant overutilization (110%-150%) for an average of 7h by 2048 and 10.8h by 2053.
- In 2043, overload occurs during peak periods (both morning and evening). By 2048, it expands to include early morning hours (1am-6am) and intensifies during peak periods. By 2053, this overload pattern further intensifies, particularly during early morning and peak hours.
- Note that the received network model includes only one ZSS with its transformers modelled, the other ZSS were connected as direct loads to the TSTS.

## MV-LV Voltage Assessment

By 2028, the MV-LV networks connected to the TSTS subtransmission network reaches 33% PV penetration, triggering moderate voltage issues that starts limiting further PV uptake.

- As voltage regulation devices in the MV-LV networks are operated to balance voltage headroom and footroom, more voltage drop issues emerge while managing PV-related voltage rise. This indicates that voltage regulation devices (i.e., tap positions) have reached their limits in maintaining customer voltages within both upper and lower boundaries.

- In 2028, of the estimated 68,787 residential customers, 1% (~688) are expected to face voltage rise issues and 4% (~2,751) voltage drop issues, which still does not exceed the code requirement that voltage non-compliance should remain below 5%.

From 2028 to 2033, the MV-LV networks experience heating electrification and a surge in EV uptake, from 14% to 50%, while PV uptake grows modestly, from 33% to 36%. Consequently, rising the net demand, which exacerbates voltage issues

- More specifically, from 2028 to 2033, voltage rise non-compliance increases by 3% and voltage drop non-compliance by 5%, bringing the voltage non-compliance outside the code requirements. Again, voltage regulation devices (i.e. tap positions) reach their limits in maintaining customers voltages within both upper and lower boundaries. Thus, efforts to address demand-related voltage drop issues further exacerbate voltage rise problems.

### MV-LV Thermal Assessment

By 2028, only 3% (~99) of the distribution transformers in the MV-LV networks connected to the TSTS subtransmission network experience overloading, with 2% (~66) facing minor overload (100%-110%). However, without network augmentation, this issue can escalate rapidly in subsequent years.

- Without network augmentation, by 2033, 16% (~528) of distribution transformers may be overloaded, with 9% (~297) facing significant (110%-150%) and 0.5% (~16) extreme (>150%) overload. By 2043, overloaded transformers increase to 34% (~1,121), with 15% (~495) experiencing significant and 15% (~495) extreme overload. This trend keeps up until reaching overload for 41% (~1,352) of distribution transformers by 2053, with 10% (~330) experiencing significant and 29% (~956) extreme overload.

### PV Curtailment Assessment

In 2028, with 33% PV penetration, some PV customers may face curtailment due to network-wide voltage rise issues. Simulations assume residential PV systems have 5 kVA inverters, which can limit export opportunities and reduce overall renewable energy penetration across the MV-LV networks.

- All PV customers may experience varying degrees of curtailment. The aggregated PV curtailment increases dramatically from 12 GWh (6%) in 2023 to 113 GWh (24%) in 2053. This curtailment is mainly due to the 5 kVA capacity limit of residential PV inverters, with further curtailment resulting from the PV Volt-Watt inverter function.

## TTS Subtransmission Network

Thomastown Terminal Station (TTS) supplies a 66kV subtransmission network that serves the north of greater Melbourne, including Thomastown, Coburg, Preston, Watsonia, North Heidelberg, Lalor, Coolaroo, and Broadmeadows areas. The electricity supply network for this region is split between Jemena Electricity Networks (61%) and AusNet Electricity Services (39%). With an operational capacity of 325 MVA and a 2023 peak load of 212 MVA, TTS supplies power to at least 5 zone substations (ZSSs).

As shown in Table 9, the results indicate that this network may experience the following technical issued during the analysis period (if no network augmentation or planned connections/expansions are considered):

- The terminal station is expected to face minor overload by 2028, escalating to a significant overloading by 2033.
- The subtransmission network is expected to face voltage drop issues at the 66kV level by 2038, which escalates in the subsequent years.
- Some ZSS transformers reach unacceptable overload levels by 2033, which escalates in the subsequent years.
- Some subtransmission lines (66kV) reach unacceptable overload levels by 2038, which escalates in the subsequent years.
- The MV-LV networks connected to the TTS subtransmission network face minor voltage issues from 2023, escalating to moderate by 2028 and significant after 2033.
- The MV-LV networks connected to the TTS subtransmission network face minor overload on several distribution transformers in 2028, affecting 27% of distribution transformers by 2033 and almost a half by 2038.
- Considerable aggregate PV curtailment occurs after 2028, constantly increasing around 3%every year.

Detailed analysis is provided below.

## Terminal Station Assessment

By 2028, TTS is expected to marginally exceed its normal operational limit by 5% for no more than 2h during the worst day (winter peak), which is well within manageable levels. However, by 2033, TTS is expected to experience considerable overload, reaching up to 46% above capacity and operating over 100% for 9h. This overloading is anticipated to intensify in subsequent years, reaching extreme levels by 2053 with up to 344% overload and continuous overutilization for 22 hours. Additionally, the terminal station is expected to face power factors below the code requirements of 0.9 from 2043, with this issue worsening over subsequent years.

- In 2028, overload occurs for less than 2h during peak hours (both morning and evening). By 2033, overloading extends to early mornings (1am-6am), while intensifying during peak hours. In subsequent years, it progressively spreads to late morning and afternoon periods, ultimately reaching 22h overload by 2053.

*Table 9. Impact assessment for the TTS subtransmission network without DOEs.*

| Subtransmission Network – TTS (Without DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 254 | 340 | 475 | 640 | 820 | 983 | 1120 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 34% | 40% | 35% | 28% | 20% | 14% |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 0.98 | 0.95 | 0.92 | 0.87 | 0.83 | 0.79 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 8% | 31% | 54% | 85% |
| Maximum Voltage (pu) | | | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 |
| Minimum Voltage (pu) | | | 0.99 | 0.97 | 0.95 | 0.92 | 0.82 | 0.76 | 0.73 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 100% | 43% | 14% | 14% | 0% | 0% | 0% |
| | | 100%-110% | 0% | 14% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 1.5 | 0 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 43% | 71% | 29% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 1.5 | 6.6 | 13.8 | 0 | 0 | 0 |
| | | > 150% | 0% | 0% | 14% | 57% | 100% | 100% | 100% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 2 | 8.8 | 11.1 | 16.3 | 18.1 |
| | Max. Utilisation of the Worst Performing Transformer | | 92% | 114% | 154% | 202% | 239% | 267% | 297% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 90% | 80% | 60% | 60% | 60% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 10% | 10% | 20% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 3 | 5 | 4.5 | 0 | 0 |
| | | > 150% | 0% | 0% | 0% | 10% | 20% | 40% | 40% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0.5 | 7.5 | 7.4 | 10.5 |
| | Max. Utilisation of the Worst Performing Line | | 65% | 85% | 114% | 151% | 194% | 226% | 244% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0% | 1% | 3% | 4% | 8% | 11% | 12% |
| Residential Voltage Drop Non-Compliance | | | 1% | 3% | 9% | 13% | 18% | 22% | 24% |
| % of LV Networks with Voltage Rise Issues | | | 1% | 15% | 25% | 29% | 31% | 34% | 34% |
| % of LV Networks with Voltage Drop Issues | | | 15% | 27% | 31% | 35% | 41% | 50% | 53% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 1% | 15% | 25% | 29% | 31% | 34% | 34% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of Distribution Transformers with Maximum Utilisation** | **<= 100%** | **100%** | **96%** | **73%** | **53%** | **46%** | **41%** | **40%** |
| | **100%-110%** | **0%** | **4%** | **10%** | **6%** | **4%** | **4%** | **2%** |
| | **110%-150%** | **0%** | **0%** | **16%** | **33%** | **24%** | **13%** | **12%** |
| | **> 150%** | **0%** | **0%** | **0%** | **8%** | **26%** | **43%** | **47%** |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of PV Customers Curtailed** | | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |
| **Aggregate Export** | **Total PV Curtailment (GWh)** | **15** | **29** | **44** | **63** | **85** | **113** | **140** |
| | **% of PV Curtailment** | **6%** | **9%** | **12%** | **15%** | **18%** | **21%** | **24%** |

- This increasing overload is primarily driven by residential adoption of electrified heating/cooling systems and EVs. From 2023 to 2033, demand surges almost 4-fold in early mornings and nearly 2-fold during peak hours. By 2053, the increase intensifies further, with loads rising 11-fold in early mornings and approximately 3.5-fold during peak hours compared to 2023 levels.
- Note that these calculations assume TTS and its corresponding subtransmission network to be isolated from the rest of the grid, disregarding potential interconnections that could be used to alleviate loading.

### Subtransmission Voltage Assessment

By 2038, 1 22kV bus is expected to face undervoltage issues, falling below the code requirement of 0.94 pu, during peak periods (both morning and evening) of the worst day (winter peak). By 2043, an additional 66kV bus and 2 22kV buses are expected to fall below their respective low voltage limits of 0.9 pu and 0.94 pu. This trend continues in subsequent years, with low voltage issues intensifying and extending to early morning and part of the late morning hours as well.

- By 2043, 1 out of 4 buses experiencing undervoltage issues are on the 66kV network, with 3 on the 22kV (secondary of ZSSs). This indicates that OLTCs and capacitor banks at these ZSSs have reached their operational limits in maintaining voltage levels.
- These low voltages result from expected high demands driven by residential adoption of electrified heating/cooling systems and EVs.
- Note that the terminal station is assumed to provide fixed voltages at 1.0151 pu (as per received model), with its transformers not being modelled. If TTS transformers were modelled, their OLTCs could potentially mitigate this voltage drop issues on the subtransmission network.

### Subtransmission Thermal Assessment

ZSS transformers are expected to start experiencing some overload by 2028, but it remains manageable with overutilization occurring for only 3 hours and reaching a maximum of 114%. This issue is projected to escalate rapidly if network augmentation is not implemented, reaching unmanageable levels by 2033 and worsening in subsequent years. Concurrently in 2033, 66kV lines are expected to start facing overutilization, which is likely manageable given the brief duration (3 hours) and low maximum (114%). However, by 2038, 66kV lines are anticipated to reach unmanageable utilization levels.

- By 2033, 14% (1) of ZSS transformers is expected to face extreme overload (>150%) during peak hours for 2h, while another 71% (5) are expected to experience significant overload (110%-150%) for an average of 6.6h. The situation is expected to worsen in subsequent years, with all 7 (100%) ZSS transformers expected to undergo extreme overutilization (>150%) by 2053, reaching up to 297% utilization.
- By 2038, 1 (10%) 66kV line is expected to face extreme overload (>150%) during peak hours for 0.5h, while another is expected to experience significant overload (110%-150%) for an average of 5h. The situation is expected to worsen rapidly in subsequent years, with 40% (4) of 66kV lines expected to experience extreme overutilization (>150%) by 2053, reaching up to 244% utilization for an average of 10.5h.

### MV-LV Voltage Assessment

By 2028, the MV-LV networks connected to the TTS subtransmission network reaches 33% PV penetration, triggering moderate voltage issues that starts limiting further PV uptake.

- As voltage regulation devices in the MV-LV networks are operated to balance voltage headroom and footroom, more voltage drop issues emerge while managing PV-related voltage rise. This indicates that voltage regulation devices (i.e., tap positions) have reached their limits in maintaining customer voltages within both upper and lower boundaries.
- In 2028, of the estimated 80,880 residential customers, 1% (~809) are expected to face voltage rise issues and 3% (~2,426) voltage drop issues, which still does not exceed the code requirement that voltage non-compliance should remain below 5%.

From 2028 to 2033, the MV-LV networks experience heating electrification and a surge in EV uptake, from 14% to 50%, while PV uptake grows modestly, from 33% to 36%. Consequently, rising the net demand, which exacerbates voltage issues

- More specifically, from 2028 to 2033, voltage rise non-compliance increases by 2% and voltage drop non-compliance by 6%, bringing the voltage non-compliance outside the code requirements. Again, voltage regulation devices (i.e. tap positions) reach their limits in maintaining customers voltages within both upper and lower boundaries. Thus, efforts to address demand-related voltage drop issues further exacerbate voltage rise problems.

## MV-LV Thermal Assessment

By 2028, only 4% (~48) of the distribution transformers in the MV-LV networks connected to the TTS subtransmission network experience minor overload (100%-110%). However, without network augmentation, this issue can escalate rapidly in subsequent years.

- Without network augmentation, by 2033, 27% (~322) of distribution transformers may be overloaded, with 16% (~191) facing significant (110%-150%). By 2038, overloaded transformers increase to almost half (~561), with 33% (~394) experiencing significant and 8% (~95) extreme overload. This trend keeps up until reaching overload for 60% (~561) of distribution transformers by 2053, with 12% (~143) experiencing significant and 47% (~561) extreme overload.

## PV Curtailment Assessment

In 2028, with 33% PV penetration, some PV customers may face curtailment due to network-wide voltage rise issues. Simulations assume residential PV systems have 5 kVA inverters, which can limit export opportunities and reduce overall renewable energy penetration across the MV-LV networks.

- All PV customers may experience varying degrees of curtailment. The aggregated PV curtailment increases dramatically from 15 GWh (6%) in 2023 to 140 GWh (24%) in 2053. This curtailment is mainly due to the 5 kVA capacity limit of residential PV inverters, with further curtailment resulting from the PV Volt-Watt inverter function.

# Whole-State Extrapolation Without DOEs

This section presents findings from a comprehensive assessment of load electrification impacts on MV-LV networks across Victoria. The study evaluates voltage and thermal impacts without DOEs, providing a baseline scenario for network performance under increased electrification. We extrapolate metrics from four representative MV feeder types from WP1.5 to estimate potential state-wide implications.

Note that the following key assumptions or limitations (used by WP1.5) need to be accounted for when interpreting the results:

1. The population growth in the assessed network area is not considered, meaning that the number of customers remains the same throughout the horizon (2023–2053).
2. Network augmentation or reconfiguration t is not considered in this study. That is, the assessed MV-LV networks are assumed to remain unchanged throughout the assessment period (2023–2053). Therefore, some voltage or thermal issues identified in this impact assessment should have been addressed before escalating to a severe level. However, changes in demand and the increase in network issues can still provide valuable insights for distribution network planning.
3. A modern design of LV conductors (i.e., featuring lower impedance and higher ampacity) is adopted in the MV-LV network model provided by WP1.4. This modelling choice may significantly underestimate LV conductor utilization.

4. For short-rural and long-rural feeders, single-wire earth return (SWER) networks are not considered in the MV-LV network models provided by WP1.4. Instead, these networks are modelled using a three-phase LV network as an alternative. This approach may lead to an underestimation of voltage issues.
5. The size and adoption rate of DERs (i.e., PV, EVs, electrified heating/cooling, and hot water) are derived from scenario planning data provided by C4NET. Forecast assumptions in scenario planning may lead to underestimation or overestimation of the results.

Table 10 shows the whole-state extrapolation based on various metrics assessed in this project.

Detailed analysis is provided below.

*Table 10. Whole-state extrapolation without DOEs.*

| Whole-State (211 ZSS out of 246) (without DOEs) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| *Voltage Assessment* | | | | | | | | |
| Residential Voltage Rise Non-Compliance | All ZSS | 0.2% | 1% | 4% | 6% | 10% | 12% | 16% |
| | <50 MVA | 0.2% | 2% | 4% | 7% | 10% | 13% | 18% |
| | 50-100 MVA | 0.2% | 2% | 4% | 7% | 10% | 12% | 16% |
| | >100 MVA | 0.1% | 1% | 3% | 5% | 8% | 11% | 13% |
| Residential Voltage Drop Non-Compliance | All ZSS | 2% | 4% | 9% | 13% | 18% | 22% | 26% |
| | <50 MVA | 2% | 4% | 9% | 13% | 17% | 21% | 27% |
| | 50-100 MVA | 2% | 4% | 9% | 13% | 18% | 22% | 26% |
| | >100 MVA | 1% | 3% | 9% | 14% | 18% | 23% | 25% |
| % of LV Networks with Voltage Rise Issues | All ZSS | 0.7% | 8% | 13% | 15% | 16% | 18% | 21% |
| | <50 MVA | 0.6% | 5% | 9% | 10% | 11% | 13% | 18% |
| | 50-100 MVA | 0.7% | 9% | 14% | 16% | 18% | 20% | 22% |
| | >100 MVA | 0.8% | 11% | 18% | 21% | 23% | 26% | 28% |
| % of LV Networks with Voltage Drop Issues | All ZSS | 8% | 14% | 17% | 20% | 23% | 28% | 36% |
| | <50 MVA | 5% | 10% | 12% | 14% | 17% | 21% | 31% |
| | 50-100 MVA | 9% | 15% | 18% | 21% | 25% | 30% | 37% |
| | >100 MVA | 11% | 20% | 23% | 26% | 31% | 38% | 45% |
| % of LV Networks with Both Voltage Rise & Drop Issues | All ZSS | 0.7% | 8% | 13% | 15% | 16% | 18% | 20% |
| | <50 MVA | 0.6% | 5% | 9% | 10% | 11% | 12% | 16% |
| | 50-100 MVA | 0.7% | 9% | 14% | 16% | 17% | 19% | 21% |
| | >100 MVA | 1% | 13% | 22% | 26% | 27% | 30% | 31% |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***Thermal Assessment*** | | | | | | | | | |
| **% of Distribution Transformers with Maximum Utilisation** | **<= 100%** | **All ZSS** | 99% | 96% | 86% | 76% | 70% | 64% | 62% |
| | | **<50 MVA** | 99% | 96% | 89% | 81% | 76% | 70% | 67% |
| | | **50-100 MVA** | 99% | 96% | 86% | 75% | 69% | 63% | 62% |
| | | **>100 MVA** | 100% | 96% | 76% | 58% | 51% | 46% | 45% |
| | **100%-110%** | **All ZSS** | 0.4% | 2% | 5% | 4% | 3% | 3% | 3% |
| | | **<50 MVA** | 1% | 1% | 3% | 3% | 3% | 3% | 3% |
| | | **50-100 MVA** | 0.4% | 2% | 5% | 4% | 3% | 3% | 2% |
| | | **>100 MVA** | 0.2% | 4% | 9% | 5% | 4% | 4% | 2% |
| | **110%-150%** | **All ZSS** | 0.5% | 1% | 8% | 15% | 13% | 11% | 11% |
| | | **<50 MVA** | 0.6% | 2% | 6% | 10% | 10% | 11% | 11% |
| | | **50-100 MVA** | 0.4% | 1% | 8% | 16% | 13% | 11% | 11% |
| | | **>100 MVA** | 0.1% | 0.5% | 15% | 29% | 22% | 12% | 12% |
| | **> 150%** | **All ZSS** | 0% | 0.5% | 2% | 6% | 14% | 22% | 25% |
| | | **<50 MVA** | 0% | 0.7% | 2% | 6% | 11% | 17% | 19% |
| | | **50-100 MVA** | 0% | 0.4% | 1% | 6% | 14% | 23% | 25% |
| | | **>100 MVA** | 0% | 0.1% | 0.5% | 8% | 23% | 38% | 42% |
| ***PV Curtailment*** | | | | | | | | | |
| **% of PV Customers Curtailed** | | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| **Aggregate Export** | **Total PV Curtailment (GWh)** | | 410 | 793 | 1218 | 1733 | 2353 | 3123 | 3878 |
| | **% of PV Curtailment** | | 6% | 9% | 12% | 15% | 18% | 21% | 24% |

## Whole-State MV-LV Voltage Assessment

By 2033, simulations assume all MV-LV networks in the state reach 36% PV penetration. Concurrently, EV adoption reaches 50%, with additional demand from heating (53% of the customers) and cooling (67% of the customers) systems. This combination triggers voltage drop issues, potentially limiting further EV and heating/cooling uptake.

- As voltage regulation devices in the MV-LV networks are operated to balance voltage headroom and footroom, more voltage drop issues emerge while managing PV-related voltage rise. This indicates that voltage regulation devices (i.e., tap positions) have reached their limits in maintaining customer voltages within both upper and lower boundaries.
- In 2033, of the estimated 96,092 residential customers, 4% (~96,000) are expected to face voltage rise issues and 9% (~216,000) voltage drop issues, exceeding the code requirement that voltage non-compliance should remain below 5%.

From 2033 to 2038, MV-LV networks experience significant heating electrification (from 53% to 65%), increase on cooling system adoption (from 67% to 75%), and EV uptake increase (from 50% to 86%), while PV adoption grows modestly (from 36% to 39%). This rise in net demand exacerbates voltage issues, exceeding both voltage rise and drop limits.

- More specifically, from 2033 to 2038, voltage rise non-compliance increases by 2% to 6% 2038, while voltage drop non-compliance rises by 4% to 13% in 2038, significantly exceeding the 5% code limit. Again, voltage regulation devices (i.e., tap positions) reach their limits in maintaining customer voltages within both upper and lower boundaries. Consequently, efforts to address demand-related voltage drop issues further exacerbate voltage rise problems.

### Whole-State MV-LV Thermal Assessment

By 2028, about 4% (~6,800) of distribution transformers in all state MV-LV networks is expected to experience overloading: 2% (~3,400) face minor overloading (100%-110%), 1% (~1,700) significant overload (110%-150%), and 1% (~1,700) extreme overload (>150%). Without network augmentation, this issue could escalate rapidly in subsequent years.

- Without network augmentation, by 2033, 14% (~23,800) of the state distribution transformers may be overloaded, with 8% (~13,600) facing significant (110%-150%) and 2% (~3,400) extreme (>150%) overloading. By 2038, overloaded transformers increase to 24% (~40,800), with 15% (~25,500) experiencing significant and 6% (~10,200) extreme overloading, severely limiting further DER uptake.

### Whole-State PV Curtailment Assessment

In 2028, with 33% PV penetration, some PV customers may face significant curtailment due to network-wide voltage rise issues. Simulations assume residential PV systems have 5 kVA inverters, which can limit export opportunities and reduce overall renewable energy penetration across the MV-LV networks.

- All PV customers may experience varying degrees of curtailment. The aggregated PV curtailment increases dramatically from 410 GWh (6%) in 2023 (when the PV penetration is assumed to be 27%) to 3,878 GWh (24%) in 2053 (when the PV penetration is assumed to be 47%). This curtailment is mainly due to the 5 kVA capacity limit of residential PV inverters, with further curtailment resulting from the PV Volt-Watt inverter function.

## Impact Assessment (With DOEs)

This section presents the results of the electrification impact assessment on the 6 Victorian subtransmission networks (66kV) with the use of DOEs by residential customers. To complement the analysis, an assessment of MV-LV networks connected to each subtransmission network's ZSSs is presented, using extrapolated metrics from WP1.5. This approach provides a comprehensive view of effects of the increasing load electrification across different network levels.

Before the results, it is essential to understand the key assumptions and limitations of this study:

1. Network Models: Subtransmission networks are assumed to remain the same throughout the assessment period (2023-2053), i.e., network augmentation or planned connections/expansions are not considered in this study.

2. Voltage at Terminal Stations: Voltage at terminal stations is set to a fixed value, which is specified individually for each subtransmission network.

3. Operational Conditions: Capacitor banks and On Load Tap Changers (OLTCs) are operated as needed to keep voltages within the required limits.

4. Thermal Limits: Thermal assessments are conducted for normal operational ratings.

5. Large Loads: Certain large loads, such as interconnections to other DNSPs, are assumed to maintain a constant load (as per the received models) throughout the simulated days.

6. Generation: Any generator connected to the subtransmission network is assumed to be continuously operating, with generation levels set according to the data received from WP1.4.

7. Network Model Simplifications: Subtransmission network models received from WP1.4 have simplifications – transformers and OLTCs of terminal stations were not modelled – that will affect the ability to manage voltages in the 66kV level.

Given these assumptions and limitations, it is crucial to interpret all results within this context.

## CBTS Subtransmission Network

As shown in Table 11, the electrification impact assessment with DOEs indicates that their adoption by residential customers slightly decreases net demand on the subtransmission network from 2033 compared to the scenario without DOEs, slightly reducing the intensity of thermal issues. Voltage issues on the subtransmission network are also mitigated, but only after 2048 when 100% of residential customers have adopted DOEs for exports and imports (for level-2 EVs). The impact is more pronounced in the MV-LV networks connected to the CBTS subtransmission network, where DOEs more effectively mitigate both voltage and thermal issues, delaying the need for network augmentation. However, the effectiveness of DOEs is significantly limited due to a large portion of demand being uncontrollable (e.g., Level-1 EV charging, electrified heating/cooling).

Detailed analysis is provided below.

### Terminal Station Assessment

With residential customers adopting DOEs, CBTS load is slightly reduced, starting with a 1% decrease in 2033 and reaching a 6% reduction by 2053. However, this reduction is insufficient to bring the terminal station within thermal limits for any of these years. The power factor also shows slightly improvement from 2048 onward, though not enough to meet the code requirement of 0.9.

*Table 11. Impact assessment for the CBTS subtransmission network with DOEs.*

| Subtransmission Network – CBTS (With DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 483 | 543 | 620 | 721 | 836 | 970 | 1078 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 12% | 14% | 16% | 16% | 16% | 11% |
| Power Factor at Terminal Station for Max. Demand | | | 0.98 | 0.98 | 0.96 | 0.94 | 0.90 | 0.86 | 0.83 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 37% | 42% | 47% |
| Maximum Voltage (pu) | | | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 | 1.06 |
| Minimum Voltage (pu) | | | 0.97 | 0.96 | 0.93 | 0.90 | 0.84 | 0.78 | 0.70 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 83% | 75% | 33% | 8% | 8% | 8% | 8% |
| | | 100%-110% | 17% | 8% | 33% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 1.5 | 5 | 4.5 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 17% | 33% | 75% | 50% | 33% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 2.5 | 6.8 | 7.7 | 10.3 | 14.5 | 0 |
| | | > 150% | 0% | 0% | 0% | 17% | 42% | 58% | 92% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 2 | 6.3 | 8.8 | 8.6 |
| | Max. Utilisation of the Worst Performing Transformer | | 106% | 119% | 136% | 155% | 187% | 218% | 218% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 85% | 77% | 46% | 38% | 38% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 8% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 15% | 23% | 31% | 38% | 15% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 3 | 6.3 | 2.8 | 5.9 | 7.3 |
| | | > 150% | 0% | 0% | 0% | 0% | 15% | 23% | 46% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 6 | 10.5 | 7.4 |
| | Max. Utilisation of the Worst Performing Line | | 82% | 98% | 118% | 146% | 180% | 228% | 259% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.3% | 2% | 4% | 7% | 8% | 8% | 10% |
| Residential Voltage Drop Non-Compliance | | | 2% | 5.1% | 8% | 12% | 15% | 20% | 25% |
| % of LV Networks with Voltage Rise Issues | | | 0.8% | 8% | 13% | 14% | 13% | 15% | 16% |
| % of LV Networks with Voltage Drop Issues | | | 9% | 16% | 19% | 22% | 25% | 30% | 34% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 0.8% | 8% | 13% | 13% | 13% | 14% | 15% |

| MV-LV Thermal Assessment (extrapolation of metrics) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| % of Distribution Transformers with Maximum Utilisation | <= 100% | 100% | 97% | 89% | 76% | 73% | 68% | 65% |
| | 100%-110% | 0.1% | 2% | 3% | 5% | 3% | 4% | 4% |
| | 110%-150% | 0.3% | 0.5% | 8% | 16% | 15% | 11% | 10% |
| | > 150% | 0% | 0.3% | 0.7% | 3% | 10% | 17% | 21% |
| **PV Curtailment Assessment (extrapolation of metrics)** | | | | | | | | |
| % of PV Customers Curtailed | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | 23 | 38 | 74 | 150 | 198 | 255 | 304 |
| | % of PV Curtailment | 6% | 8% | 13% | 24% | 28% | 31% | 34% |
| **EV Management Assessment (extrapolation of metrics)** | | | | | | | | |
| % of EVs Affected | | - | - | 9% | 12% | 16% | 20% | 24% |
| Average EV Charging Delay (h) | | - | - | 3.3 | 4.9 | 5 | 4.9 | 4.8 |

- This overloading is primarily driven by the adoption of electrified heating, increased adoption of cooling systems, as well as increased EV usage among residential customers, resulting in higher net demand. The impact of import DOEs on reducing demand is limited, as they are only applied to Level-2 EV charging, while the majority of load increase stems from electrified heating/cooling systems.
- The improvement in power factor and reduction of net demand may potentially decrease the required augmentation investment.

### Subtransmission Voltage Assessment

With residential customers adopting DOEs, subtransmission voltages show slight improvements in 2048 (from 0.75 pu to 0.78 pu) and 2053 (from 0.67 pu to 0.7 pu), with negligible effects in other years. However, this improvement is insufficient to bring voltages within the code limit of 0.9 pu.

- The improvement on the minimum voltage from 2048 onwards is attributed to the assumption that 100% of residential customers have adopted DOEs for both exports and imports (level-2 EVs only) by this time.

### Subtransmission Thermal Assessment

With residential customers adopting DOEs, ZSS transformer and 66kV line loadings are slightly reduced from 2033, decreasing both the intensity and duration of overloads. However, network upgrades remain necessary as the number of transformers and lines experiencing overutilization has not decreased, and capacity issues persist.

- By 2033, export DOEs are adopted by 50% of customers with PV systems, while import DOEs are adopted by 10% of the EVs, reaching a sufficient adoption rate to begin reducing power flows in the network.

- This small reduction in net demand may potentially reduce or delay the need for network augmentation.

### MV-LV Voltage Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the CBTS subtransmission network demonstrate improved voltage performance. Voltage rise issues are now expected to emerge from 2033 in the area, effectively delaying these problems by at least 5 years compared to the scenario without DOEs. While voltage drop issues are still expected to begin from 2028, fewer customers are expected to be affected.

- As DOEs are gradually implemented for PV and Level-2 EV customers (2028-2038), both voltage rise and drop non-compliance rates decrease by 2% in 2033 and 2038. This reduction translates to approximately 1,921 fewer affected residential customers.
- Beyond 2043, DOEs' effectiveness in reducing voltage rise non-compliance becomes more pronounced, leading to decreases of 4% (~3,844 customers) in 2043, 6% (~5,765 customers) in 2048, and 8% (~7,687 customers) in 2053 compared to the scenario without DOEs.
- Regarding voltage drop non-compliance beyond 2043, improvements become slightly more pronounced, leading to decreases of 3% (~2,883 customers) in 2043 and 2048, and 2% (~1,921 customers) in 2053 compared to the scenario without DOEs.
- However, the non-compliance rate remains above 5% from 2028, requiring additional voltage management strategies.

### MV-LV Thermal Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the CBTS subtransmission network show positive impacts on thermal performance. These improvements begin in 2033, coinciding with a higher DOE adoption rate.

- From 2033 to 2053, the number of overloaded distribution transformers decreases by 3% (298) in 2033, 1% (99) in 2038, 3% (298) in 2043, 4% (397) in 2048, and 3% (298) in 2053.
- Between 2038 and 2053, the severity of overloading is also reduced, with 2% (198) to 5% (496) fewer distribution transformers exceeding 150% loading compared to the scenario without DOEs.
- These reductions in thermal problems will decrease/delay the required network augmentation investments.

### PV Curtailment Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the CBTS subtransmission network initially experience a slight reduction in PV curtailment (2028). However, over time, curtailment increases, surpassing levels observed in the scenario without DOEs. This occurs because DOEs impose additional constraints on existing PV inverter functions (Volt-Watt and

Volt-Var). Moreover, the "Equal Allocation" strategy adopted in this study, which gives all flexible customers the same export limit during corresponding time intervals, does not maximize aggregate PV generation.

- All PV customers may experience varying degrees of curtailment. In 2028, aggregated PV curtailment is approximately 8% (38 GWh), lower than the 9% (29 GWh) in the scenario without DOEs. This percentage reduction occurs as a small fraction of PV systems begins adopting DOEs. However, the total curtailed energy increases because inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential.
- As DOE adoption increases, the "Equal Allocation" strategy's limitations become evident. DOE values, constrained by customers with the most severe voltage issues, negatively impact all customers within the same LV network. Consequently, aggregated PV curtailment reaches 74 GWh (13%) by 2033, significantly higher than the 45 GWh (12%) in the scenario without DOEs. By 2053, it reaches 304 GWh (34%), far exceeding the 142 GWh (24%) without DOEs. However, note that PV inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential but also increasing curtailment.

### EV Management Assessment

With residential customers adopting import DOEs for Level-2 EVs from 2033, the MV-LV networks connected to the CBTS subtransmission network experience some EV charging delays. Analysis shows these delays average under 5 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

## ERTS Subtransmission Network

As shown in Table 12, the electrification impact assessment with DOEs indicates that their adoption by residential customers slightly decreases net demand on the subtransmission network from 2033 compared to the scenario without DOEs, slightly reducing the intensity of thermal issues. Voltage issues on the subtransmission network are also mitigated, but only after 2038 when higher number of residential customers have adopted DOEs for exports and imports (for level-2 EVs). The impact is more pronounced in the MV-LV networks connected to the ERTS subtransmission network, where DOEs more effectively mitigate both voltage and thermal issues, delaying the need for network augmentation. However, the effectiveness of DOEs is significantly limited due to a large portion of demand being uncontrollable (e.g., Level-1 EV charging, electrified heating/cooling).

Detailed analysis is provided below.

### Terminal Station Assessment

With residential customers adopting DOEs, ERTS load is slightly reduced, starting with a 1% decrease in 2033 and reaching a 14% reduction by 2053. However, this reduction is insufficient to bring the terminal station within thermal limits for any of these years. The power factor also shows slightly improvement from 2038 onward, though not enough to meet the code requirement of 0.9.

*Table 12. Impact assessment for the ERTS subtransmission network with DOEs.*

| Subtransmission Network – ERTS (With DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 504 | 653 | 896 | 1189 | 1462 | 1858 | 2032 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 30% | 37% | 33% | 23% | 27% | 9% |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 0.97 | 0.90 | 0.84 | 0.80 | 0.74 | 0.71 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 0% | 17% | 26% |
| Maximum Voltage (pu) | | | 1.06 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 |
| Minimum Voltage (pu) | | | 0.98 | 0.98 | 0.98 | 0.97 | 0.96 | 0.80 | 0.74 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 88% | 88% | 71% | 47% | 47% | 47% | 47% |
| | | 100%-110% | 12% | 0% | 6% | 6% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 3 | 0.0 | 3 | 1 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 12% | 12% | 24% | 29% | 12% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 4.5 | 5.5 | 3.5 | 10.5 | 17.3 | 0 |
| | | > 150% | 0% | 0% | 12% | 24% | 24% | 41% | 53% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 6 | 5.9 | 13.5 | 10 | 10.2 |
| | Max. Utilisation of the Worst Performing Transformer | | 110% | 137% | 194% | 232% | 271% | 303% | 313% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 94% | 81% | 75% | 75% | 62% |
| | | 100%-110% | 0% | 0% | 6% | 0% | 0% | 0% | 12% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 4 | 0 | 0 | 0 | 1 |
| | | 110%-150% | 0% | 0% | 0% | 19% | 12% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 5.8 | 5.8 | 0 | 0 |
| | | > 150% | 0% | 0% | 0% | 0% | 12% | 25% | 25% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 1.8 | 5.6 | 9.4 |
| | Max. Utilisation of the Worst Performing Line | | 66% | 81% | 106% | 129% | 156% | 204% | 207% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.1% | 1% | 2% | 3% | 4% | 5.1% | 4% |
| Residential Voltage Drop Non-Compliance | | | 1% | 3% | 8% | 12% | 15% | 20% | 24% |
| % of LV Networks with Voltage Rise Issues | | | 1% | 11% | 17% | 18% | 16% | 19% | 19% |
| % of LV Networks with Voltage Drop Issues | | | 12% | 21% | 26% | 28% | 31% | 35% | 39% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 1% | 11% | 17% | 18% | 16% | 18% | 18% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of Distribution Transformers with Maximum Utilisation** | **<= 100%** | **100%** | **97%** | **85%** | **68%** | **64%** | **60%** | **56%** |
| | **100%-110%** | **0%** | **3%** | **4%** | **7%** | **3%** | **4%** | **4%** |
| | **110%-150%** | **0.2%** | **0.2%** | **11%** | **22%** | **19%** | **13%** | **12%** |
| | **> 150%** | **0%** | **0.2%** | **0.3%** | **3%** | **13%** | **23%** | **28%** |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of PV Customers Curtailed** | | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |
| **Aggregate Export** | **Total PV Curtailment (GWh)** | **38** | **65** | **125** | **244** | **336** | **450** | **536** |
| | **% of PV Curtailment** | **6%** | **8%** | **13%** | **23%** | **28%** | **33%** | **36%** |
| ***EV Management Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of EVs Affected** | | - | - | **9%** | **13%** | **16%** | **21%** | **24%** |
| **Average EV Charging Delay (h)** | | - | - | **3.7** | **5.2** | **5.6** | **5.5** | **5.4** |

- This overloading is primarily driven by the adoption of electrified heating, increased adoption of cooling systems, as well as increased EV usage among residential customers, resulting in higher net demand. The impact of import DOEs on reducing demand is limited, as they are only applied to Level-2 EV charging, while the majority of load increase stems from electrified heating/cooling systems.
- The improvement in power factor and reduction of net demand may potentially decrease the required augmentation investment.

### Subtransmission Voltage Assessment

With residential customers adopting DOEs, subtransmission voltages show slight improvements in 2043 (from 0.94 pu to 0.96 pu), 2048 (from 0.75 pu to 0.8 pu), and 2053 (from 0.71 pu to 0.74 pu), with negligible effects in other years. However, this improvement is insufficient to bring voltages within the code limit of 0.9 pu after 2048.

- The improvement on the minimum voltage from 2043 onwards is attributed to the assumption that 100% of residential customers have adopted export DOE and high levels of import DOE (level-2 EVs) by this time.

### Subtransmission Thermal Assessment

With residential customers adopting DOEs, ZSS transformer and 66kV line loadings are slightly reduced from 2033, decreasing both the intensity and duration of overloads. However, network upgrades remain necessary as the number of transformers and lines experiencing overutilization has not decreased, and capacity issues persist.

- By 2033, export DOEs are adopted by 50% of customers with PV systems, while import DOEs are adopted by 10% of the EVs, reaching a sufficient adoption rate to begin reducing power flows in the network.

- This small reduction in net demand may potentially reduce or delay the need for network augmentation.

### MV-LV Voltage Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the ERTS subtransmission network demonstrate improved voltage performance. Voltage rise issues are now projected to emerge in the area only in 2048, nearly eliminating these problems throughout the assessment period (2023-2053) when compared to the scenario without DOEs. While voltage drop issues are still expected to begin from 2033, fewer customers are expected to be affected.

- As DOEs are gradually implemented for PV and Level-2 EV customers (2028-2038), both voltage rise and drop non-compliance rates decrease by 1% in 2033 and 2% in 2038. This reduction translates to approximately 1,180 fewer affected residential customers in 2033 and 2,360 in 2038.
- Beyond 2043, DOEs' effectiveness in reducing voltage rise non-compliance becomes more pronounced, leading to decreases of 5% (~5,900 customers) in 2043, nearly 7% (~8,260 customers) in 2048, and 10% (~11,800 customers) in 2053 compared to the scenario without DOEs.
- Regarding voltage drop non-compliance beyond 2043, improvements become slightly more pronounced, leading to decreases of 4% (~4,720 customers) in 2043, 3% (~3,540 customers) in 2048, and 2% (~2,360 customers) in 2053 compared to the scenario without DOEs.
- However, the non-compliance rate remains above 5% from 2033, requiring additional voltage management strategies.

### MV-LV Thermal Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the ERTS subtransmission network show positive impacts on thermal performance. These improvements begin in 2033, coinciding with a higher DOE adoption rate.

- From 2033 to 2053, the number of overloaded distribution transformers decreases by 3% (~124) in 2033, 1% (~41) in 2038, 3% (~124) in 2043, 4% (~165) in 2048, and 2% (~83) in 2053.
- Between 2038 and 2053, the severity of overloading is also reduced, with 3% (~124) to 5% (~207) fewer distribution transformers exceeding 150% loading compared to the scenario without DOEs.
- These reductions in thermal problems will decrease/delay the required network augmentation investments.

### PV Curtailment Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the ERTS subtransmission network initially experience a slight reduction in PV curtailment (2028). However, over time, curtailment increases, surpassing levels observed in the scenario without DOEs. This occurs because DOEs impose additional constraints on existing PV inverter functions (Volt-Watt and Volt-Var). Moreover, the "Equal Allocation" strategy adopted in this study, which gives all flexible customers the same export limit during corresponding time intervals, does not maximize aggregate PV generation.

- All PV customers may experience varying degrees of curtailment. In 2028, aggregated PV curtailment is approximately 8% (65 GWh), lower than the 9% (55 GWh) in the scenario without DOEs. This percentage reduction occurs as a small fraction of PV systems begins adopting DOEs. However, the total curtailed energy increases because inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential.
- As DOE adoption increases, the "Equal Allocation" strategy's limitations become evident. DOE values, constrained by customers with the most severe voltage issues, negatively impact all customers within the same LV network. Consequently, aggregated PV curtailment reaches 125 GWh (13%) by 2033, significantly higher than the 84 GWh (12%) in the scenario without DOEs. By 2053, it reaches 536 GWh (36%), far exceeding the 268 GWh (24%) without DOEs. However, note that PV inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential but also increasing curtailment.

### EV Management Assessment

With residential customers adopting import DOEs for Level-2 EVs from 2033, the MV-LV networks connected to the ERTS subtransmission network experience some EV charging delays. Analysis shows these delays average under 6 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

## GNTS-MBTS Subtransmission Network

As shown in Table 13, the electrification impact assessment with DOEs indicates that their adoption by residential customers slightly decreases net demand on the subtransmission network from 2028 compared to the scenario without DOEs, slightly reducing the intensity of thermal issues faced from 2048. Voltage issues on the subtransmission network are also mitigated, but only after 2038 when higher number of residential customers have adopted DOEs for exports and imports (for level-2 EVs). The impact is more pronounced in the MV-LV networks connected to the GNTS-MBTS subtransmission network, where DOEs more effectively mitigate both voltage and thermal issues, delaying the need for network augmentation. However, the effectiveness of DOEs is significantly limited due to a large portion of demand being uncontrollable (e.g., Level-1 EV charging, electrified heating/cooling).

Detailed analysis is provided below.

*Table 13. Impact assessment for the GNTS-MBTS subtransmission network with DOEs.*

| Subtransmission Network – GNTS + MBTS (With DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at GN Terminal Station (MVA) | | | 104 | 133 | 185 | 239 | 276 | 320 | 341 |
| Maximum Demand at MB Terminal Station (MVA) | | | 23 | 28 | 36 | 44 | 52 | 59 | 67 |
| Increase of Max. Demand at Terminal Stations (MVA) | | | - | 28% | 39% | 29% | 15% | 16% | 7% |
| Power Factor at GN Terminal Station for Max. Demand | | | 0.97 | 0.95 | 0.90 | 0.87 | 0.86 | 0.83 | 0.83 |
| Power Factor at MB Terminal Station for Max. Demand | | | 1.00 | 1.00 | 0.98 | 0.97 | 0.97 | 0.95 | 0.93 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 7% | 13% | 13% | 20% | 20% |
| Maximum Voltage (pu) | | | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 |
| Minimum Voltage (pu) | | | 0.99 | 0.95 | 0.86 | 0.77 | 0.72 | 0.68 | 0.65 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 95% | 95% | 64% | 50% | 50% | 45% | 45% |
| | | 100%-110% | 0% | 0% | 18% | 0% | 5% | 5% | 5% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0.8 | 0 | 0.05 | 0.2 | 0.8 |
| | | 110%-150% | 5% | 5% | 14% | 41% | 18% | 14% | 23% |
| | | Avg. Overloading Duration (hr) | 1.1 | 0.6 | 0.7 | 3.8 | 2.7 | 2.1 | 1.5 |
| | | > 150% | 0% | 0% | 5% | 9% | 27% | 36% | 27% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0.9 | 1.1 | 2 | 4.4 | 1.8 |
| | Max. Utilisation of the Worst Performing Transformer | | 123% | 132% | 171% | 211% | 183% | 223% | 221% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 100% | 100% | 95% | 95% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 5% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 0% | 0% | 5% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Max. Utilisation of the Worst Performing Line | | 47% | 55% | 69% | 81% | 93% | 107% | 119% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.3% | 2% | 4% | 7% | 7% | 7% | 18% |
| Residential Voltage Drop Non-Compliance | | | 1% | 4% | 5.2% | 7% | 9% | 13% | 24% |
| % of LV Networks with Voltage Rise Issues | | | 0.5% | 3% | 5% | 5% | 5% | 7% | 12% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| % of LV Networks with Voltage Drop Issues | | 4% | 6% | 7% | 10% | 12% | 16% | 26% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | 0.5% | 3% | 5% | 5% | 5% | 6% | 10% |
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| % of Distribution Transformers with Maximum Utilisation | <= 100% | 98% | 95% | 92% | 86% | 82% | 77% | 75% |
| | 100%-110% | 0.9% | 1% | 2% | 3% | 2% | 4% | 4% |
| | 110%-150% | 0.7% | 3% | 4% | 7% | 8% | 9% | 9% |
| | > 150% | 0% | 0.8% | 3% | 4% | 7% | 10% | 12% |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| % of PV Customers Curtailed | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | 8 | 14 | 23 | 45 | 59 | 77 | 93 |
| | % of PV Curtailment | 6% | 7% | 11% | 19% | 22% | 25% | 27% |
| ***EV Management Assessment (extrapolation of metrics)*** | | | | | | | | |
| % of EVs Affected | | - | - | 8% | 12% | 16% | 20% | 24% |
| Average EV Charging Delay (h) | | - | - | 3 | 4.1 | 4.2 | 4.1 | 4.1 |

### Terminal Station Assessment

With residential customers adopting DOEs, GNTS load is slightly reduced, starting with a 2% decrease in 2028 and reaching a 10% reduction by 2053. However, this reduction is insufficient to bring the terminal station within thermal limits from 2048. The power factor also shows slightly improvement from 2043 onward, though not enough to meet the code requirement of 0.9.

- This overloading is primarily driven by the adoption of electrified heating, increased adoption of cooling systems, as well as increased EV usage among residential customers, resulting in higher net demand. The impact of import DOEs on reducing demand is limited, as they are only applied to Level-2 EV charging, while the majority of load increase stems from electrified heating/cooling systems.
- The improvement in power factor and reduction of net demand may potentially decrease the required augmentation investment.

### Subtransmission Voltage Assessment

With residential customers adopting DOEs, subtransmission voltages show slight improvements in 2038 (from 0.76 pu to 0.77 pu), 2043 (from 0.71 pu to 0.72 pu), 2048 (from 0.66 pu to 0.68 pu), and 2053 (from 0.63 pu to 0.65 pu), with negligible effects in other years. However, this improvement is insufficient to bring voltages within the code limit of 0.9 pu after 2048.

- The improvement on the minimum voltage from 2038 onwards is attributed to the assumption that 100% of residential customers have adopted export DOE and medium levels of import DOE (level-2 EVs) by this time.

## Subtransmission Thermal Assessment

With residential customers adopting DOEs, ZSS transformer and 66kV line loadings are slightly reduced from 2028, decreasing both the intensity and duration of overloads. However, network upgrades remain necessary, particularly transformers since many of them are still overutilized.

- By 2033, export DOEs are adopted by 50% of customers with PV systems, while import DOEs are adopted by 10% of the EVs, reaching a sufficient adoption rate to begin reducing power flows in the network.
- This small reduction in net demand may potentially reduce or delay the need for network augmentation.

## MV-LV Voltage Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the GNTS-MBTS subtransmission network demonstrate improved voltage performance. While voltage rise and drop issues are still expected to begin from 2033, the number of affected customers is expected to be reduced.

- As DOEs are gradually implemented for PV and Level-2 EV customers (2028-2038), both voltage rise and drop non-compliance rates decrease by nearly 1% in 2033 and 2038. This reduction translates to approximately 371 fewer affected residential customers in both years.
- Beyond 2043, DOEs' effectiveness in reducing voltage rise non-compliance becomes more pronounced, leading to decreases of 3% (~1,113 customers) in 2043, 5% (~1,856 customers) in 2048, and 4% (~1,484 customers) in 2053 compared to the scenario without DOEs.
- Regarding voltage drop non-compliance beyond 2043, improvements become slightly more pronounced, leading to decreases of 1% (~371 customers) in 2043, 2% (~742 customers) in 2048, and 2% (~742 customers) in 2053 compared to the scenario without DOEs.
- However, the non-compliance rate remains above 5% from 2033, requiring additional voltage management strategies.

## MV-LV Thermal Assessment

With residential customers adopting DOEs, the MV-LV networks connected to theGNTS-MBTS subtransmission network show positive impacts on thermal performance. These improvements begin in 2033, coinciding with a higher DOE adoption rate.

- From 2033 to 2053, the number of overloaded distribution transformers decreases by 2% (~158) in 2033, 2% (~158) in 2038, 4% (~316) in 2043, 5% (~395) in 2048, and 5% (~395) in 2053.
- Between 2038 and 2053, the severity of overloading is also reduced, with 1% (~79) to 4% (~316) fewer distribution transformers exceeding 150% loading compared to the scenario without DOEs.

- These reductions in thermal problems will decrease/delay the required network augmentation investments.

### PV Curtailment Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the GNTS-MBTS subtransmission network initially experience a slight reduction in PV curtailment (2028). However, over time, curtailment increases, surpassing levels observed in the scenario without DOEs. This occurs because DOEs impose additional constraints on existing PV inverter functions (Volt-Watt and Volt-Var). Moreover, the "Equal Allocation" strategy adopted in this study, which gives all flexible customers the same export limit during corresponding time intervals, does not maximize aggregate PV generation.

- All PV customers may experience varying degrees of curtailment. In 2028, aggregated PV curtailment is approximately 7% (14 GWh), lower than the 9% (9 GWh) in the scenario without DOEs. This percentage reduction occurs as a small fraction of PV systems begins adopting DOEs. However, the total curtailed energy increases because inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential.
- As DOE adoption increases, the "Equal Allocation" strategy's limitations become evident. DOE values, constrained by customers with the most severe voltage issues, negatively impact all customers within the same LV network. Consequently, aggregated PV curtailment reaches 23 GWh (11%) by 2033, significantly higher than the 14 GWh (12%) in the scenario without DOEs. By 2053, it reaches 93 GWh (27%), far exceeding the 44 GWh (23%) without DOEs. However, note that PV inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential but also increasing curtailment.

### EV Management Assessment

With residential customers adopting import DOEs for Level-2 EVs from 2033, the MV-LV networks connected to the GNTS-MBTS subtransmission network experience some EV charging delays. Analysis shows these delays average under 5 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

## SMTS Subtransmission Network

As shown in Table 14, the electrification impact assessment with DOEs indicates that their adoption by residential customers slightly decreases net demand on the subtransmission network from 2038 compared to the scenario without DOEs, slightly reducing the intensity of thermal issues. Voltage issues on the subtransmission network are also mitigated, but only after 2048 when higher number of residential customers have adopted DOEs for exports and imports (for level-2 EVs). The impact is more pronounced in the MV-LV networks connected to the SMTS subtransmission network, where DOEs more effectively mitigate both voltage and thermal issues, delaying the need for network augmentation. However, the effectiveness of DOEs is significantly limited due to a large portion of demand being uncontrollable (e.g., Level-1 EV charging, electrified heating/cooling).

*Table 14. Impact assessment for the SMTS subtransmission network with DOEs.*

| Subtransmission Network – SMTS (With DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 274 | 338 | 431 | 540 | 627 | 713 | 776 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 23% | 28% | 25% | 16% | 14% | 9% |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 0.99 | 0.97 | 0.95 | 0.93 | 0.93 | 0.91 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 18% | 39% | 42% | 42% | 45% |
| Maximum Voltage (pu) | | | 1.04 | 1.04 | 1.05 | 1.05 | 1.06 | 1.05 | 1.05 |
| Minimum Voltage (pu) | | | 0.93 | 0.90 | 0.85 | 0.75 | 0.70 | 0.66 | 0.64 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 95% | 85% | 65% | 60% | 60% | 50% | 50% |
| | | 100%-110% | 5% | 5% | 15% | 5% | 0% | 10% | 0% |
| | | Avg. Overloading Duration (hr) | 1.5 | 3 | 4.5 | 6 | 0 | 5.5 | 0 |
| | | 110%-150% | 0% | 10% | 15% | 25% | 5% | 5% | 10% |
| | | Avg. Overloading Duration (hr) | 0 | 2 | 5.7 | 10.1 | 6.5 | 10.5 | 2.5 |
| | | > 150% | 0% | 0% | 5% | 10% | 35% | 35% | 40% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 14 | 12.3 | 7.6 | 12.6 | 13 |
| | Max. Utilisation of the Worst Performing Transformer | | 104% | 118% | 212% | 305% | 370% | 414% | 425% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 96% | 84% | 84% | 64% | 60% |
| | | 100%-110% | 0% | 0% | 4% | 4% | 0% | 20% | 4% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 2.5 | 5 | 0 | 2.8 | 2 |
| | | 110%-150% | 0% | 0% | 0% | 12% | 12% | 8% | 24% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 6.3 | 9.8 | 14 | 4 |
| | | > 150% | 0% | 0% | 0% | 0% | 4% | 8% | 12% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 4.5 | 8.5 | 8.7 |
| | Max. Utilisation of the Worst Performing Line | | 66% | 81% | 106% | 139% | 156% | 168% | 176% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.3% | 2% | 4% | 6% | 6% | 7% | 11% |
| Residential Voltage Drop Non-Compliance | | | 2% | 4% | 7% | 10% | 13% | 18% | 24% |
| % of LV Networks with Voltage Rise Issues | | | 0.5% | 5% | 7% | 8% | 7% | 9% | 13% |
| % of LV Networks with Voltage Drop Issues | | | 5% | 9% | 11% | 13% | 16% | 20% | 29% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 0.5% | 5% | 7% | 8% | 7% | 8% | 11% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of Distribution Transformers with Maximum Utilisation** | **<= 100%** | **99%** | **96%** | **90%** | **82%** | **78%** | **74%** | **71%** |
| | **100%-110%** | **0.6%** | **1%** | **2%** | **4%** | **2%** | **4%** | **4%** |
| | **110%-150%** | **0.6%** | **2%** | **6%** | **11%** | **11%** | **10%** | **10%** |
| | **> 150%** | **0%** | **0.6%** | **2%** | **4%** | **8%** | **13%** | **16%** |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of PV Customers Curtailed** | | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |
| **Aggregate Export** | **Total PV Curtailment (GWh)** | **19** | **32** | **59** | **117** | **156** | **204** | **244** |
| | **% of PV Curtailment** | **6%** | **8%** | **12%** | **22%** | **26%** | **30%** | **32%** |
| ***EV Management Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of EVs Affected** | | **-** | **-** | **9%** | **12%** | **16%** | **20%** | **24%** |
| **Average EV Charging Delay (h)** | | **-** | **-** | **3.2** | **4.7** | **4.9** | **4.8** | **4.7** |

Detailed analysis is provided below.

## Terminal Station Assessment

With residential customers adopting DOEs, SMTS load is slightly reduced, starting with a 1% decrease in 2033 and reaching a 7% reduction by 2053. However, this reduction is insufficient to bring the terminal station within thermal limits for any of these years.

- This overloading is primarily driven by the adoption of electrified heating, increased adoption of cooling systems, as well as increased EV usage among residential customers, resulting in higher net demand. The impact of import DOEs on reducing demand is limited, as they are only applied to Level-2 EV charging, while the majority of load increase stems from electrified heating/cooling systems.

## Subtransmission Voltage Assessment

With residential customers adopting DOEs, subtransmission voltages show slight improvements in 2048 (from 0.65 pu to 0.66 pu), and 2053 (from 0.62 pu to 0.64 pu), with negligible effects in other years. However, this improvement is insufficient to bring voltages within the code limit of 0.9 pu.

- The improvement on the minimum voltage from 2048 onwards is attributed to the assumption that 100% of residential customers have adopted export DOE and high levels of import DOE (level-2 EVs) by this time.

## Subtransmission Thermal Assessment

With residential customers adopting DOEs, ZSS transformer and 66kV line loadings are slightly reduced from 2033, decreasing both the intensity and duration of overloads. However, network upgrades remain necessary as the number of transformers and lines experiencing overutilization has not decreased, and capacity issues persist.

- By 2033, export DOEs are adopted by 50% of customers with PV systems, while import DOEs are adopted by 10% of the EVs, reaching a sufficient adoption rate to begin reducing power flows in the network.

### MV-LV Voltage Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the SMTS subtransmission network demonstrate improved voltage performance. Voltage rise and drop issues are still expected to begin from 2038 and 2033 respectively, but the number of affected customers is expected to be reduced.

- As DOEs are gradually implemented for PV and Level-2 EV customers (2028-2038), both voltage rise and drop non-compliance rates decrease by 1% in 2033 and 2% in 2038. This reduction translates to approximately 814 fewer affected residential customers in 2033 and 1,628 in 2038.
- Beyond 2043, DOEs' effectiveness in reducing voltage rise non-compliance becomes more pronounced, leading to decreases of 5% (~4,071 customers) in 2043, 6% (~4,885 customers) in 2048, and 7% (~5,699 customers) in 2053 compared to the scenario without DOEs.
- Regarding voltage drop non-compliance beyond 2043, improvements become slightly more pronounced, leading to decreases of 3% (~2,443 customers) in 2043, 2% (~1,628 customers) in 2048, and 2% (~1,628 customers) in 2053 compared to the scenario without DOEs.
- However, the non-compliance rate remains above 5% from 2033, requiring additional voltage management strategies.

### MV-LV Thermal Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the SMTS subtransmission network show positive impacts on thermal performance. These improvements begin in 2033, coinciding with a higher DOE adoption rate.

- From 2033 to 2053, the number of overloaded distribution transformers decreases by 2% (~196) in 2033, 2% (~196) in 2038, 3% (~294) in 2043, 5% (~490) in 2048, and 4% (~392) in 2053.
- Between 2038 and 2053, the severity of overloading is also reduced, with 1% (~98) to 4% (~392) fewer distribution transformers exceeding 150% loading compared to the scenario without DOEs.
- These reductions in thermal problems will decrease/delay the required network augmentation investments.

### PV Curtailment Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the SMTS subtransmission network initially experience a slight reduction in PV curtailment (2028). However, over time, curtailment increases, surpassing levels observed in the scenario without DOEs. This occurs because DOEs impose additional constraints on existing PV inverter functions (Volt-Watt and Volt-Var). Moreover, the "Equal Allocation" strategy adopted in this study, which gives all flexible customers the same export limit during corresponding time intervals, does not maximize aggregate PV generation.

- All PV customers may experience varying degrees of curtailment. In 2028, aggregated PV curtailment is approximately 8% (32 GWh), lower than the 9% (24 GWh) in the scenario without DOEs. This percentage reduction occurs as a small fraction of PV systems begins adopting DOEs. However, the total curtailed energy increases because inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential.
- As DOE adoption increases, the "Equal Allocation" strategy's limitations become evident. DOE values, constrained by customers with the most severe voltage issues, negatively impact all customers within the same LV network. Consequently, aggregated PV curtailment reaches 59 GWh (12%) by 2033, significantly higher than the 37 GWh (12%) in the scenario without DOEs. By 2053, it reaches 244 GWh (32%), far exceeding the 117 GWh (24%) without DOEs. However, note that PV inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential but also increasing curtailment.

### EV Management Assessment

With residential customers adopting import DOEs for Level-2 EVs from 2033, the MV-LV networks connected to the SMTS subtransmission network experience some EV charging delays. Analysis shows these delays average under 5 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

## TSTS Subtransmission Network

As shown in ***Table 15***, the electrification impact assessment with DOEs indicates that their adoption by residential customers slightly decreases net demand on the subtransmission network from 2033 compared to the scenario without DOEs, slightly reducing the intensity of thermal issues. Voltages are not really affected, and they always within code requirements. The impact is more pronounced in the MV-LV networks connected to the TSTS subtransmission network, where DOEs more effectively mitigate both voltage and thermal issues, delaying the need for network augmentation. However, the effectiveness of DOEs is significantly limited due to a large portion of demand being uncontrollable (e.g., Level-1 EV charging, electrified heating/cooling).

Detailed analysis is provided below.

*Table 15. Impact assessment for the TSTS subtransmission network with DOEs.*

| Subtransmission Network – TSTS (With DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 359 | 433 | 530 | 647 | 755 | 861 | 936 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 20% | 23% | 22% | 17% | 14% | 9% |
| Power Factor at Terminal Station for Max. Demand | | | 0.99 | 0.99 | 0.97 | 0.97 | 0.96 | 0.95 | 0.95 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Maximum Voltage (pu) | | | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| Minimum Voltage (pu) | | | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 0% | 0% | 0% | 0% |
| | | 100%-110% | 0% | 0% | 0% | 100% | 33% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 3.2 | 5.5 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 67% | 100% | 100% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 4.5 | 7 | 8.3 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Max. Utilisation of the Worst Performing Transformer | | 77% | 86% | 96% | 108% | 118% | 130% | 138% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Max. Utilisation of the Worst Performing Line | | 52% | 59% | 66% | 76% | 84% | 93% | 100% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.2% | 1% | 3% | 4% | 5.1% | 6% | 5.5% |
| Residential Voltage Drop Non-Compliance | | | 2% | 4% | 8% | 12% | 15% | 20% | 24% |
| % of LV Networks with Voltage Rise Issues | | | 0.8% | 9% | 13% | 14% | 13% | 15% | 15% |
| % of LV Networks with Voltage Drop Issues | | | 10% | 17% | 20% | 22% | 26% | 31% | 35% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 0.8% | 8% | 13% | 14% | 13% | 15% | 15% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| % of Distribution Transformers with Maximum Utilisation | <= 100% | 100% | 97% | 87% | 73% | 69% | 65% | 62% |
| | 100%-110% | 0% | 2% | 3% | 6% | 3% | 4% | 4% |
| | 110%-150% | 0.2% | 0.2% | 9% | 19% | 17% | 12% | 11% |
| | > 150% | 0% | 0.2% | 0.5% | 3% | 11% | 19% | 24% |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| % of PV Customers Curtailed | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | 17 | 28 | 54 | 106 | 145 | 193 | 230 |
| | Percentage of PV Curtailment | 6% | 8% | 13% | 23% | 28% | 32% | 35% |
| ***EV Management Assessment (extrapolation of metrics)*** | | | | | | | | |
| % of EVs Affected | | - | - | 9% | 12% | 16% | 20% | 24% |
| Average EV Charging Delay (h) | | - | - | 3.5 | 5.1 | 5.4 | 5.4 | 5.3 |

## Terminal Station Assessment

With residential customers adopting DOEs, TSTS load is slightly reduced, starting with a 2% decrease in 2033, and reaching a 7% reduction by 2053. The net demand reduction in 2033 was enough to bring it within its thermal capacity, delaying upgrade investments by 5 years. However, for the following years the reduction is insufficient to bring the terminal station within thermal limits. The power factor is not affected, but it is always within limits.

- This overloading is primarily driven by the adoption of electrified heating, increased adoption of cooling systems, as well as increased EV usage among residential customers, resulting in higher net demand. The impact of import DOEs on reducing demand is limited, as they are only applied to Level-2 EV charging, while the majority of load increase stems from electrified heating/cooling systems.
- The reduction of net demand has delayed augmentation investments by 5 years, and it may also decrease the required augmentation investment.

## Subtransmission Voltage Assessment

With residential customers adopting DOEs, subtransmission voltages stayed the same as without DOEs.

- This happens because in the received model most of the loads are connected directly to the terminal station.

## Subtransmission Thermal Assessment

With residential customers adopting DOEs, ZSS transformer and 66kV line loadings are slightly reduced from 2038, decreasing both the intensity and duration of overloads. With the demand decrease, lines are within their capacity limits throughout the assessment period (2023-2053). However, upgrades on the ZSS transformers remain necessary.

- By 2033, export DOEs are adopted by 50% of customers with PV systems, while import DOEs are adopted by 10% of the EVs, reaching a sufficient adoption rate to begin reducing power flows in the network.
- This small reduction in net demand is expected to reduce the network augmentation investment.

### MV-LV Voltage Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the TSTS subtransmission network demonstrate improved voltage performance. Voltage rise issues are now expected to emerge from 2043 in the area, effectively delaying these problems by at least 5 years compared to the scenario without DOEs. While voltage drop issues are still expected to begin from 2033, fewer customers are expected to be affected.

- As DOEs are gradually implemented for PV and Level-2 EV customers (2028-2038), both voltage rise and drop non-compliance rates decrease by 1% in 2033 and 2% in 2038. This reduction translates to approximately 689 fewer affected residential customers in 2033 and 1,376 in 2038.
- Beyond 2043, DOEs' effectiveness in reducing voltage rise non-compliance becomes more pronounced, leading to decreases of nearly 5% (~3,439 customers) in 2043, 6% (~4,127 customers) in 2048, and nearly 10% (~6,878 customers) in 2053 compared to the scenario without DOEs.
- Regarding voltage drop non-compliance beyond 2043, improvements become slightly more pronounced, leading to decreases of 3% (~2,063 customers) in 2043, 3% (~2,063 customers) in 2048, and 2% (~1,375 customers) in 2053 compared to the scenario without DOEs.
- However, the non-compliance rate remains above 5% from 2033, requiring additional voltage management strategies.

### MV-LV Thermal Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the TSTS subtransmission network show positive impacts on thermal performance. These improvements begin in 2033, coinciding with a higher DOE adoption rate.

- From 2033 to 2053, the number of overloaded distribution transformers decreases by 3% (~99) in 2033, 1% (~33) in 2038, 3% (~99) in 2043, 4% (~132) in 2048, and 3% (~99) in 2053.
- Between 2038 and 2053, the severity of overloading is also reduced, with 2% (~66) to 5% (~165) fewer distribution transformers exceeding 150% loading compared to the scenario without DOEs.
- These reductions in thermal problems will decrease/delay the required network augmentation investments.

## PV Curtailment Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the TSTS subtransmission network initially experience a slight reduction in PV curtailment (2028). However, over time, curtailment increases, surpassing levels observed in the scenario without DOEs. This occurs because DOEs impose additional constraints on existing PV inverter functions (Volt-Watt and Volt-Var). Moreover, the "Equal Allocation" strategy adopted in this study, which gives all flexible customers the same export limit during corresponding time intervals, does not maximize aggregate PV generation.

- All PV customers may experience varying degrees of curtailment. In 2028, aggregated PV curtailment is approximately 8% (28 GWh), lower than the 9% (23 GWh) in the scenario without DOEs. This percentage reduction occurs as a small fraction of PV systems begins adopting DOEs. However, the total curtailed energy increases because inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential.
- As DOE adoption increases, the "Equal Allocation" strategy's limitations become evident. DOE values, constrained by customers with the most severe voltage issues, negatively impact all customers within the same LV network. Consequently, aggregated PV curtailment reaches 54 GWh (13%) by 2033, significantly higher than the 35 GWh (12%) in the scenario without DOEs. By 2053, it reaches 230 GWh (35%), far exceeding the 113 GWh (24%) without DOEs. However, note that PV inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential but also increasing curtailment.

## EV Management Assessment

With residential customers adopting import DOEs for Level-2 EVs from 2033, the MV-LV networks connected to the TSTS subtransmission network experience some EV charging delays. Analysis shows these delays average under 6 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

# TTS Subtransmission Network

As shown in Table 16, the electrification impact assessment with DOEs indicates that their adoption by residential customers slightly decreases net demand on the subtransmission network from 2033 compared to the scenario without DOEs, slightly reducing the intensity of thermal issues. Voltage issues on the subtransmission network are also mitigated, but only after 2038 when higher number of residential customers have adopted DOEs for exports and imports (for level-2 EVs). The impact is more pronounced in the MV-LV networks connected to the TTS subtransmission network, where DOEs more effectively mitigate both voltage and thermal issues, delaying the need for network augmentation. However, the effectiveness of DOEs is significantly limited due to a large portion of demand being uncontrollable (e.g., Level-1 EV charging, electrified heating/cooling).

Detailed analysis is provided below.

*Table 16. Impact assessment for the TTS subtransmission network with DOEs.*

| Subtransmission Network – TTS (With DOEs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 254 | 340 | 468 | 626 | 785 | 918 | 1013 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | 34% | 38% | 34% | 25% | 17% | 10% |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 0.98 | 0.95 | 0.92 | 0.87 | 0.84 | 0.81 |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | |
| % of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| % of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 8% | 54% | 54% |
| Maximum Voltage (pu) | | | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 |
| Minimum Voltage (pu) | | | 0.99 | 0.97 | 0.95 | 0.93 | 0.82 | 0.78 | 0.75 |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | |
| HV Transformers | % of Transformers with Maximum Utilisation | <= 100% | 100% | 43% | 14% | 14% | 0% | 0% | 0% |
| | | 100%-110% | 0% | 14% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 1.5 | 0 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 43% | 86% | 29% | 14% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 1.5 | 7.4 | 11.3 | 17.0 | 0 | 0 |
| | | > 150% | 0% | 0% | 0% | 57% | 86% | 100% | 100% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 7.8 | 11.6 | 15.1 | 16.9 |
| | Max. Utilisation of the Worst Performing Transformer | | 92% | 114% | 149% | 198% | 232% | 252% | 273% |
| HV Lines | % of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 90% | 80% | 60% | 60% | 60% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 10% | 20% | 20% | 20% | 0% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 1.5 | 7.3 | 1.0 | 8.5 | 0 |
| | | > 150% | 0% | 0% | 0% | 0% | 20% | 20% | 40% |
| | | Avg. Overloading Duration (hr) | 0 | 0 | 0 | 0 | 4.5 | 11.8 | 7.9 |
| | Max. Utilisation of the Worst Performing Line | | 65% | 85% | 112% | 147% | 186% | 214% | 229% |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.1% | 0.8% | 2% | 2% | 3% | 4% | 3% |
| Residential Voltage Drop Non-Compliance | | | 1% | 3% | 7% | 11% | 15% | 19% | 23% |
| % of LV Networks with Voltage Rise Issues | | | 1% | 13% | 20% | 21% | 19% | 22% | 21% |
| % of LV Networks with Voltage Drop Issues | | | 15% | 26% | 31% | 32% | 37% | 38% | 43% |
| % of LV Networks with Both Voltage Rise & Drop Issues | | | 1% | 13% | 20% | 21% | 19% | 21% | 21% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of Distribution Transformers with Maximum Utilisation** | **<= 100%** | **100%** | **96%** | **78%** | **54%** | **48%** | **45%** | **41%** |
| | **100%-110%** | **0%** | **4%** | **6%** | **10%** | **5%** | **5%** | **4%** |
| | **110%-150%** | **0%** | **0%** | **16%** | **32%** | **28%** | **17%** | **15%** |
| | **> 150%** | **0%** | **0%** | **0%** | **4%** | **19%** | **33%** | **40%** |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of PV Customers Curtailed** | | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |
| **Aggregate Export** | **Total PV Curtailment (GWh)** | **20** | **34** | **63** | **122** | **170** | **232** | **276** |
| | **% of PV Curtailment** | **6%** | **8%** | **13%** | **22%** | **27%** | **33%** | **35%** |
| ***EV Management Assessment (extrapolation of metrics)*** | | | | | | | | |
| **% of EVs Affected** | | - | - | **9%** | **13%** | **16%** | **21%** | **24%** |
| **Average EV Charging Delay (h)** | | - | - | **3.8** | **5.2** | **5.7** | **5.7** | **5.5** |

## Terminal Station Assessment

With residential customers adopting DOEs, TTS load is slightly reduced, starting with a 1% decrease in 2033 and reaching a 10% reduction by 2053. However, this reduction is insufficient to bring the terminal station within thermal limits for any of these years. The power factor also shows slightly improvement from 2048 onward, though not enough to meet the code requirement of 0.9.

- This overloading is primarily driven by the adoption of electrified heating, increased adoption of cooling systems, as well as increased EV usage among residential customers, resulting in higher net demand. The impact of import DOEs on reducing demand is limited, as they are only applied to Level-2 EV charging, while the majority of load increase stems from electrified heating/cooling systems.
- The improvement in power factor and reduction of net demand may potentially decrease the required augmentation investment.

## Subtransmission Voltage Assessment

With residential customers adopting DOEs, subtransmission voltages show slight improvements in 2038 (from 0.92 pu to 0.93 pu), 2048 (from 0.76 pu to 0.78 pu), and 2053 (from 0.73 pu to 0.75 pu), with negligible effects in other years. The small improvement in voltages in 2038 is sufficient to eliminate voltage issues for that year, potentially delaying necessary upgrades by 5 years. However, voltage improvements are insufficient to bring voltages within the code limit of 0.9 pu after 2043.

- The improvement on the minimum voltage from 2038 onwards is attributed to the assumption that 100% of residential customers have adopted export DOE and moderate levels of import DOE (level-2 EVs) by this time.

## Subtransmission Thermal Assessment

With residential customers adopting DOEs, ZSS transformer and 66kV line loadings are slightly reduced from 2033, decreasing both the intensity and duration of overloads. However, network upgrades remain necessary as the number of transformers and lines experiencing overutilization has not decreased, and capacity issues persist.

- By 2033, export DOEs are adopted by 50% of customers with PV systems, while import DOEs are adopted by 10% of the EVs, reaching a sufficient adoption rate to begin reducing power flows in the network.
- This small reduction in net demand may potentially reduce or delay the need for network augmentation.

## MV-LV Voltage Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the TTS subtransmission network demonstrate improved voltage performance. Voltage rise issues are not expected anymore throughout the assessment period (2023-2053) when compared to the scenario without DOEs. While voltage drop issues are still expected to begin from 2033, fewer customers are expected to be affected.

- As DOEs are gradually implemented for PV and Level-2 EV customers (2028-2038), voltage rise non-compliance rate decrease by 1% in 2033 and 2% in 2038, resulting in approximately 809 fewer affected residential customers in 2033 and 1,618 in 2038. While voltage drop non-compliance rate decrease by 2% in 2033 and 2038, resulting in approximately 1,618 fewer affected residential customers in each year.
- Beyond 2043, DOEs' effectiveness in reducing voltage rise non-compliance becomes more pronounced, leading to decreases of 5% (~4,044 customers) in 2043, 7% (~5,662 customers) in 2048, and 9% (~7,279 customers) in 2053 compared to the scenario without DOEs.
- Regarding voltage drop non-compliance beyond 2043, improvements become slightly more pronounced, leading to decreases of 3% (~2,426 customers) in 2043, 3% (~2,426 customers) in 2048, and 1% (~809 customers) in 2053 compared to the scenario without DOEs.
- However, the non-compliance rate remains above 5% from 2033, requiring additional voltage management strategies.

## MV-LV Thermal Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the TTS subtransmission network show positive impacts on thermal performance. These improvements begin in 2033, coinciding with a higher DOE adoption rate.

- From 2033 to 2053, the number of overloaded distribution transformers decreases by 5% (~60) in 2033, 1% (~12) in 2038, 2% (~24) in 2043, 4% (~48) in 2048, and 1% (~12) in 2053.

- Between 2038 and 2053, the severity of overloading is also reduced, with 4% (~48) to 7% (~83) fewer distribution transformers exceeding 150% loading compared to the scenario without DOEs.
- These reductions in thermal problems will decrease/delay the required network augmentation investments.

### PV Curtailment Assessment

With residential customers adopting DOEs, the MV-LV networks connected to the TTS subtransmission network initially experience a slight reduction in PV curtailment (2028). However, over time, curtailment increases, surpassing levels observed in the scenario without DOEs. This occurs because DOEs impose additional constraints on existing PV inverter functions (Volt-Watt and Volt-Var). Moreover, the "Equal Allocation" strategy adopted in this study, which gives all flexible customers the same export limit during corresponding time intervals, does not maximize aggregate PV generation.

- All PV customers may experience varying degrees of curtailment. In 2028, aggregated PV curtailment is approximately 8% (34 GWh), lower than the 9% (29 GWh) in the scenario without DOEs. This percentage reduction occurs as a small fraction of PV systems begins adopting DOEs. However, the total curtailed energy increases because inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential.
- As DOE adoption increases, the "Equal Allocation" strategy's limitations become evident. DOE values, constrained by customers with the most severe voltage issues, negatively impact all customers within the same LV network. Consequently, aggregated PV curtailment reaches 63 GWh (13%) by 2033, significantly higher than the 44 GWh (12%) in the scenario without DOEs. By 2053, it reaches 276 GWh (35%), far exceeding the 140 GWh (24%) without DOEs. However, note that PV inverters are upgraded to 10 kVA in the with-DOEs scenario, unlocking greater PV potential but also increasing curtailment.

### EV Management Assessment

With residential customers adopting import DOEs for Level-2 EVs from 2033, the MV-LV networks connected to the TTS subtransmission network experience some EV charging delays. Analysis shows these delays average under 6 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

## Whole-State Extrapolation With DOEs

This section presents findings from a comprehensive assessment of load electrification impacts on MV-LV networks across Victoria. The study evaluates voltage and thermal impacts with DOEs, providing an alternative, and more likely, scenario for network performance under increased electrification. We extrapolate metrics from four representative MV feeder types from WP1.5 to estimate potential state-wide implications.

Note that the following key assumptions or limitations (used by WP1.5) need to be accounted for when interpreting the results:

1. The population growth in the assessed network area is not considered, meaning that the number of customers remains the same throughout the horizon (2023–2053).
2. Network augmentation or reconfiguration t is not considered in this study. That is, the assessed MV-LV networks are assumed to remain unchanged throughout the assessment period (2023–2053). Therefore, some voltage or thermal issues identified in this impact assessment should have been addressed before escalating to a severe level. However, changes in demand and the increase in network issues can still provide valuable insights for distribution network planning.
3. A modern design of LV conductors (i.e., featuring lower impedance and higher ampacity) is adopted in the MV-LV network model provided by WP1.4. This modelling choice may significantly underestimate LV conductor utilization.
4. For short-rural and long-rural feeders, single-wire earth return (SWER) networks are not considered in the MV-LV network models provided by WP1.4. Instead, these networks are modelled using a three-phase LV network as an alternative. This approach may lead to an underestimation of voltage issues.
5. The size and adoption rate of DERs (i.e., PV, EVs, electrified heating/cooling, and hot water) are derived from scenario planning data provided by C4NET. Forecast assumptions in scenario planning may lead to underestimation or overestimation of the results.

Table 17 shows the whole-state extrapolation based on various metrics assessed in this project with the use of DOEs by residential customers.

Detailed analysis is provided below.

### Whole-State MV-LV Voltage Assessment

With residential customers adopting DOEs, the state MV-LV networks has shown positive impacts on voltage performance. Voltage rise issues are now expected to start from 2043 across the state, effectively delaying these problems by at least 5 years compared to the scenario without DOEs. While voltage drop issues are still anticipated to begin from 2033.

- As DOEs are gradually implemented for PV and Level-2 EV customers (2028-2038), voltage rise non-compliance rates decrease by 1% in 2033 and 2% by 2038. This reduction translates to approximately 24,000 and 48,000 fewer residential customers affected by overvoltage in each respective year.
- Regarding voltage drop non-compliance rates, they decrease by 2% in both 2033 and 2038. This reduction translates to approximately 48,000 fewer residential customers affected by undervoltage issues.
- Beyond 2043, DOEs' effectiveness in reducing voltage rise non-compliance becomes more pronounced, leading to decreases of 5% (~120,000 customers) in 2043, 6% (~144,000

customers) in 2048, and 9% (~216,000 customers) in 2053 compared to the scenario without DOEs.

- Regarding voltage drop non-compliance beyond 2043, improvements become slightly more pronounced, leading to decreases of 4% (~96,000 customers) in 2043, 3% (~72,000 customers) in 2048, and 2% (~48,000 customers) in 2053 compared to the scenario without DOEs.
- However, the non-compliance rate remains above 5% beyond 2033, requiring additional DER management strategies.

*Table 17. Whole-state extrapolation with DOEs.*

| Whole-State (211 ZSS out of 246) (with DOEs) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | | 2023 | 2028 | 2033 | 2038 | 2043 | 2048 | 2053 |
| *Voltage Assessment* | | | | | | | | |
| Residential Voltage Rise Non-Compliance | All ZSS | 0.2% | 1% | 3% | 4% | 5.1% | 6% | 7% |
| | <50 MVA | 0.2% | 1% | 3% | 5.1% | 6% | 6% | 10% |
| | 50-100 MVA | 0.2% | 1% | 3% | 5% | 5.4% | 6% | 7% |
| | >100 MVA | 0.1% | 0.9% | 2% | 3% | 4% | 5% | 3% |
| Residential Voltage Drop Non-Compliance | All ZSS | 2% | 4% | 7% | 11% | 14% | 19% | 24% |
| | <50 MVA | 2% | 4% | 7% | 11% | 14% | 19% | 25% |
| | 50-100 MVA | 2% | 4% | 7% | 11% | 14% | 19% | 24% |
| | >100 MVA | 1% | 3% | 7% | 11% | 15% | 20% | 23% |
| % of LV Networks with Voltage Rise Issues | All ZSS | 0.7% | 7% | 11% | 11% | 11% | 13% | 15% |
| | <50 MVA | 0.6% | 5% | 7% | 8% | 7% | 9% | 14% |
| | 50-100 MVA | 0.7% | 8% | 12% | 12% | 11% | 13% | 16% |
| | >100 MVA | 0.8% | 10% | 15% | 16% | 14% | 17% | 19% |
| % of LV Networks with Voltage Drop Issues | All ZSS | 8% | 14% | 16% | 18% | 21% | 25% | 32% |
| | <50 MVA | 5% | 9% | 11% | 13% | 16% | 20% | 29% |
| | 50-100 MVA | 9% | 15% | 17% | 19% | 23% | 27% | 33% |
| | >100 MVA | 11% | 19% | 23% | 24% | 29% | 30% | 38% |
| % of LV Networks with Both Voltage Rise & Drop Issues | All ZSS | 0.7% | 7% | 11% | 11% | 11% | 12% | 14% |
| | <50 MVA | 0.6% | 5% | 7% | 8% | 7% | 8% | 12% |
| | 50-100 MVA | 0.7% | 7% | 12% | 12% | 11% | 13% | 15% |
| | >100 MVA | 1% | 11% | 18% | 19% | 17% | 19% | 20% |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***Thermal Assessment*** | | | | | | | | | |
| % of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 99% | 96% | 89% | 77% | 73% | 69% | 66% |
| | | <50 MVA | 99% | 96% | 91% | 83% | 80% | 75% | 72% |
| | | 50-100 MVA | 99% | 96% | 88% | 76% | 73% | 68% | 65% |
| | | >100 MVA | 100% | 96% | 81% | 59% | 54% | 50% | 46% |
| | 100%-110% | All ZSS | 0.4% | 2% | 3% | 5% | 3% | 4% | 4% |
| | | <50 MVA | 0.7% | 1% | 2% | 4% | 2% | 4% | 4% |
| | | 50-100 MVA | 0.4% | 2% | 3% | 5% | 3% | 4% | 4% |
| | | >100 MVA | 0.2% | 3% | 5% | 9% | 4% | 5% | 4% |
| | 110%-150% | All ZSS | 0.5% | 1% | 7% | 14% | 14% | 11% | 11% |
| | | <50 MVA | 0.6% | 2% | 5% | 9% | 10% | 9% | 10% |
| | | 50-100 MVA | 0.4% | 1% | 8% | 15% | 14% | 11% | 11% |
| | | >100 MVA | 0.1% | 0.5% | 14% | 28% | 25% | 16% | 14% |
| | > 150% | All ZSS | 0% | 0.5% | 1% | 4% | 10% | 16% | 20% |
| | | <50 MVA | 0% | 0.7% | 2% | 4% | 8% | 12% | 14% |
| | | 50-100 MVA | 0% | 0.4% | 1% | 4% | 10% | 17% | 20% |
| | | >100 MVA | 0% | 0.1% | 0.5% | 4% | 17% | 30% | 35% |
| ***PV Curtailment*** | | | | | | | | | |
| % of PV Customers Curtailed | | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 581 | 983 | 1865 | 3656 | 4974 | 6600 | 7872 |
| | % of PV Curtailment | | 6% | 8% | 13% | 22% | 27% | 32% | 34% |
| ***EV Management*** | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | 9% | 13% | 16% | 20% | 24% |
| Average EV Charging Delay (h) | | | - | - | 3.5 | 5 | 5.3 | 5.2 | 5.1 |

## MV-LV Thermal Assessment

With residential customers adopting DOEs, the state MV-LV networks has shown positive impacts on thermal performance. These improvements begin in 2033, coinciding with a higher DOE adoption rate.

- From 2033 to 2053, the number of overloaded distribution transformers decreases by 3% (~5,100) in 2033, 1% (~1,700) in 2038, 3% (~5,100) in 2043, 5% (~8,500) in 2048, and 4% (~6,800) in 2053.
- Between 2038 and 2053, the severity of overloading is also reduced, with 2% (~3,400) to 5% (~8,500) fewer distribution transformers exceeding 150% loading compared to the scenario without DOEs.

- These reductions in thermal problems will decrease considerably the required network augmentation investments in the whole state.

### PV Curtailment Assessment

With residential customers adopting DOEs, the state MV-LV networks initially experience a slight reduction in PV curtailment (2028). However, over time, curtailment increases, surpassing levels observed in the scenario without DOEs. This occurs because DOEs impose additional constraints on existing PV inverter functions (Volt-Watt and Volt-Var). Moreover, the "Equal Allocation" strategy adopted in this study, which gives all flexible customers the same export limit during corresponding time intervals, does not maximize aggregate PV generation.

- All PV customers may experience varying degrees of curtailment. In 2028, aggregated PV curtailment is approximately 8% (~983 GWh), lower than the 9% (~793 GWh) in the scenario without DOEs. This percentual reduction occurs as a small fraction of PV systems begins adopting DOEs, with their inverters upgraded to 10 kVA, unlocking greater PV potential.
- As DOE adoption increases, the "Equal Allocation" strategy's limitations become evident. DOE values, constrained by customers with the most severe voltage issues, negatively impact all customers within the same LV network. Consequently, aggregated PV curtailment reaches 1,865 GWh (13%) by 2033 (when PV penetration is assumed to be 36%), higher than the 1,218 GWh (12%) in the scenario without DOEs. By 2053, when PV penetration is assumed to be 47%, it reaches 7,872 GWh (34%), far exceeding the 3,878 GWh (24%) without DOEs. However, note that PV inverters are upgraded to 10 kVA in the DOEs scenario, unlocking greater PV potential but also increasing curtailment.

### EV Management Assessment

With residential customers adopting import DOEs for Level-2 EVs from 2033, the state MV-LV networks experience some EV charging delays. Analysis shows these delays average around 5 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

# 4. Key Findings

Based on DER scenarios developed by C4NET in collaboration with participating DNSPs, and assuming no population growth or network upgrades (e.g., network augmentation), the key findings from the electrification impact assessment for the whole state and subtransmission networks are as follows, for both scenarios, “without DOE” and “with DOE”.

## Whole-State Extrapolation

### MV-LV Voltage Assessment

1. In the next decade (starting from 2023), PV penetration is expected to grow steadily, and voltage issues can emerge as a limiting factor for further PV uptake. Typically for those ZSS with MV-LV networks less robust to voltage changes (i.e., ZSS with many urban and short-rural feeders).
2. From 2033, the PV uptake slows down and net demand rises significantly due to the presence of increasing EV adoption and residential electrification (i.e., heating/cooling and hot water systems), which further exacerbate voltage issues. Note that since the voltage regulation devices in this study are operated to ensure equal voltage headroom and footroom, more voltage drop issues have emerged as a result of managing PV-related voltage rise issues. This indicates that voltage regulation devices (i.e., tap positions) have been exhausted to maintain customer voltages within both upper and lower limits.
3. The adoption of export DOEs by residential customers effectively mitigate voltage rise issues caused by PV export once applied to all residential PV customers (by 2038). However, since PV inverters functions (i.e., Volt-Watt and Volt-Var) already enforce PV curtailment to help regulate voltages in the scenario without DOEs, the additional benefits of export DOEs may be limited.
4. Since import DOEs are applied only to Level-2 EV charging, only a small fraction of the demand is managed (up to 30%). Over time, the demand from residential electrification (i.e., heating/cooling and hot water systems) becomes significant, resulting in more voltage drops and heavy asset utilisation. Consequently, managing Level-2 EV demand alone is insufficient to resolve both voltage and thermal l issues.

### MV-LV Thermal Assessment

1. By 2028, about 4% (~6,800, out of the estimated 170, 000) of state distribution transformers are expected to experience overloading, escalating to 14% (~23,800) by 2033, and 24% (~40,800) by 2038. This rapid increase in overloaded transformers could severely limit further DER uptake without network augmentation.
2. The adoption of import DOEs by residential customers shows positive impacts on thermal performance of distribution transformer from 2033 onwards. The number of overloaded transformers decreases by 1% (~1,700) to 5% (~8,500) annually between 2033 and 2053, with 2% (~3,400) to 5% (~8,500) fewer transformers experiencing extreme overloading (>150%).

These improvements will significantly reduce required network augmentation investments across the state.

### PV Curtailment Assessment

1. For the scenario without DOEs, PV curtailment increases from 410 GWh (6%) in 2023 to 3,878 GWh (24%) in 2053 as PV penetration grows from 27% to 47%. This curtailment is mainly due to 5 kVA inverter capacity limits and Volt-Watt function constraints, limiting renewable energy penetration across MV-LV networks.

2. For the scenario with DOEs, initially, export DOEs reduce curtailment slightly (8% or 983 GWh in 2028, compared to 9% or 793 GWh without DOEs). However, as export DOE adoption increases, curtailment surpasses the without-DOEs scenario due to additional constraints and the "Equal Allocation" strategy. By 2033, curtailment reaches 1,865 GWh (13%), and by 2053, it reaches 7,872 GWh (34%). Note that PV inverters are upgraded to 10 kVA in the DOEs scenario, unlocking greater PV potential but also increasing curtailment.

### EV Management Assessment

1. With residential customers adopting import DOEs for Level-2 EVs from 2033, Victorian residential customers should expect some EV charging delays. Analysis shows these delays average around 5 hours throughout the study period. Nevertheless, these delays primarily occur overnight, minimizing disruptions for EV users.

## Impact Assessment of Subtransmission Networks

### Terminal Station Assessment

1. Terminal stations are expected to face severe overloading issues between 2033 and 2048, with 2033 peak utilization rates of 119-146% and overutilization periods of 8-14 hours during peak demand days. ERTS and TTS are the earliest to face significant overloading by 2033, reaching 133% and 146% utilization respectively. By 2053, the situation worsens across all networks, with overloading reaching 131-345% and overutilization periods extending to 14-24 hours. ERTS and TTS show the most severe projections, potentially exceeding 340% utilization, while GNTS shows the least severe overloading at 131% by 2053, though still critical.

2. Terminal stations are expected to have diverse power factor performance from 2023 to 2053. Three stations (MBTS, SMTS, and TSTS) maintain power factors higher than the 0.9 statutory limit throughout the entire period. Four others face challenges: ERTS and GNTS drop below 0.9 by 2038, TTS by 2043, and CBTS by 2048. These power factor issues are projected to worsen over time for these four stations.

3. The adoption of import DOEs by residential customers consistently reduces load across all terminal stations, with impacts ranging from less than 1% in 2023 to 14% by 2053. ERTS shows the most significant reduction (14%, 318 MVA) by 2053. However, despite these reductions, all six terminal stations continue to exceed their thermal limits in the same years as in the scenario

without DOEs. TSTS experiences a brief respite in 2033, with load reduction bringing it within thermal capacity (531 MVA) and potentially delaying upgrades by 5 years, but this benefit is short-lived. While import DOEs provide some load relief, they are insufficient to resolve the long-term thermal capacity issues or significantly delay the need for upgrades at these terminal stations.

4. The adoption of import DOEs by residential customers results in slight power factor improvements at terminal stations. GNTS shows improvement from 2043, while CBTS, ERTS, and TTS improve from 2048 onward. However, compared to the scenario without DOEs, these improvements are insufficient to bring any station into compliance with the statutory power factor limit (≥0.9).

### Subtransmission Voltage Assessment

1. Subtransmission networks are expected to face varying degrees of undervoltage issues projected to occur between 2033 and 2048, with TSTS being the only exception, showing no voltage issues throughout the assessment period (2023-2053). The percentage of affected buses ranges from 7% in GNTS-MBTS by 2033 to 39% in SMTS by 2038. These undervoltage problems primarily affect the 66kV networks, but some 22kV networks (secondary of ZSSs) are also impacted, indicating that OLTCs at both terminal stations and ZSSs, as well as capacitor banks, have reached their operational limits in maintaining voltage levels. The issues generally occur during early morning and peak periods (morning and evening) of the worst day (winter peak), attributed to high loading conditions caused by electrified heating systems, increased adoption of cooling systems, and rising EV usage by residential customers.

2. The adoption of import DOEs by residential customers generally results in slight improvements to subtransmission voltages, with effects becoming noticeable between 2038 and 2053, depending on the network. However, these improvements are largely insufficient to bring voltages within statutory limits for most networks, when compared to the scenario without DOEs. The TTS subtransmission network stands out as an exception, where the small voltage improvement in 2038 is enough to eliminate voltage issues for that year, potentially delaying necessary upgrades by 5 years. Nevertheless, even for TTS, the improvements are not sufficient to maintain voltages within statutory limits after 2043.

### Subtransmission Thermal Assessment

1. ZSS transformers across all subtransmission networks are expected to face escalating overloading issues. ERTS, SMTS, and TTS encounter concerning problems by 2033, CBTS and GNTS-MBTS by 2038, and TSTS by 2048. By 2053, overloading becomes critical, with 36% (GNTS-MBTS) to 100% (TTS) of transformers exceeding 150% utilization. Peak rates reach up to 441% (SMTS), with some networks experiencing overloads for an average of 11 hours during peak demand days.

2. Subtransmission networks are expected to face varying degrees of 66kV line overloading issues between 2038 and 2053. Four networks (CBTS, ERTS, SMTS, and TTS) face significant challenges, while GNTS-MBTS and TSTS are expected to remain without issues throughout the

assessment period (2023-2053). By 2038, the affected networks show 10-23% of lines experiencing significant overload (110-150%) for 5-7 hours on average, with some lines in TTS already facing extreme overload (>150%). The situation worsens by 2053, with CBTS experiencing the most severe issues (62% of lines exceeding 150% utilization for over 8 hours), followed by TTS (40% of lines exceeding 150%). Peak utilization rates reach up to 241% in ERTS and 244% in TTS.

3. The adoption of import DOEs by residential customers across all six subtransmission networks results in slight loading reductions on ZSS transformers, observed from as early as 2028 in GNTS-MBTS to 2038 in TSTS. These reductions decrease both the intensity and duration of overloads, but upgrades remain necessary for all networks as the number of overutilized transformers has not significantly decreased, and capacity issues persist.
4. The adoption of import DOEs by residential customers reduces the intensity and duration of 66kV line overloads in CBTS, ERTS, SMTS, and TTS networks from 2033-2038. However, while providing some relief, these reductions are insufficient to eliminate the need for network upgrades as capacity issues persist.

# 5. Recommendations

The following recommendations, based on the findings from the electrification impact assessment for the whole state and subtransmission networks considering both scenarios, “without” and “with” DOEs, are intended to help Victorian distribution companies in network planning beyond 2030.

## Whole-State Extrapolation

1. **Continue implementing export DOEs** to enable larger export limits (greater than 5 kVA) where/when network conditions allow. This approach should allow some customers to generate more renewable energy and make a more efficient use of the network infrastructure, while mitigating both voltage and thermal issues.
2. **DOEs should not stop in exports, import DOEs should also be implemented** to mitigate high power flows, which is expected to be driven by widespread EV adoption and electrification of loads. However, **import DOEs should be extended to most if not all controllable loads** (e.g., heating/cooling) where possible, given that this study shows that implementing import DOEs only to level-2 EVs is not enough to solve voltage issues.
3. **Upgrade voltage regulation devices** on MV-LV networks across the state by expanding the tap range of zone substation OLTCs or by upgrading distribution transformers with additional tap positions. This will enable better voltage management and facilitate further DER uptake. Implement these upgrades starting with networks already experiencing problems, followed by those prone to future voltage issues.
4. **Upgrade distribution transformers facing significant (110%-150%) overload for long periods, and extreme (>150%) overload** to increase network capacity. Any upgrades should account for expected future loads to ensure sufficient capacity in the medium to long term, minimizing the need for frequent reinforcements.

## Subtransmission Networks

1. **Take measures to address the expected high loading conditions** at ERTS and TTS by 2033, at CBTS and TSTS by 2038, at SMTS by 2043, and at GNTS-MBTS by 2048. Options may include upgrading the substation's capacity, implementing demand management strategies, or exploring alternative power supply configurations (e.g., use interconnection with other subtransmission networks).
2. **Take measures to correct the expected low inductive power factor** at ERTS by 2038, at TTS by 2043, and at CBTS and GNTS by 2048. Options may include upgrading existing capacitor banks or installing additional ones.
3. **Conduct further studies with detailed modelling of the terminal stations of CBTS, SMTS, TTS**, including its transformers and OLTCs, since the current models do not include them. This

would provide a more accurate assessment of voltage profiles under load electrification scenarios during peak demand days, potentially eliminating voltage issues on these networks.

4. **Upgrade ZSSs facing significant (110%-150%) overload for long periods, and extreme (>150%) overload** to increase network capacity. Any upgrades should account for expected future loads to ensure sufficient capacity in the medium to long term, minimizing the need for frequent reinforcements.
5. **Take measures to reduce the loading on subtransmission lines facing significant (110%-150%) overload for long periods, and extreme (>150%) overload** to increase network capacity. Options may include constructing new subtransmission lines, implementing demand management strategies, or exploring alternative power supply configurations (e.g., use interconnection with other subtransmission networks).
6. **Expand import DOEs to cater for all controllable loads**, given that this study shows that implementing import DOEs only to level-2 EVs already alleviate the demand on subtransmission networks, but it is not substantial. This will mitigate the expected surge in demand over the next 30 years. This strategy should reduce augmentation investments in both MV-LV and subtransmission networks.

![University of Melbourne logo]

# 6. Appendix

## Appendix 1: Full Whole-State Extrapolation Table (Without DOEs) – AusNet

| AusNet Services (56 ZSS out of 56) (without DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| *Overview* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | | 0.3% | 0.1% | 0.03% | **0.3%** | 2% | 2% | 0.3% | **2%** | 5% | 3% | 2% | **5%** | 8% | 4% | 4% | **8%** | 11% | 6% | 7% | **11%** | 13% | 8% | 9% | **13%** | 18% | 9% | 11% | **18%** |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | | All ZSS | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 68% | 23% | 0% | **68%** | 84% | 55% | 59% | **84%** | 98% | 77% | 79% | **98%** | 98% | 80% | 88% | **98%** | 100% | 93% | 96% | **100%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 83% | 43% | 0% | **83%** | 96% | 78% | 78% | **96%** | 96% | 87% | 87% | **96%** | 96% | 91% | 96% | **96%** | 100% | 96% | 96% | **100%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 61% | 10% | 0% | **61%** | 77% | 42% | 48% | **77%** | 100% | 74% | 74% | **100%** | 100% | 74% | 84% | **100%** | 100% | 90% | 97% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 50% | 0% | 0% | **50%** | 100% | 0% | 50% | **100%** | 100% | 50% | 50% | **100%** | 100% | 100% | 100% | **100%** |
| Overall Residential Voltage Drop Non-Compliance | | | 1% | 2% | 1% | **2%** | 5% | 4% | 1% | **5%** | 9% | 6% | 5% | **9%** | 13% | 9% | 8% | **13%** | 17% | 14% | 12% | **17%** | 21% | 17% | 15% | **21%** | 27% | 19% | 17% | **27%** |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residential Customers | | All ZSS | 0% | 0% | 0% | **0%** | 52% | 20% | 0% | **52%** | 93% | 86% | 50% | **93%** | 96% | 93% | 91% | **96%** | 98% | 96% | 96% | **98%** | 98% | 98% | 98% | **98%** | 100% | 98% | 98% | **100%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 74% | 39% | 0% | **74%** | 96% | 87% | 74% | **96%** | 96% | 96% | 91% | **96%** | 96% | 96% | 96% | **96%** | 96% | 96% | 96% | **96%** | 100% | 96% | 96% | **100%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 39% | 6% | 0% | **39%** | 90% | 84% | 35% | **90%** | 97% | 90% | 90% | **97%** | 100% | 97% | 97% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 100% | 0% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| Total Overloaded MV Conductor Length (km) | | All | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 1 | 0 | 0 | **1** | 292 | 115 | 0 | **292** | 421 | 348 | 0 | **421** | 924 | 699 | 61 | **924** | 1618 | 1580 | 127 | **1618** |
| | | <50 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0.2 | 0 | 0 | **0.2** | 66 | 20 | 0 | **66** | 95 | 74 | 0 | **95** | 196 | 137 | 12 | **196** | 358 | 366 | 23 | **366** |
| | | 50-100 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0.5 | 0 | 0 | **0.5** | 217 | 90 | 0 | **217** | 314 | 262 | 0 | **314** | 697 | 536 | 47 | **697** | 1207 | 1164 | 98 | **1207** |
| | | >100 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 9 | 5 | 0 | **9** | 13 | 12 | 0 | **13** | 31 | 27 | 2 | **31** | 53 | 50 | 5 | **53** |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | | All ZSS | 43% | 0% | 43% | **43%** | 89% | 89% | 43% | **89%** | 89% | 89% | 43% | **89%** | 100% | 100% | 89% | **100%** | 100% | 100% | 89% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | <50 MVA | 43% | 0% | 43% | **43%** | 96% | 96% | 43% | **96%** | 96% | 96% | 43% | **96%** | 100% | 100% | 96% | **100%** | 100% | 100% | 96% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | 50-100 MVA | 45% | 0% | 45% | **45%** | 87% | 87% | 45% | **87%** | 87% | 87% | 45% | **87%** | 100% | 100% | 87% | **100%** | 100% | 100% | 87% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 50% | 50% | 0% | **50%** | 50% | 50% | 0% | **50%** | 100% | 100% | 50% | **100%** | 100% | 100% | 50% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| Percentage of ZSS with LV Circuits Utililisation > 150% | | All ZSS | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| *Voltage Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | All ZSS | 0.3% | 0.1% | 0.03% | **0.3%** | 2% | 2% | 0.3% | **2%** | 5% | 3% | 2% | **5%** | 8% | 4% | 4% | **8%** | 11% | 6% | 7% | **11%** | 13% | 8% | 9% | **13%** | 18% | 9% | 11% | **18%** |
| | | <50 MVA | 0.4% | 0.2% | 0.02% | **0.4%** | 2% | 3% | 0.3% | **3%** | 6% | 4% | 2% | **6%** | 10% | 6% | 6% | **10%** | 13% | 8% | 8% | **13%** | 15% | 11% | 11% | **15%** | 22% | 12% | 14% | **22%** |
| | | 50-100 MVA | 0.3% | 0.1% | 0.03% | **0.3%** | 2% | 2% | 0.3% | **2%** | 5% | 3% | 2% | **5%** | 8% | 4% | 4% | **8%** | 11% | 6% | 6% | **11%** | 13% | 8% | 9% | **13%** | 18% | 9% | 11% | **18%** |
| | | >100 MVA | 0.1% | 0.03% | 0.1% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 5.1% | 2% | 2% | **5.1%** | 9% | 4% | 4% | **9%** | 12% | 5% | 6% | **12%** | 14% | 6% | 7% | **14%** |
| Residential Voltage Drop Non-Compliance | | All ZSS | 1% | 2% | 1% | **2%** | 5% | 4% | 1% | **5%** | 9% | 6% | 5% | **9%** | 13% | 9% | 8% | **13%** | 17% | 14% | 12% | **17%** | 21% | 17% | 15% | **21%** | 27% | 19% | 17% | **27%** |
| | | <50 MVA | 1% | 2% | 1% | **2%** | 6% | 4% | 2% | **6%** | 9% | 7% | 6% | **9%** | 13% | 10% | 9% | **13%** | 17% | 15% | 12% | **17%** | 21% | 18% | 16% | **21%** | 29% | 20% | 18% | **29%** |
| | | 50-100 MVA | 1% | 2% | 1% | **2%** | 5% | 4% | 1% | **5%** | 9% | 6% | 4% | **9%** | 13% | 9% | 7% | **13%** | 17% | 14% | 11% | **17%** | 21% | 17% | 15% | **21%** | 26% | 19% | 17% | **26%** |
| | | >100 MVA | 1% | 1% | 0.3% | **1%** | 3% | 3% | 1% | **3%** | 9% | 6% | 3% | **9%** | 14% | 9% | 6% | **14%** | 18% | 13% | 11% | **18%** | 23% | 17% | 15% | **23%** | 25% | 19% | 17% | **25%** |
| Percentage of LV Networks with Voltage Rise Issues | | All ZSS | 1% | 1% | 0.4% | **1%** | 7% | 5% | 2% | **7%** | 11% | 7% | 8% | **11%** | 13% | 10% | 8% | **13%** | 14% | 12% | 11% | **14%** | 16% | 13% | 11% | **16%** | 19% | 14% | 14% | **19%** |
| | | <50 MVA | 1% | 1% | 0.2% | **1%** | 5% | 4% | 2% | **5%** | 8% | 5% | 6% | **8%** | 9% | 8% | 6% | **9%** | 10% | 9% | 8% | **10%** | 12% | 10% | 8% | **12%** | 15% | 10% | 11% | **15%** |
| | | 50-100 MVA | 1% | 0.5% | 0.4% | **1%** | 8% | 6% | 3% | **8%** | 12% | 7% | 8% | **12%** | 14% | 11% | 9% | **14%** | 16% | 12% | 11% | **16%** | 17% | 14% | 12% | **17%** | 21% | 15% | 15% | **21%** |
| | | >100 MVA | 1% | 0.1% | 1% | **1%** | 15% | 13% | 5% | **15%** | 24% | 15% | 17% | **24%** | 28% | 20% | 17% | **28%** | 31% | 23% | 22% | **31%** | 33% | 26% | 24% | **33%** | 34% | 29% | 27% | **34%** |
| Percentage of LV Networks with Voltage Drop Issues | | All ZSS | 4% | 7% | 4% | **7%** | 12% | 13% | 8% | **13%** | 14% | 15% | 11% | **15%** | 18% | 18% | 14% | **18%** | 21% | 21% | 16% | **21%** | 26% | 26% | 19% | **26%** | 34% | 27% | 22% | **34%** |
| | | <50 MVA | 3% | 5% | 3% | **5%** | 9% | 9% | 6% | **9%** | 10% | 11% | 8% | **11%** | 14% | 14% | 11% | **14%** | 17% | 17% | 13% | **17%** | 20% | 21% | 15% | **21%** | 29% | 22% | 16% | **29%** |
| | | 50-100 MVA | 4% | 8% | 4% | **8%** | 13% | 14% | 8% | **14%** | 15% | 16% | 12% | **16%** | 19% | 19% | 15% | **19%** | 23% | 23% | 17% | **23%** | 27% | 27% | 20% | **27%** | 36% | 28% | 23% | **36%** |
| | | >100 MVA | 7% | 15% | 7% | **15%** | 25% | 26% | 16% | **26%** | 31% | 30% | 24% | **31%** | 34% | 34% | 30% | **34%** | 38% | 40% | 32% | **40%** | 48% | 46% | 35% | **48%** | 52% | 46% | 39% | **52%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | All ZSS | 1% | 1% | 0% | **1%** | 7% | 5% | 2% | **7%** | 11% | 7% | 7% | **11%** | 13% | 10% | 8% | **13%** | 14% | 12% | 11% | **14%** | 16% | 13% | 11% | **16%** | 18% | 14% | 12% | **18%** |
| | | <50 MVA | 1% | 1% | 0% | **1%** | 5% | 4% | 1% | **5%** | 8% | 5% | 5% | **8%** | 9% | 8% | 6% | **9%** | 10% | 9% | 8% | **10%** | 12% | 10% | 8% | **12%** | 14% | 10% | 8% | **14%** |
| | | 50-100 MVA | 1% | 0.5% | 0% | **1%** | 8% | 6% | 2% | **8%** | 12% | 7% | 8% | **12%** | 14% | 11% | 9% | **14%** | 15% | 12% | 11% | **15%** | 17% | 14% | 12% | **17%** | 20% | 15% | 13% | **20%** |
| | | >100 MVA | 1% | 0.1% | 0% | **1%** | 15% | 13% | 3% | **15%** | 24% | 15% | 16% | **24%** | 28% | 20% | 17% | **28%** | 30% | 23% | 22% | **30%** | 33% | 26% | 24% | **33%** | 34% | 29% | 26% | **34%** |
| *Thermal Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 99% | 99% | 99% | **99%** | 96% | 97% | 99% | **96%** | 88% | 92% | 97% | **88%** | 79% | 82% | 93% | **79%** | 74% | 77% | 86% | **74%** | 68% | 71% | 79% | **68%** | 66% | 70% | 75% | **66%** |
| | | <50 MVA | 99% | 99% | 99% | **99%** | 97% | 97% | 99% | **97%** | 92% | 94% | 97% | **92%** | 86% | 88% | 94% | **86%** | 82% | 84% | 88% | **82%** | 75% | 79% | 83% | **75%** | 73% | 77% | 80% | **73%** |
| | | 50-100 MVA | 99% | 99% | 100% | **99%** | 96% | 97% | 99% | **96%** | 87% | 91% | 97% | **87%** | 77% | 80% | 93% | **77%** | 72% | 74% | 85% | **72%** | 66% | 69% | 78% | **66%** | 64% | 67% | 73% | **64%** |
| | | >100 MVA | 100% | 100% | 100% | **100%** | 96% | 98% | 100% | **96%** | 75% | 85% | 100% | **75%** | 56% | 62% | 94% | **56%** | 49% | 53% | 79% | **49%** | 45% | 46% | 66% | **45%** | 43% | 45% | 58% | **43%** |
| | 100%-110% | All ZSS | 0.2% | 0.4% | 0.2% | **0.4%** | 2% | 1% | 0.5% | **2%** | 4% | 3% | 1% | **4%** | 3% | 4% | 3% | **3%** | 3% | 4% | 4% | **3%** | 3% | 5% | 4% | **3%** | 3% | 4% | 4% | **3%** |
| | | <50 MVA | 0.2% | 0.5% | 0.3% | **0.5%** | 1% | 1% | 1% | **1%** | 2% | 2% | 1% | **2%** | 2% | 3% | 2% | **2%** | 3% | 3% | 3% | **3%** | 2% | 5% | 3% | **2%** | 3% | 4% | 3% | **3%** |
| | | 50-100 MVA | 0.2% | 0.4% | 0.2% | **0.4%** | 2% | 1% | 0.5% | **2%** | 4% | 3% | 1% | **4%** | 3% | 5% | 3% | **3%** | 3% | 4% | 5% | **3%** | 3% | 5% | 4% | **3%** | 3% | 4% | 4% | **3%** |
| | | >100 MVA | 0.0% | 0.0% | 0.0% | **0%** | 4% | 1% | 0% | **4%** | 10% | 7% | 0% | **10%** | 6% | 8% | 4% | **6%** | 4% | 5% | 8% | **4%** | 4% | 7% | 6% | **4%** | 2% | 2% | 6% | **2%** |
| | 110%-150% | All ZSS | 1% | 0.5% | 0.2% | **0.5%** | 1% | 1% | 1% | **1%** | 6% | 5% | 2% | **6%** | 12% | 12% | 3% | **12%** | 11% | 13% | 8% | **11%** | 10% | 10% | 13% | **10%** | 10% | 10% | 15% | **10%** |
| | | <50 MVA | 1% | 1% | 0.3% | **1%** | 2% | 2% | 1% | **2%** | 4% | 4% | 2% | **4%** | 7% | 7% | 3% | **7%** | 8% | 9% | 7% | **8%** | 10% | 8% | 9% | **10%** | 10% | 8% | 11% | **10%** |
| | | 50-100 MVA | 1% | 0.5% | 0.2% | **0.5%** | 1% | 1% | 1% | **1%** | 7% | 5% | 2% | **7%** | 14% | 13% | 3% | **14%** | 12% | 14% | 9% | **12%** | 11% | 11% | 14% | **11%** | 10% | 10% | 17% | **10%** |
| | | >100 MVA | 0.04% | 0.04% | 0% | **0.04%** | 0.04% | 1% | 0% | **0.04%** | 15% | 7% | 0.04% | **15%** | 30% | 26% | 1% | **30%** | 22% | 25% | 13% | **22%** | 12% | 16% | 25% | **12%** | 11% | 14% | 30% | **11%** |
| | > 150% | All ZSS | 0.02% | 0% | 0.02% | **0%** | 1% | 0.4% | 0.2% | **1%** | 2% | 1% | 0.5% | **2%** | 5% | 2% | 1% | **5%** | 11% | 7% | 2% | **11%** | 19% | 13% | 4% | **19%** | 21% | 17% | 6% | **21%** |
| | | <50 MVA | 0.03% | 0% | 0.03% | **0%** | 1% | 0.4% | 0.2% | **1%** | 2% | 1% | 1% | **2%** | 4% | 2% | 1% | **4%** | 7% | 4% | 2% | **7%** | 13% | 8% | 4% | **13%** | 14% | 11% | 6% | **14%** |
| | | 50-100 MVA | 0.02% | 0% | 0.02% | **0%** | 1% | 0.3% | 0.2% | **1%** | 2% | 1% | 0.5% | **2%** | 6% | 3% | 1% | **6%** | 13% | 8% | 2% | **13%** | 21% | 15% | 4% | **21%** | 23% | 19% | 6% | **23%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0.04% | 0.04% | 0.00% | **0.04%** | 0.1% | 0.04% | 0% | **0.1%** | 8% | 4% | 0.04% | **8%** | 24% | 17% | 0.04% | **24%** | 39% | 31% | 3% | **39%** | 43% | 39% | 6% | **43%** |
| *PV Curtailment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0.9% | 100% | 85% | **100%** | 86% | 100% | 86% | **100%** | 85% | 100% | 85% | **100%** | 85% | 100% | 85% | **100%** | 84% | 100% | 100% | **100%** | 83% | 100% | 100% | **100%** | 82% | 100% | 100% | **100%** |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.3 | 0.3 | **94** | 0.01 | 0.6 | 0.5 | **181** | 0.1 | 1.0 | 0.8 | **278** | 0.2 | 1.3 | 1.1 | **396** | 0.4 | 1.8 | 1.5 | **537** | 0.6 | 2.3 | 2.0 | **712** | 0.9 | 2.8 | 2.5 | **885** |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | **6%** | 0.3% | 10% | 10% | **9%** | 2% | 14% | 13% | **12%** | 5% | 17% | 16% | **15%** | 7% | 20% | 19% | **18%** | 10% | 23% | 22% | **21%** | 13% | 25% | 24% | **24%** |

# Appendix 2: Full Whole-State Extrapolation Table (Without DOEs) – CitiPower

| CitiPower (22 ZSS out of 45) (without DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| *Overview* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | | 0.04% | 0% | 0.1% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 4% | 2% | 1% | **4%** | 8% | 3% | 4% | **8%** | 11% | 4% | 5.3% | **11%** | 13% | 6% | 6% | **13%** |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | | All ZSS | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 5% | 0% | 0% | **5%** | 9% | 0% | 0% | **9%** | 100% | 5% | 5% | **100%** | 100% | 9% | 59% | **100%** | 100% | 100% | 100% | **100%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 13% | 0% | 0% | **13%** | 25% | 0% | 0% | **25%** | 100% | 13% | 13% | **100%** | 100% | 25% | 63% | **100%** | 100% | 100% | 100% | **100%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 0% | 0% | **100%** | 100% | 0% | 57% | **100%** | 100% | 100% | 100% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Overall Residential Voltage Drop Non-Compliance | | | 1% | 1% | 0.2% | **1%** | 3% | 3% | 1% | **3%** | 9% | 6% | 3% | **9%** | 14% | 9% | 6% | **14%** | 19% | 13% | 11% | **19%** | 23% | 17% | 15% | **23%** | 25% | 19% | 17% | **25%** |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residencial Customers | | All ZSS | 0% | 0% | 0% | **0%** | 5% | 5% | 0% | **5%** | 100% | 100% | 5% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 13% | 13% | 0% | **13%** | 100% | 100% | 13% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 100% | 0% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Total Overloaded MV Conductor Length (km) | | All | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 20 | 13 | 0 | **20** | 30 | 28 | 0 | **30** | 73 | 64 | 6 | **73** | 123 | 116 | 13 | **123** |
| | | <50 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 4 | 3 | 0 | **4** | 6 | 6 | 0 | **6** | 15 | 13 | 1 | **15** | 24 | 23 | 3 | **24** |
| | | 50-100 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 16 | 10 | 0 | **16** | 24 | 22 | 0 | **24** | 58 | 51 | 4 | **58** | 99 | 93 | 10 | **99** |
| | | >100 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | | All ZSS | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 100% | 0% | **100%** | 100% | 100% | 0% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 100% | 0% | **100%** | 100% | 100% | 0% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 100% | 0% | **100%** | 100% | 100% | 0% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of ZSS with LV Circuits Utilisation > 150% | | All ZSS | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| *Voltage Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | All ZSS | 0.04% | 0% | 0.1% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 4% | 2% | 1% | **4%** | 8% | 3% | 4% | **8%** | 11% | 4% | 5% | **11%** | 13% | 6% | 6% | **13%** |
| | | <50 MVA | 0.04% | 0% | 0.1% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 5% | 2% | 1% | **5%** | 9% | 4% | 4% | **9%** | 12% | 5% | 6% | **12%** | 14% | 6% | 7% | **14%** |
| | | 50-100 MVA | 0.04% | 0% | 0.1% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 4% | 2% | 1% | **4%** | 8% | 3% | 4% | **8%** | 11% | 4% | 5% | **11%** | 13% | 5% | 6% | **13%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| Residential Voltage Drop Non-Compliance | | All ZSS | 1% | 1% | 0.2% | **1%** | 3% | 3% | 1% | **3%** | 9% | 6% | 3% | **9%** | 14% | 9% | 6% | **14%** | 19% | 13% | 11% | **19%** | 23% | 17% | 15% | **23%** | 25% | 19% | 17% | **25%** |
| | | <50 MVA | 1% | 2% | 0.3% | **2%** | 3% | 4% | 1% | **4%** | 10% | 7% | 3% | **10%** | 15% | 10% | 7% | **15%** | 20% | 14% | 12% | **20%** | 26% | 19% | 16% | **26%** | 28% | 21% | 19% | **28%** |
| | | 50-100 MVA | 1% | 1% | 0.2% | **1%** | 3% | 3% | 1% | **3%** | 9% | 6% | 3% | **9%** | 14% | 9% | 6% | **14%** | 18% | 13% | 11% | **18%** | 23% | 17% | 14% | **23%** | 25% | 19% | 17% | **25%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| Percentage of LV Networks with Voltage Rise Issues | | All ZSS | 1% | 0% | 1% | **1%** | 16% | 13% | 6% | **16%** | 26% | 16% | 18% | **26%** | 30% | 21% | 18% | **30%** | 33% | 25% | 24% | **33%** | 35% | 28% | 26% | **35%** | 36% | 31% | 28% | **36%** |
| | | <50 MVA | 1% | 0% | 1% | **1%** | 17% | 15% | 6% | **17%** | 28% | 17% | 20% | **28%** | 33% | 23% | 20% | **33%** | 36% | 27% | 26% | **36%** | 38% | 30% | 28% | **38%** | 39% | 34% | 31% | **39%** |
| | | 50-100 MVA | 1% | 0% | 1% | **1%** | 15% | 13% | 5% | **15%** | 25% | 15% | 17% | **25%** | 30% | 21% | 17% | **30%** | 32% | 24% | 23% | **32%** | 34% | 27% | 25% | **34%** | 35% | 30% | 28% | **35%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| Percentage of LV Networks with Voltage Drop Issues | | All ZSS | 8% | 16% | 8% | **16%** | 27% | 28% | 17% | **28%** | 32% | 32% | 26% | **32%** | 36% | 36% | 31% | **36%** | 40% | 42% | 33% | **42%** | 51% | 48% | 36% | **51%** | 54% | 48% | 41% | **54%** |
| | | <50 MVA | 9% | 17% | 9% | **17%** | 30% | 31% | 18% | **31%** | 36% | 35% | 28% | **36%** | 39% | 39% | 35% | **39%** | 43% | 44% | 36% | **44%** | 52% | 50% | 39% | **52%** | 55% | 50% | 43% | **55%** |
| | | 50-100 MVA | 8% | 15% | 8% | **15%** | 26% | 27% | 16% | **27%** | 32% | 31% | 25% | **32%** | 35% | 35% | 31% | **35%** | 40% | 41% | 32% | **41%** | 50% | 48% | 36% | **50%** | 53% | 48% | 40% | **53%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | All ZSS | 1% | 0% | 0% | **1%** | 16% | 13% | 3% | **16%** | 26% | 16% | 17% | **26%** | 30% | 21% | 18% | **30%** | 32% | 25% | 24% | **32%** | 35% | 28% | 26% | **35%** | 36% | 31% | 28% | **36%** |
| | | <50 MVA | 1% | 0% | 0% | **1%** | 17% | 15% | 4% | **17%** | 28% | 17% | 18% | **28%** | 33% | 23% | 20% | **33%** | 35% | 27% | 26% | **35%** | 38% | 30% | 28% | **38%** | 39% | 34% | 30% | **39%** |
| | | 50-100 MVA | 1% | 0% | 0% | **1%** | 15% | 13% | 3% | **15%** | 25% | 15% | 16% | **25%** | 30% | 21% | 17% | **30%** | 31% | 24% | 23% | **31%** | 34% | 27% | 25% | **34%** | 35% | 30% | 27% | **35%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| *Thermal Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 100% | 100% | 100% | **100%** | 96% | 98% | 100% | **96%** | 73% | 84% | 100% | **73%** | 53% | 60% | 94% | **53%** | 46% | 50% | 78% | **46%** | 41% | 42% | 63% | **41%** | 40% | 42% | 56% | **40%** |
| | | <50 MVA | 100% | 100% | 100% | **100%** | 96% | 98% | 100% | **96%** | 74% | 84% | 100% | **74%** | 53% | 61% | 94% | **53%** | 46% | 51% | 79% | **46%** | 41% | 43% | 64% | **41%** | 40% | 42% | 57% | **40%** |
| | | 50-100 MVA | 100% | 100% | 100% | **100%** | 96% | 98% | 100% | **96%** | 73% | 84% | 100% | **73%** | 53% | 60% | 94% | **53%** | 46% | 50% | 78% | **46%** | 41% | 42% | 63% | **41%** | 40% | 42% | 56% | **40%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| | 100%-110% | All ZSS | 0% | 0% | 0% | **0%** | 4% | 1% | 0% | **4%** | 10% | 8% | 0% | **10%** | 6% | 9% | 5% | **6%** | 4% | 5% | 9% | **4%** | 4% | 7% | 6% | **4%** | 2% | 2% | 7% | **2%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 4% | 1% | 0% | **4%** | 10% | 8% | 0% | **10%** | 6% | 8% | 5% | **6%** | 4% | 6% | 8% | **4%** | 4% | 8% | 6% | **4%** | 2% | 2% | 7% | **2%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 4% | 1% | 0% | **4%** | 10% | 8% | 0% | **10%** | 6% | 9% | 5% | **6%** | 4% | 5% | 9% | **4%** | 4% | 7% | 6% | **4%** | 2% | 2% | 7% | **2%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| | 110%-150% | All ZSS | 0% | 0% | 0% | **0%** | 0% | 1% | 0% | **0%** | 16% | 8% | 0% | **16%** | 32% | 27% | 1% | **32%** | 24% | 27% | 13% | **24%** | 13% | 17% | 27% | **13%** | 12% | 15% | 32% | **12%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 1% | 0% | **0%** | 16% | 8% | 0% | **16%** | 31% | 27% | 1% | **31%** | 24% | 26% | 13% | **24%** | 13% | 17% | 26% | **13%** | 12% | 15% | 31% | **12%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 1% | 0% | **0%** | 16% | 8% | 0% | **16%** | 33% | 28% | 1% | **33%** | 24% | 27% | 13% | **24%** | 13% | 17% | 27% | **13%** | 12% | 15% | 32% | **12%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| | > 150% | All ZSS | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 9% | 4% | 0% | **9%** | 26% | 18% | 0% | **26%** | 42% | 33% | 4% | **42%** | 46% | 41% | 6% | **46%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 9% | 4% | 0% | **9%** | 26% | 18% | 0% | **26%** | 42% | 32% | 4% | **42%** | 46% | 40% | 6% | **46%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 9% | 4% | 0% | **9%** | 26% | 18% | 0% | **26%** | 42% | 33% | 4% | **42%** | 47% | 42% | 6% | **47%** |
| | | >100 MVA | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** | - | - | - | **-** |
| *PV Curtailment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0.2% | 100% | 85% | **100%** | 86% | 100% | 86% | **100%** | 85% | 100% | 85% | **100%** | 85% | 100% | 85% | **100%** | 84% | 100% | 100% | **100%** | 83% | 100% | 100% | **100%** | 82% | 100% | 100% | **100%** |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.1 | 0.1 | **39** | 0.01 | 0.3 | 0.2 | **75** | 0.04 | 0.4 | 0.3 | **116** | 0.1 | 0.5 | 0.5 | **164** | 0.2 | 0.7 | 0.6 | **224** | 0.3 | 1 | 0.9 | **297** | 0.4 | 1.2 | 1.1 | **369** |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | **6%** | 0.3% | 10% | 10% | **9%** | 2% | 13% | 13% | **12%** | 5% | 16% | 16% | **15%** | 7% | 19% | 19% | **18%** | 10% | 23% | 22% | **21%** | 13% | 25% | 24% | **24%** |

## Appendix 3: Full Whole-State Extrapolation Table (Without DOEs) – Jemena

| Jemena (26 ZSS out of 30) (without DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| *Overview* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | | 0.1% | 0.03% | 0.05% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 5.3% | 2% | 2% | **5.3%** | 9% | 4% | 5% | **9%** | 12% | 5.1% | 6% | **11.8%** | 14% | 6% | 8% | **13.8%** |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | | All ZSS | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 12% | 0% | 0% | **12%** | 31% | 4% | 4% | **31%** | 100% | 23% | 27% | **100%** | 100% | 31% | 58% | **100%** | 100% | 100% | 100% | **100%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 13% | 0% | 0% | **13%** | 27% | 0% | 0% | **27%** | 100% | 27% | 27% | **100%** | 100% | 27% | 60% | **100%** | 100% | 100% | 100% | **100%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 11% | 0% | 0% | **11%** | 33% | 11% | 11% | **33%** | 100% | 22% | 33% | **100%** | 100% | 33% | 56% | **100%** | 100% | 100% | 100% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 50% | 0% | 0% | **50%** | 100% | 0% | 0% | **100%** | 100% | 50% | 50% | **100%** | 100% | 100% | 100% | **100%** |
| Overall Residential Voltage Drop Non-Compliance | | | 1% | 1% | 0.3% | **1%** | 3% | 3% | 1% | **3%** | 9% | 7% | 3% | **9%** | 14% | 9% | 6% | **14%** | 18% | 13% | 11% | **18%** | 23% | 17% | 15% | **23%** | 25% | 19% | 17% | **25%** |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residencial Customers | | All ZSS | 0% | 0% | 0% | **0%** | 4% | 0% | 0% | **4%** | 100% | 100% | 4% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 100% | 0% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 11% | 0% | 0% | **11%** | 100% | 100% | 11% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 100% | 0% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| Total Overloaded MV Conductor Length (km) | | All | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 56 | 36 | 0 | **56** | 84 | 78 | 0 | **84** | 204 | 179 | 16 | **204** | 369 | 360 | 36 | **369** |
| | | <50 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 27 | 17 | 0 | **27** | 40 | 38 | 0 | **40** | 97 | 85 | 8 | **97** | 167 | 161 | 17 | **167** |
| | | 50-100 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 23 | 14 | 0 | **23** | 34 | 31 | 0 | **34** | 83 | 73 | 6 | **83** | 160 | 160 | 14 | **160** |
| | | >100 MVA | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 7 | 4 | 0 | **7** | 10 | 9 | 0 | **10** | 24 | 21 | 2 | **24** | 42 | 39 | 4 | **42** |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | | All ZSS | 0% | 0% | 0% | **0%** | 31% | 31% | 0% | **31%** | 31% | 31% | 0% | **31%** | 100% | 100% | 31% | **100%** | 100% | 100% | 31% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 27% | 27% | 0% | **27%** | 27% | 27% | 0% | **27%** | 100% | 100% | 27% | **100%** | 100% | 100% | 27% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 33% | 33% | 0% | **33%** | 33% | 33% | 0% | **33%** | 100% | 100% | 33% | **100%** | 100% | 100% | 33% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 50% | 50% | 0% | **50%** | 50% | 50% | 0% | **50%** | 100% | 100% | 50% | **100%** | 100% | 100% | 50% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** |
| Percentage of ZSS with LV Circuits Utililisation > 150% | | All ZSS | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| *Voltage Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | All ZSS | 0.1% | 0.03% | 0.0% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 5.3% | 2% | 2% | **5.3%** | 9% | 4% | 5% | **9%** | 12% | 5.1% | 6% | **12%** | 14% | 6% | 8% | **14%** |
| | | <50 MVA | 0.1% | 0.03% | 0.1% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 5.3% | 2% | 2% | **5.3%** | 9% | 4% | 5% | **9%** | 12% | 5.04% | 6% | **12%** | 14% | 6% | 8% | **14%** |
| | | 50-100 MVA | 0.1% | 0.05% | 0.0% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 6% | 3% | 2% | **6%** | 9% | 4% | 5% | **9%** | 12% | 5.3% | 6% | **12%** | 14% | 7% | 8% | **14%** |
| | | >100 MVA | 0.1% | 0.02% | 0.1% | **0.1%** | 1% | 1% | 0.2% | **1%** | 3% | 1% | 1% | **3%** | 5% | 2% | 2% | **5%** | 8% | 4% | 4% | **8%** | 11% | 4% | 6% | **11%** | 13% | 6% | 7% | **13%** |
| Residential Voltage Drop Non-Compliance | | All ZSS | 1% | 1% | 0.3% | **1%** | 3% | 3% | 1% | **3%** | 9% | 7% | 3% | **9%** | 14% | 9% | 6% | **14%** | 18% | 13% | 11% | **18%** | 23% | 17% | 15% | **23%** | 25% | 19% | 17% | **25%** |
| | | <50 MVA | 1% | 1% | 0.3% | **1%** | 3% | 3% | 1% | **3%** | 9% | 7% | 3% | **9%** | 14% | 9% | 7% | **14%** | 19% | 14% | 12% | **19%** | 24% | 18% | 15% | **24%** | 26% | 20% | 18% | **26%** |
| | | 50-100 MVA | 1% | 1% | 0.3% | **1%** | 4% | 3% | 1% | **4%** | 9% | 6% | 4% | **9%** | 14% | 9% | 7% | **14%** | 18% | 13% | 11% | **18%** | 23% | 17% | 15% | **23%** | 25% | 19% | 17% | **25%** |
| | | >100 MVA | 1% | 1% | 0.3% | **1%** | 3% | 3% | 1% | **3%** | 9% | 6% | 3% | **9%** | 14% | 9% | 6% | **14%** | 18% | 13% | 11% | **18%** | 23% | 17% | 14% | **23%** | 25% | 19% | 17% | **25%** |
| Percentage of LV Networks with Voltage Rise Issues | | All ZSS | 1% | 0% | 1% | **1%** | 13% | 11% | 5% | **13%** | 21% | 13% | 14% | **21%** | 24% | 18% | 15% | **24%** | 26% | 20% | 19% | **26%** | 28% | 23% | 21% | **28%** | 29% | 25% | 24% | **29%** |
| | | <50 MVA | 1% | 0% | 1% | **1%** | 14% | 12% | 5% | **14%** | 24% | 14% | 16% | **24%** | 27% | 20% | 16% | **27%** | 30% | 23% | 22% | **30%** | 32% | 25% | 24% | **32%** | 33% | 28% | 26% | **33%** |
| | | 50-100 MVA | 1% | 0% | 1% | **1%** | 11% | 9% | 4% | **11%** | 18% | 11% | 12% | **18%** | 20% | 15% | 13% | **20%** | 22% | 17% | 16% | **22%** | 24% | 20% | 18% | **24%** | 25% | 21% | 21% | **25%** |
| | | >100 MVA | 1% | 0% | 1% | **1%** | 15% | 13% | 5% | **15%** | 24% | 15% | 17% | **24%** | 28% | 20% | 17% | **28%** | 31% | 23% | 22% | **31%** | 33% | 26% | 24% | **33%** | 34% | 29% | 27% | **34%** |
| Percentage of LV Networks with Voltage Drop Issues | | All ZSS | 6% | 13% | 6% | **13%** | 22% | 23% | 14% | **23%** | 26% | 26% | 21% | **26%** | 30% | 30% | 25% | **30%** | 34% | 35% | 27% | **35%** | 43% | 41% | 31% | **43%** | 47% | 42% | 35% | **47%** |
| | | <50 MVA | 7% | 14% | 7% | **14%** | 25% | 26% | 15% | **26%** | 30% | 29% | 24% | **30%** | 33% | 33% | 29% | **33%** | 37% | 38% | 31% | **38%** | 46% | 45% | 34% | **46%** | 50% | 45% | 38% | **50%** |
| | | 50-100 MVA | 6% | 11% | 5% | **11%** | 19% | 19% | 12% | **19%** | 22% | 23% | 18% | **23%** | 26% | 26% | 22% | **26%** | 30% | 32% | 24% | **32%** | 38% | 38% | 27% | **38%** | 43% | 38% | 31% | **43%** |
| | | >100 MVA | 7% | 15% | 7% | **15%** | 25% | 26% | 16% | **26%** | 30% | 30% | 24% | **30%** | 34% | 34% | 29% | **34%** | 38% | 40% | 31% | **40%** | 49% | 47% | 35% | **49%** | 52% | 46% | 39% | **52%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | All ZSS | 1% | 0% | 0% | **1%** | 13% | 11% | 3% | **13%** | 21% | 13% | 14% | **21%** | 24% | 18% | 15% | **24%** | 26% | 20% | 19% | **26%** | 28% | 23% | 21% | **28%** | 29% | 25% | 22% | **29%** |
| | | <50 MVA | 1% | 0% | 0% | **1%** | 14% | 12% | 3% | **14%** | 24% | 14% | 15% | **24%** | 27% | 20% | 16% | **27%** | 29% | 23% | 22% | **29%** | 32% | 25% | 24% | **32%** | 32% | 28% | 25% | **32%** |
| | | 50-100 MVA | 1% | 0% | 0% | **1%** | 11% | 9% | 2% | **11%** | 18% | 11% | 12% | **18%** | 20% | 15% | 13% | **20%** | 22% | 17% | 16% | **22%** | 24% | 20% | 18% | **24%** | 25% | 21% | 19% | **25%** |
| | | >100 MVA | 1% | 0% | 0% | **1%** | 15% | 13% | 3% | **15%** | 24% | 15% | 16% | **24%** | 28% | 20% | 17% | **28%** | 30% | 23% | 22% | **30%** | 33% | 26% | 24% | **33%** | 34% | 29% | 26% | **34%** |
| *Thermal Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 100% | 100% | 100% | **100%** | 97% | 98% | 100% | **97%** | 80% | 88% | 100% | **80%** | 64% | 68% | 95% | **64%** | 57% | 60% | 82% | **57%** | 52% | 54% | 70% | **52%** | 51% | 53% | 64% | **51%** |
| | | <50 MVA | 100% | 100% | 100% | **100%** | 96% | 98% | 100% | **96%** | 77% | 86% | 100% | **77%** | 60% | 65% | 95% | **60%** | 53% | 57% | 81% | **53%** | 48% | 49% | 68% | **48%** | 47% | 49% | 61% | **47%** |
| | | 50-100 MVA | 100% | 100% | 100% | **100%** | 97% | 98% | 100% | **97%** | 82% | 89% | 100% | **82%** | 69% | 72% | 95% | **69%** | 63% | 65% | 83% | **63%** | 57% | 59% | 73% | **57%** | 56% | 58% | 67% | **56%** |
| | | >100 MVA | 100% | 100% | 100% | **100%** | 96% | 98% | 100% | **96%** | 74% | 85% | 100% | **74%** | 55% | 61% | 94% | **55%** | 48% | 52% | 79% | **48%** | 43% | 45% | 65% | **43%** | 42% | 44% | 57% | **42%** |
| | 100%-110% | All ZSS | 0% | 0% | 0% | **0%** | 3% | 1% | 0% | **3%** | 8% | 6% | 0% | **8%** | 5% | 7% | 4% | **5%** | 4% | 4% | 7% | **4%** | 3% | 6% | 5% | **3%** | 2% | 3% | 5% | **2%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 4% | 1% | 0% | **4%** | 9% | 7% | 0% | **9%** | 5% | 7% | 4% | **5%** | 4% | 5% | 7% | **4%** | 4% | 7% | 5% | **4%** | 2% | 3% | 6% | **2%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 3% | 1% | 0% | **3%** | 7% | 5% | 0% | **7%** | 4% | 6% | 3% | **4%** | 3% | 4% | 6% | **3%** | 3% | 6% | 5% | **3%** | 2% | 3% | 5% | **2%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 4% | 1% | 0% | **4%** | 10% | 8% | 0% | **10%** | 6% | 9% | 4% | **6%** | 4% | 5% | 9% | **4%** | 4% | 7.0% | 6.0% | **4%** | 2% | 2% | 6% | **2%** |
| | 110%-150% | All ZSS | 0.1% | 0.1% | 0.0% | **0.1%** | 0.1% | 1% | 0% | **0.1%** | 12% | 6% | 0% | **12%** | 25% | 22% | 1% | **25%** | 19% | 22% | 11% | **19%** | 11% | 14% | 22% | **11%** | 11% | 12% | 26% | **11%** |
| | | <50 MVA | 0.1% | 0.1% | 0.0% | **0.1%** | 0.1% | 1% | 0% | **0.1%** | 14% | 7% | 0% | **14%** | 27% | 23% | 1% | **27%** | 21% | 23% | 12% | **21%** | 12% | 16% | 23% | **12%** | 11% | 13% | 28% | **11%** |
| | | 50-100 MVA | 0.2% | 0.2% | 0.0% | **0.2%** | 0.2% | 1% | 0% | **0.2%** | 11% | 6% | 0% | **11%** | 21% | 19% | 1% | **21%** | 17% | 19% | 10% | **17%** | 11% | 13% | 20% | **11%** | 10% | 11% | 23% | **10%** |
| | | >100 MVA | 0.02% | 0.02% | 0.0% | **0.02%** | 0.0% | 1% | 0% | **0.02%** | 16% | 7% | 0% | **16%** | 31% | 27% | 1% | **31%** | 23% | 26% | 13% | **23%** | 12% | 17% | 26% | **12%** | 11% | 14% | 31% | **11%** |
| | > 150% | All ZSS | 0% | 0% | 0% | **0%** | 0.1% | 0.1% | 0% | **0%** | 0.3% | 0.1% | 0% | **0%** | 7% | 3% | 0.1% | **7%** | 20% | 14% | 0.1% | **20%** | 33% | 26% | 3% | **33%** | 37% | 32% | 5% | **37%** |
| | | <50 MVA | 0% | 0% | 0% | **0%** | 0.1% | 0.1% | 0% | **0%** | 0.2% | 0.1% | 0% | **0%** | 8% | 4% | 0.1% | **8%** | 22% | 15% | 0.1% | **22%** | 36% | 28% | 3% | **36%** | 40% | 35% | 5% | **40%** |
| | | 50-100 MVA | 0% | 0% | 0% | **0%** | 0.2% | 0.2% | 0% | **0%** | 0.4% | 0.2% | 0% | **0%** | 6% | 3% | 0.2% | **6%** | 17% | 12% | 0.2% | **17%** | 29% | 22% | 3% | **29%** | 32% | 28% | 5% | **32%** |
| | | >100 MVA | 0% | 0% | 0% | **0%** | 0.02% | 0.02% | 0% | **0%** | 0.05% | 0.0% | 0% | **0%** | 8% | 4% | 0.02% | **8%** | 25% | 17% | 0.02% | **25%** | 41% | 32% | 3% | **41%** | 45% | 40% | 6% | **45%** |
| *PV Curtailment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0.4% | 100% | 85% | **100%** | 86% | 100% | 86% | **100%** | 85% | 100% | 85% | **100%** | 85% | 100% | 85% | **100%** | 84% | 100% | 100% | **100%** | 83% | 100% | 100% | **100%** | 82% | 100% | 100% | **100%** |
| Aggregate Export | | Total PV Curtailment (GWh) | 0 | 0.2 | 0.2 | **64** | 0.01 | 0.4 | 0.4 | **124** | 0.1 | 0.6 | 0.6 | **190** | 0.2 | 0.9 | 0.8 | **270** | 0.3 | 1.2 | 1.1 | **366** | 0.4 | 1.6 | 1.4 | **486** | 0.6 | 1.9 | 1.7 | **604** |
| | | Percentage of PV Curtailment | 0% | 7% | 7% | **6%** | 0.3% | 10% | 10% | **9%** | 2% | 13% | 13% | **12%** | 5% | 16% | 16% | **15%** | 7% | 19% | 19% | **18%** | 10% | 23% | 22% | **21%** | 13% | 25% | 24% | **24%** |

## Appendix 4: Full Whole-State Extrapolation Table (Without DOEs) – Powercor

| Powercor (60 ZSS out of 68) (without DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| **Overview** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 2% | 0.3% | 2% | 5% | 3% | 2% | 5% | 8% | 4% | 4% | 8% | 10% | 6% | 6% | 10% | 13% | 8% | 8% | 13% | 18% | 9% | 10% | 18% |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 50% | 10% | 0% | 50% | 68% | 38% | 38% | 68% | 87% | 58% | 60% | 87% | 95% | 68% | 72% | 95% | 100% | 80% | 83% | 100% |
| | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 46% | 7% | 0% | 46% | 64% | 39% | 39% | 64% | 75% | 54% | 54% | 75% | 89% | 64% | 64% | 89% | 100% | 68% | 71% | 100% |
| | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 55% | 13% | 0% | 55% | 74% | 39% | 39% | 74% | 97% | 65% | 68% | 97% | 100% | 74% | 77% | 100% | 100% | 90% | 94% | 100% |
| | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 100% | 0% | 100% | 100% | 100% | 100% | 100% | 100% |
| Overall Residential Voltage Drop Non-Compliance | | 1% | 2% | 1% | 2% | 4% | 3% | 1% | 4% | 8% | 6% | 4% | 8% | 12% | 9% | 7% | 12% | 16% | 13% | 11% | 16% | 20% | 16% | 14% | 20% | 27% | 18% | 16% | 27% |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residencial Customers | All ZSS | 0% | 0% | 0% | 0% | 35% | 13% | 0% | 35% | 78% | 62% | 35% | 78% | 83% | 78% | 75% | 83% | 93% | 87% | 85% | 93% | 95% | 90% | 90% | 95% | 100% | 95% | 90% | 100% |
| | <50 MVA | 0% | 0% | 0% | 0% | 32% | 11% | 0% | 32% | 64% | 39% | 32% | 64% | 68% | 64% | 61% | 68% | 86% | 75% | 75% | 86% | 89% | 79% | 79% | 89% | 100% | 89% | 79% | 100% |
| | 50-100 MVA | 0% | 0% | 0% | 0% | 39% | 16% | 0% | 39% | 90% | 84% | 39% | 90% | 97% | 90% | 90% | 97% | 100% | 97% | 94% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Total Overloaded MV Conductor Length (km) | All | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 344 | 118 | 0 | 344 | 494 | 397 | 0 | 494 | 1063 | 775 | 67 | 1063 | 1760 | 1654 | 135 | 1760 |
| | <50 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 127 | 21 | 0 | 127 | 178 | 129 | 0 | 178 | 357 | 221 | 18 | 357 | 528 | 446 | 31 | 528 |
| | 50-100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0.4 | 203 | 92 | 0 | 203 | 295 | 251 | 0 | 295 | 660 | 520 | 46 | 660 | 1158 | 1145 | 98 | 1158 |
| | >100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0.04 | 15 | 5 | 0 | 15 | 21 | 17 | 0 | 21 | 46 | 34 | 3 | 46 | 73 | 63 | 6 | 73 |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | All ZSS | 60% | 0% | 60% | 60% | 87% | 87% | 60% | 87% | 87% | 87% | 60% | 87% | 100% | 100% | 87% | 100% | 100% | 100% | 87% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | <50 MVA | 79% | 0% | 79% | 79% | 89% | 89% | 79% | 89% | 89% | 89% | 79% | 89% | 100% | 100% | 89% | 100% | 100% | 100% | 89% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | 50-100 MVA | 42% | 0% | 42% | 42% | 84% | 84% | 42% | 84% | 84% | 84% | 42% | 84% | 100% | 100% | 84% | 100% | 100% | 100% | 84% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | >100 MVA | 100% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Percentage of ZSS with LV Circuits Utilisation > 150% | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Voltage Assessment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | All ZSS | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 2% | 0% | 1.8% | 5% | 3% | 2% | 4.6% | 8% | 4% | 4% | 7.6% | 10% | 6% | 6% | 10.4% | 13% | 8% | 8% | 12.6% | 18% | 9% | 10% | 18.3% |
| | <50 MVA | 0.3% | 0.2% | 0.02% | 0.3% | 2% | 2% | 0% | 1.8% | 4% | 3% | 2% | 4.3% | 7% | 4% | 4% | 7.2% | 9% | 6% | 6% | 9.3% | 12% | 7% | 8% | 11.5% | 21% | 8% | 10% | 21.1% |
| | 50-100 MVA | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 2% | 0% | 1.8% | 5% | 3% | 2% | 4.8% | 8% | 4% | 4% | 7.8% | 11% | 6% | 6% | 10.9% | 13% | 8% | 9% | 13.1% | 18% | 9% | 11% | 17.5% |
| | >100 MVA | 0.1% | 0.1% | 0.03% | 0.1% | 1% | 1% | 0% | 1.1% | 3.0% | 1.5% | 1.0% | 3.0% | 5% | 3% | 2% | 5.0% | 7% | 4% | 4% | 7.2% | 10% | 5% | 5% | 9.7% | 17% | 6% | 7% | 17.2% |
| Residential Voltage Drop Non-Compliance | All ZSS | 1% | 2% | 1% | 2% | 4.35% | 3.37% | 1.41% | 4% | 8% | 6% | 4% | 8% | 12% | 9% | 7% | 12% | 16% | 13% | 11% | 16% | 20% | 16% | 14% | 20% | 27% | 18% | 16% | 27% |
| | <50 MVA | 1% | 1% | 0.5% | 1% | 4% | 3% | 1% | 4% | 7% | 5% | 4% | 7% | 9% | 7% | 6% | 9% | 13% | 11% | 9% | 13% | 16% | 13% | 12% | 16% | 27% | 16% | 13% | 27% |
| | 50-100 MVA | 1% | 2% | 1% | 2% | 4.5% | 3.6% | 1.5% | 5% | 9% | 6% | 4% | 9% | 13% | 9% | 8% | 13% | 17% | 14% | 12% | 17% | 22% | 17% | 15% | 22% | 27% | 19% | 18% | 27% |
| | >100 MVA | 0.4% | 1% | 0.3% | 1% | 3% | 2% | 1% | 3% | 6% | 4% | 3% | 6% | 9% | 6% | 5% | 9% | 12% | 9% | 8% | 12% | 16% | 12% | 10% | 16% | 24% | 14% | 12% | 24% |
| Percentage of LV Networks with Voltage Rise Issues | All ZSS | 1% | 0.5% | 0.4% | 1% | 7% | 5% | 2% | 7% | 11% | 6% | 7% | 11% | 12% | 10% | 8% | 12% | 13% | 11% | 10% | 13% | 15% | 12% | 11% | 15% | 19% | 13% | 13% | 19% |
| | <50 MVA | 0.4% | 0.4% | 0.2% | 0.4% | 4% | 3% | 1% | 4% | 6% | 4% | 4% | 6% | 7% | 6% | 5% | 7% | 8% | 6% | 6% | 8% | 10% | 7% | 6% | 10% | 16% | 7% | 8% | 16% |
| | 50-100 MVA | 1% | 0.5% | 0.5% | 1% | 8% | 6% | 3% | 8% | 13% | 8% | 9% | 13% | 15% | 12% | 10% | 15% | 17% | 13% | 12% | 17% | 19% | 15% | 13% | 19% | 21% | 16% | 16% | 21% |
| | >100 MVA | 1% | 0.2% | 1% | 1% | 8% | 7% | 3% | 8% | 13% | 8% | 9% | 13% | 15% | 11% | 9% | 15% | 17% | 12% | 12% | 17% | 19% | 14% | 13% | 19% | 24% | 15% | 15% | 24% |
| Percentage of LV Networks with Voltage Drop Issues | All ZSS | 4% | 7% | 3% | 7% | 11% | 12% | 7% | 12% | 13% | 14% | 11% | 14% | 17% | 16% | 13% | 17% | 20% | 20% | 15% | 20% | 24% | 24% | 18% | 24% | 33% | 25% | 20% | 33% |
| | <50 MVA | 2% | 4% | 2% | 4% | 7% | 7% | 4% | 7% | 8% | 8% | 6% | 8% | 10% | 10% | 8% | 10% | 13% | 12% | 9% | 13% | 16% | 15% | 11% | 16% | 28% | 17% | 13% | 28% |
| | 50-100 MVA | 4% | 8% | 4% | 8% | 14% | 15% | 9% | 15% | 17% | 17% | 13% | 17% | 20% | 20% | 17% | 20% | 24% | 24% | 19% | 24% | 29% | 28% | 21% | 29% | 36% | 29% | 24% | 36% |
| | >100 MVA | 4% | 8% | 4% | 8% | 13% | 14% | 8% | 14% | 16% | 16% | 13% | 16% | 19% | 19% | 16% | 19% | 23% | 23% | 17% | 23% | 29% | 27% | 20% | 29% | 38% | 28% | 23% | 38% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | All ZSS | 1% | 0.5% | 0% | 1% | 7% | 5% | 2% | 7% | 11% | 6% | 7% | 11% | 12% | 10% | 8% | 12% | 13% | 11% | 10% | 13% | 15% | 12% | 11% | 15% | 18% | 13% | 11% | 18% |
| | <50 MVA | 0.4% | 0.4% | 0% | 0.4% | 4% | 3% | 1% | 4% | 6% | 4% | 4% | 6% | 7% | 6% | 5% | 7% | 7% | 6% | 6% | 7% | 9% | 7% | 6% | 9% | 14% | 7% | 6% | 14% |
| | 50-100 MVA | 1% | 0.5% | 0% | 1% | 8% | 6% | 2% | 8% | 13% | 8% | 9% | 13% | 15% | 12% | 10% | 15% | 16% | 13% | 12% | 16% | 18% | 15% | 13% | 18% | 20% | 16% | 14% | 20% |
| | >100 MVA | 1% | 0.2% | 0% | 1% | 8% | 7% | 2% | 8% | 13% | 8% | 8% | 13% | 15% | 11% | 9% | 15% | 16% | 12% | 12% | 16% | 18% | 14% | 13% | 18% | 22% | 15% | 14% | 22% |
| **Thermal Assessment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation: <= 100% | All ZSS | 99% | 99% | 99% | 99% | 96% | 96% | 98% | 96% | 88% | 91% | 96% | 88% | 79% | 81% | 92% | 79% | 73% | 76% | 85% | 73% | 67% | 71% | 78% | 67% | 65% | 69% | 74% | 65% |
| | <50 MVA | 99% | 98% | 99% | 98% | 95% | 95% | 97% | 95% | 89% | 91% | 94% | 89% | 82% | 85% | 90% | 82% | 76% | 80% | 84% | 76% | 70% | 75% | 79% | 70% | 67% | 73% | 76% | 67% |
| | 50-100 MVA | 99% | 99% | 100% | 99% | 96% | 97% | 99% | 96% | 87% | 91% | 98% | 87% | 77% | 80% | 94% | 77% | 72% | 74% | 85% | 72% | 66% | 69% | 78% | 66% | 64% | 67% | 74% | 64% |
| | >100 MVA | 99% | 99% | 99% | 99% | 95% | 96% | 98% | 95% | 81% | 88% | 96% | 81% | 68% | 72% | 91% | 68% | 61% | 65% | 80% | 61% | 56% | 59% | 71% | 56% | 54% | 58% | 66% | 54% |
| 100%-110% | All ZSS | 0.3% | 1% | 0.3% | 1% | 2% | 2% | 1% | 2% | 4% | 3% | 1% | 4% | 3% | 4% | 3% | 3% | 3% | 4% | 4% | 3% | 3% | 5% | 4% | 3% | 3% | 4% | 4% | 3% |
| | <50 MVA | 0.4% | 1% | 1% | 1% | 1% | 2% | 1% | 1% | 3% | 2% | 2% | 3% | 3% | 4% | 3% | 3% | 4% | 4% | 3% | 4% | 3% | 5% | 4% | 3% | 3% | 4% | 3% | 3% |
| | 50-100 MVA | 0.1% | 0.3% | 0.2% | 0.3% | 2% | 1% | 0.4% | 2% | 4% | 3% | 1% | 4% | 3% | 5% | 3% | 3% | 3% | 4% | 4% | 3% | 3% | 5% | 4% | 3% | 2% | 4% | 4% | 2% |
| | >100 MVA | 0.3% | 1% | 0.4% | 1% | 2% | 2% | 1% | 2% | 6% | 5% | 1% | 6% | 4% | 7% | 4% | 4% | 4% | 4% | 6% | 4% | 4% | 6% | 5% | 4% | 3% | 3% | 5% | 3% |
| 110%-150% | All ZSS | 1% | 1% | 0.3% | 1% | 2% | 2% | 1% | 2% | 7% | 5% | 2% | 7% | 12% | 12% | 3% | 12% | 12% | 13% | 9% | 12% | 11% | 11% | 13% | 11% | 11% | 10% | 15% | 11% |
| | <50 MVA | 1% | 1% | 1% | 1% | 3% | 2% | 1% | 3% | 5% | 5% | 3% | 5% | 9% | 9% | 5% | 9% | 10% | 10% | 8% | 10% | 11% | 10% | 10% | 11% | 11% | 10% | 12% | 11% |
| | 50-100 MVA | 1% | 0.4% | 0.2% | 0.4% | 1% | 1% | 0.5% | 1% | 7% | 5% | 1% | 7% | 14% | 13% | 3% | 14% | 12% | 14% | 9% | 12% | 11% | 11% | 14% | 11% | 10% | 10% | 17% | 10% |
| | >100 MVA | 1% | 0.5% | 0.4% | 0.5% | 2% | 2% | 1% | 2% | 11% | 7% | 2% | 11% | 20% | 18% | 4% | 20% | 17% | 19% | 11% | 17% | 12% | 14% | 18% | 12% | 12% | 12% | 21% | 12% |
| > 150% | All ZSS | 0.03% | 0.0% | 0.03% | 0% | 1% | 0.4% | 0.2% | 1% | 2% | 1% | 1% | 2% | 6% | 3% | 1% | 6% | 12% | 7% | 2% | 12% | 19% | 13% | 5% | 19% | 22% | 17% | 7% | 22% |
| | <50 MVA | 0.1% | 0% | 0.1% | 0% | 1% | 0.4% | 0.4% | 1% | 3% | 1% | 1% | 3% | 6% | 3% | 2% | 6% | 11% | 6% | 4% | 11% | 16% | 10% | 7% | 16% | 18% | 13% | 9% | 18% |
| | 50-100 MVA | 0.02% | 0.0% | 0.02% | 0% | 0.5% | 0.3% | 0.1% | 0.5% | 1% | 1% | 0.4% | 1% | 5% | 3% | 1% | 5% | 12% | 8% | 1% | 12% | 21% | 15% | 4% | 21% | 23% | 19% | 6% | 23% |
| | >100 MVA | 0.04% | 0.0% | 0.04% | 0% | 1% | 0.2% | 0.3% | 1% | 2% | 1% | 1% | 2% | 8% | 3% | 1% | 8% | 18% | 11% | 3% | 18% | 29% | 21% | 6% | 29% | 32% | 26% | 8% | 32% |
| **PV Curtailment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | 0.8% | 100% | 85% | 100% | 86% | 100% | 86% | 100% | 85% | 100% | 85% | 100% | 85% | 100% | 85% | 100% | 84% | 100% | 100% | 100% | 83% | 100% | 100% | 100% | 82% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | 0 | 0.3 | 0.3 | 92 | 0.01 | 0.6 | 0.5 | 178 | 0.1 | 0.9 | 0.8 | 273 | 0.2 | 1.3 | 1.1 | 389 | 0.4 | 1.7 | 1.5 | 527 | 0.6 | 2.3 | 2 | 700 | 0.9 | 2.8 | 2.5 | 869 |
| | Percentage of PV Curtailment | 0% | 7% | 7% | 6% | 0.3% | 10% | 10% | 9% | 2% | 14% | 13% | 12% | 5% | 17% | 16% | 15% | 7% | 20% | 19% | 18% | 10% | 23% | 22% | 21% | 13% | 25% | 24% | 24% |

# Appendix 5: Full Whole-State Extrapolation Table (Without DOEs) – United Energy

**United Energy (47 ZSS out of 47)**
**(without DOEs)**

| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| *Overview* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | | 0.1% | 0.02% | 0.05% | 0.1% | 1% | 1% | 0.2% | 1% | 3% | 1% | 1% | 3% | 5% | 2% | 2% | 5% | 8% | 4% | 4% | 8% | 11% | 5% | 6% | 11% | 14% | 6% | 7% | 14% |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 2% | 19% | 2% | 2% | 19% | 100% | 6% | 13% | 100% | 100% | 19% | 64% | 100% | 100% | 100% | 100% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 100% | 0% | 67% | 100% | 100% | 100% | 100% | 100% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 4% | 25% | 4% | 4% | 25% | 100% | 11% | 18% | 100% | 100% | 25% | 68% | 100% | 100% | 100% | 100% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 13% | 0% | 0% | 13% | 100% | 0% | 6% | 100% | 100% | 13% | 56% | 100% | 100% | 100% | 100% | 100% |
| Overall Residential Voltage Drop Non-Compliance | | | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 9% | 6% | 3% | 9% | 14% | 9% | 6% | 14% | 18% | 13% | 11% | 18% | 23% | 17% | 14% | 23% | 25% | 19% | 17% | 25% |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residential Customers | | All ZSS | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 2% | 100% | 98% | 2% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 4% | 100% | 96% | 4% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Total Overloaded MV Conductor Length (km) | | All | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.1 | 121 | 64 | 0 | 121 | 178 | 157 | 0 | 178 | 414 | 342 | 30 | 414 | 681 | 632 | 66 | 681 |
| | | <50 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 2 | 3 | 3 | 0 | 3 | 7 | 6 | 1 | 7 | 12 | 11 | 1 | 12 |
| | | 50-100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.1 | 84 | 40 | 0 | 84 | 123 | 106 | 0 | 123 | 281 | 225 | 20 | 281 | 455 | 419 | 43 | 455 |
| | | >100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 22 | 0 | 35 | 52 | 48 | 0 | 52 | 126 | 110 | 10 | 126 | 214 | 202 | 22 | 214 |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | | All ZSS | 15% | 0% | 15% | 15% | 19% | 19% | 15% | 19% | 19% | 19% | 15% | 19% | 100% | 100% | 19% | 100% | 100% | 100% | 19% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | 50-100 MVA | 25% | 0% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 100% | 100% | 25% | 100% | 100% | 100% | 25% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 13% | 13% | 0% | 13% | 13% | 13% | 0% | 13% | 100% | 100% | 13% | 100% | 100% | 100% | 13% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Percentage of ZSS with LV Circuits Utililisation > 150% | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| *Voltage Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | All ZSS | 0.1% | 0.02% | 0.05% | 0.1% | 1% | 1% | 0.2% | 1% | 3% | 1% | 1% | 3% | 5% | 2% | 2% | 5% | 8% | 4% | 4% | 8% | 11% | 5% | 6% | 11% | 14% | 6% | 7% | 14% |
| | | <50 MVA | 0.04% | 0% | 0.1% | 0.1% | 1% | 1% | 0.2% | 1% | 3% | 1% | 1% | 3% | 5% | 2% | 1% | 5% | 9% | 4% | 4% | 9% | 12% | 4% | 6% | 12% | 14% | 6% | 7% | 14% |
| | | 50-100 MVA | 0.1% | 0.03% | 0.05% | 0.1% | 1% | 1% | 0.2% | 1% | 3% | 1% | 1% | 3% | 5.01% | 2% | 2% | 5.01% | 9% | 4% | 4% | 9% | 11% | 5% | 6% | 11% | 14% | 6% | 7% | 14% |
| | | >100 MVA | 0.05% | 0.01% | 0.1% | 0.1% | 1% | 1% | 0.2% | 1% | 3% | 1% | 1% | 3% | 5% | 2% | 1% | 5% | 8% | 4% | 4% | 8% | 11% | 4% | 5.4% | 11% | 13% | 6% | 7% | 13% |
| Residential Voltage Drop Non-Compliance | | All ZSS | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 9% | 6% | 3% | 9% | 14% | 9% | 6% | 14% | 18% | 13% | 11% | 18% | 23% | 17% | 14% | 23% | 25% | 19% | 17% | 25% |
| | | <50 MVA | 1% | 1% | 0.3% | 1% | 3% | 4% | 1% | 4% | 10% | 7% | 3% | 10% | 15% | 9% | 7% | 15% | 20% | 14% | 12% | 20% | 25% | 18% | 16% | 25% | 27% | 20% | 18% | 27% |
| | | 50-100 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 9% | 6% | 3% | 9% | 13% | 9% | 6% | 13% | 18% | 13% | 11% | 18% | 22% | 17% | 14% | 22% | 26% | 19% | 17% | 26% |
| | | >100 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 9% | 6% | 3% | 9% | 14% | 9% | 6% | 14% | 18% | 13% | 11% | 18% | 23% | 17% | 15% | 23% | 25% | 19% | 17% | 25% |
| Percentage of LV Networks with Voltage Rise Issues | | All ZSS | 1% | 0.2% | 1% | 1% | 12% | 10% | 4% | 12% | 20% | 12% | 14% | 20% | 23% | 17% | 14% | 23% | 25% | 19% | 18% | 25% | 28% | 22% | 20% | 28% | 30% | 24% | 22% | 30% |
| | | <50 MVA | 1% | 0% | 1% | 1% | 17% | 14% | 6% | 17% | 28% | 17% | 19% | 28% | 32% | 23% | 19% | 32% | 35% | 26% | 25% | 35% | 37% | 29% | 28% | 37% | 38% | 33% | 30% | 38% |
| | | 50-100 MVA | 1% | 0.2% | 1% | 1% | 11% | 9% | 4% | 11% | 18% | 11% | 12% | 18% | 21% | 15% | 13% | 21% | 23% | 17% | 16% | 23% | 25% | 19% | 18% | 25% | 28% | 22% | 20% | 28% |
| | | >100 MVA | 1% | 0.03% | 1% | 1% | 15% | 13% | 5% | 15% | 25% | 15% | 17% | 25% | 29% | 21% | 17% | 29% | 32% | 24% | 23% | 32% | 34% | 27% | 25% | 34% | 35% | 30% | 28% | 35% |
| Percentage of LV Networks with Voltage Drop Issues | | All ZSS | 6% | 12% | 6% | 12% | 21% | 22% | 13% | 22% | 25% | 25% | 20% | 25% | 29% | 28% | 25% | 29% | 32% | 33% | 26% | 33% | 40% | 39% | 29% | 40% | 46% | 39% | 33% | 46% |
| | | <50 MVA | 8% | 17% | 8% | 17% | 29% | 30% | 18% | 30% | 35% | 34% | 28% | 35% | 38% | 38% | 34% | 38% | 42% | 43% | 35% | 43% | 52% | 50% | 38% | 52% | 55% | 49% | 43% | 55% |
| | | 50-100 MVA | 6% | 11% | 5% | 11% | 19% | 20% | 12% | 20% | 23% | 23% | 18% | 23% | 26% | 25% | 22% | 26% | 29% | 30% | 24% | 30% | 36% | 35% | 26% | 36% | 43% | 36% | 30% | 43% |
| | | >100 MVA | 8% | 15% | 8% | 15% | 26% | 27% | 16% | 27% | 31% | 31% | 25% | 31% | 35% | 35% | 30% | 35% | 39% | 41% | 32% | 41% | 50% | 47% | 36% | 50% | 53% | 47% | 40% | 53% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | All ZSS | 1% | 0.2% | 0% | 1% | 12% | 10% | 3% | 12% | 20% | 12% | 13% | 20% | 23% | 17% | 14% | 23% | 25% | 19% | 18% | 25% | 27% | 22% | 20% | 27% | 29% | 24% | 21% | 29% |
| | | <50 MVA | 1% | 0% | 0% | 1% | 17% | 14% | 4% | 17% | 28% | 17% | 18% | 28% | 32% | 23% | 19% | 32% | 34% | 26% | 25% | 34% | 37% | 29% | 28% | 37% | 38% | 33% | 29% | 38% |
| | | 50-100 MVA | 1% | 0.2% | 0% | 1% | 11% | 9% | 2% | 11% | 18% | 11% | 12% | 18% | 21% | 15% | 13% | 21% | 22% | 17% | 16% | 22% | 25% | 19% | 18% | 25% | 27% | 22% | 19% | 27% |
| | | >100 MVA | 1% | 0.03% | 0% | 1% | 15% | 13% | 3% | 15% | 25% | 15% | 16% | 25% | 29% | 21% | 17% | 29% | 31% | 24% | 23% | 31% | 34% | 27% | 25% | 34% | 35% | 30% | 27% | 35% |
| *Thermal Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 100% | 100% | 100% | 100% | 96% | 97% | 99% | 96% | 79% | 87% | 98% | 79% | 62% | 68% | 93% | 62% | 56% | 60% | 80% | 56% | 51% | 53% | 69% | 51% | 49% | 52% | 63% | 49% |
| | | <50 MVA | 100% | 100% | 100% | 100% | 96% | 98% | 100% | 96% | 74% | 84% | 100% | 74% | 53% | 61% | 94% | 53% | 46% | 50% | 78% | 46% | 41% | 43% | 64% | 41% | 40% | 42% | 56% | 40% |
| | | 50-100 MVA | 99% | 99% | 100% | 99% | 96% | 97% | 99% | 96% | 80% | 88% | 98% | 80% | 66% | 71% | 93% | 66% | 59% | 63% | 81% | 59% | 54% | 57% | 71% | 54% | 52% | 56% | 65% | 52% |
| | | >100 MVA | 100% | 100% | 100% | 100% | 96% | 98% | 100% | 96% | 74% | 85% | 100% | 74% | 54% | 61% | 94% | 54% | 47% | 51% | 78% | 47% | 42% | 44% | 64% | 42% | 41% | 43% | 57% | 41% |
| | 100%-110% | All ZSS | 0.1% | 0.3% | 0.1% | 0.3% | 3% | 1% | 0.3% | 3% | 8% | 6% | 0.4% | 8% | 5% | 7% | 4% | 5% | 4% | 5% | 7% | 4% | 4% | 7% | 5% | 4% | 2% | 3% | 6% | 2% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 10% | 8% | 0% | 10% | 6% | 8% | 5% | 6% | 4% | 5% | 8% | 4% | 4% | 8% | 6% | 4% | 2% | 2% | 7% | 2% |
| | | 50-100 MVA | 0.2% | 0.4% | 0.2% | 0.4% | 3% | 1% | 0.4% | 3% | 7% | 5% | 1% | 7% | 5% | 7% | 4% | 5% | 4% | 5% | 6% | 4% | 4% | 6% | 5% | 4% | 2% | 3% | 5% | 2.4% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 10% | 8% | 0.01% | 10% | 6% | 9% | 5% | 6% | 4% | 5% | 9% | 4% | 3.9% | 7% | 6.1% | 4% | 2% | 2% | 6% | 2% |
| | 110%-150% | All ZSS | 0.3% | 0.2% | 0.2% | 0.2% | 1% | 1% | 0.4% | 1% | 13% | 7% | 1% | 13% | 25% | 22% | 2% | 25% | 19% | 22% | 12% | 19% | 12% | 15% | 22% | 12% | 11% | 13% | 25% | 11% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 16% | 8% | 0% | 16% | 32% | 27% | 1% | 32% | 24% | 26% | 13% | 24% | 13% | 17% | 26% | 13% | 12% | 15% | 31% | 12% |
| | | 50-100 MVA | 0.4% | 0.3% | 0.2% | 0.3% | 1% | 2% | 1% | 1% | 11% | 6% | 1% | 11% | 22% | 19% | 3% | 22% | 18% | 20% | 11% | 18% | 12% | 14% | 20% | 12% | 11% | 13% | 23% | 11% |
| | | >100 MVA | 0.01% | 0.01% | 0% | 0.01% | 0% | 1% | 0% | 0% | 16% | 8% | 0.01% | 16% | 32% | 27% | 1% | 32% | 24% | 27% | 13% | 24% | 12% | 17% | 26% | 12% | 12% | 14% | 31% | 12% |
| | > 150% | All ZSS | 0.01% | 0% | 0.01% | 0% | 0.2% | 0.1% | 0.1% | 0.2% | 1% | 0.3% | 0.3% | 1% | 8% | 4% | 1% | 8% | 21% | 14% | 1% | 21% | 34% | 25% | 4% | 34% | 37% | 32% | 6% | 37% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 9% | 4% | 0% | 9% | 26% | 18% | 0% | 26% | 42% | 32% | 4% | 42% | 46% | 41% | 6% | 46% |
| | | 50-100 MVA | 0.02% | 0.0% | 0.02% | 0% | 0.3% | 0.2% | 0.1% | 0.3% | 1% | 0.5% | 0.4% | 1% | 7% | 3% | 1% | 7% | 19% | 13% | 1% | 19% | 31% | 23% | 5% | 31% | 34% | 29% | 7% | 34% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0.01% | 0.01% | 0% | 0.01% | 0.03% | 0.01% | 0% | 0.03% | 8% | 4% | 0.01% | 8% | 25% | 17% | 0.01% | 25% | 41% | 32% | 3% | 41% | 45% | 40% | 6% | 45% |
| *PV Curtailment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0.3% | 100% | 85% | 100% | 86% | 100% | 86% | 100% | 85% | 100% | 85% | 100% | 85% | 100% | 85% | 100% | 84% | 100% | 100% | 100% | 83% | 100% | 100% | 100% | 82% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.4 | 0.4 | 122 | 0.02 | 0.8 | 0.7 | 236 | 0.1 | 1.2 | 1.1 | 361 | 0.3 | 1.7 | 1.5 | 514 | 0.5 | 2.3 | 2.0 | 699 | 0.8 | 3.0 | 2.7 | 928 | 1.1 | 3.7 | 3.3 | 1152 |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | 6% | 0.3% | 10% | 10% | 9% | 2% | 13% | 13% | 12% | 5% | 16% | 16% | 15% | 7% | 19% | 19% | 18% | 10% | 23% | 22% | 21% | 13% | 25% | 24% | 24% |

## Appendix 6: Full Whole-State Extrapolation Table (With DOEs) – AusNet

**AusNet Services (56 ZSS out of 56) (with DOEs)**

| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| **Overview** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 1% | 0.2% | 2% | 4% | 2% | 1% | 4% | 6% | 3% | 2% | 6% | 7% | 3% | 2% | 7% | 7% | 3% | 4% | 7% | 10% | 3% | 3% | 10% |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 43% | 16% | 0% | 43% | 71% | 25% | 16% | 71% | 77% | 32% | 18% | 77% | 80% | 34% | 36% | 80% | 86% | 21% | 30% | 86% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 70% | 35% | 0% | 70% | 83% | 48% | 35% | 83% | 87% | 61% | 35% | 87% | 91% | 61% | 61% | 91% | 96% | 39% | 61% | 96% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 26% | 3% | 0% | 26% | 68% | 10% | 3% | 68% | 74% | 13% | 6% | 74% | 74% | 16% | 19% | 74% | 84% | 10% | 10% | 84% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 50% | 0% | 0% | 50% | 0% | 0% | 0% | 0% |
| Overall Residential Voltage Drop Non-Compliance | | | 1% | 2% | 1% | 2% | 4% | 3% | 1% | 4% | 7% | 5% | 3% | 7% | 11% | 6% | 5% | 11% | 14% | 8% | 7% | 14% | 19% | 10% | 10% | 19% | 24% | 11% | 10% | 24% |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residential Customers | | All ZSS | 0% | 0% | 0% | 0% | 48% | 0% | 0% | 48% | 88% | 52% | 23% | 88% | 96% | 82% | 54% | 96% | 96% | 91% | 88% | 96% | 98% | 95% | 95% | 98% | 100% | 98% | 95% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 74% | 0% | 0% | 74% | 87% | 61% | 43% | 87% | 96% | 91% | 78% | 96% | 96% | 91% | 87% | 96% | 96% | 96% | 96% | 96% | 100% | 96% | 96% | 100% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 32% | 0% | 0% | 32% | 87% | 45% | 10% | 87% | 97% | 77% | 39% | 97% | 97% | 90% | 87% | 97% | 100% | 94% | 94% | 100% | 100% | 100% | 94% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 50% | 0% | 100% | 100% | 50% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Total Overloaded MV Conductor Length (km) | | All | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 288 | 49 | 0 | 288 | 403 | 300 | 1 | 403 | 622 | 388 | 1 | 622 | 1126 | 538 | 79 | 1126 |
| | | <50 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.2 | 66 | 8 | 0 | 66 | 92 | 59 | 0 | 92 | 135 | 84 | 0 | 135 | 255 | 108 | 18 | 255 |
| | | 50-100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0.5 | 214 | 38 | 0 | 214 | 299 | 229 | 0 | 299 | 467 | 291 | 0 | 467 | 837 | 410 | 59 | 837 |
| | | >100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 2 | 0 | 8 | 12 | 12 | 0 | 12 | 20 | 13 | 0 | 20 | 35 | 20 | 2 | 35 |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | | All ZSS | 43% | 0% | 43% | 43% | 89% | 89% | 43% | 89% | 89% | 89% | 43% | 89% | 100% | 100% | 43% | 100% | 100% | 100% | 43% | 100% | 100% | 100% | 43% | 100% | 100% | 100% | 89% | 100% |
| | | <50 MVA | 43% | 0% | 43% | 43% | 96% | 96% | 43% | 96% | 96% | 96% | 43% | 96% | 100% | 100% | 43% | 100% | 100% | 100% | 43% | 100% | 100% | 100% | 43% | 100% | 100% | 100% | 96% | 100% |
| | | 50-100 MVA | 45% | 0% | 45% | 45% | 87% | 87% | 45% | 87% | 87% | 87% | 45% | 87% | 100% | 100% | 45% | 100% | 100% | 100% | 45% | 100% | 100% | 100% | 45% | 100% | 100% | 100% | 87% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 50% | 50% | 0% | 50% | 50% | 50% | 0% | 50% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 50% | 100% |
| Percentage of ZSS with LV Circuits Utilisation > 150% | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| ***Voltage Assessment*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | All ZSS | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 1% | 0.2% | 2% | 4% | 2% | 1% | 4% | 6% | 3% | 2% | 6% | 7% | 3% | 2% | 7% | 7% | 3% | 4% | 7% | 10% | 3% | 3% | 10% |
| | | <50 MVA | 0.4% | 0.2% | 0.02% | 0.4% | 2% | 2% | 0.2% | 2% | 5% | 3% | 1% | 5% | 8% | 4% | 3% | 8% | 9% | 5% | 3% | 9% | 9% | 5% | 5% | 9% | 15% | 4% | 4% | 15% |
| | | 50-100 MVA | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 1% | 0.2% | 2% | 4% | 2% | 1% | 4% | 6% | 2% | 2% | 6% | 6% | 3% | 2% | 6% | 7% | 3% | 3% | 7% | 10% | 2% | 3% | 10% |
| | | >100 MVA | 0.1% | 0.03% | 0.1% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 1% | 1% | 2% | 3.1% | 1% | 1% | 3.1% | 4% | 1% | 1% | 4% | 5% | 1% | 1% | 5% | 4% | 1% | 1% | 4% |
| Residential Voltage Drop Non-Compliance | | All ZSS | 1% | 2% | 1% | 2% | 4% | 3% | 1% | 4% | 7% | 5% | 3% | 7% | 11% | 6% | 5% | 11% | 14% | 8% | 7% | 14% | 19% | 10% | 10% | 19% | 24% | 11% | 10% | 24% |
| | | <50 MVA | 1% | 2% | 1% | 2% | 6% | 4% | 2% | 6% | 8% | 5% | 4% | 8% | 11% | 7% | 6% | 11% | 14% | 8% | 7% | 14% | 19% | 10% | 10% | 19% | 26% | 12% | 10% | 26% |
| | | 50-100 MVA | 1% | 2% | 1% | 2% | 4% | 3% | 1% | 4% | 7% | 5% | 3% | 7% | 11% | 6% | 5% | 11% | 14% | 7% | 7% | 14% | 19% | 10% | 9% | 19% | 24% | 11% | 10% | 24% |
| | | >100 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 3% | 7% | 12% | 5% | 3% | 12% | 15% | 7% | 6% | 15% | 20% | 10% | 9% | 20% | 24% | 11% | 11% | 24% |
| Percentage of LV Networks with Voltage Rise Issues | | All ZSS | 1% | 1% | 0.4% | 1% | 6% | 3% | 2% | 6% | 10% | 5% | 5% | 10% | 10% | 4% | 5% | 10% | 9% | 6% | 7% | 9% | 11% | 5% | 7% | 11% | 14% | 5% | 6% | 14% |
| | | <50 MVA | 1% | 1% | 0.2% | 1% | 5% | 2% | 1% | 5% | 7% | 3% | 4% | 7% | 8% | 4% | 4% | 8% | 7% | 5% | 6% | 7% | 9% | 4% | 6% | 9% | 13% | 4% | 5% | 13% |
| | | 50-100 MVA | 1% | 0.5% | 0.4% | 1% | 7% | 3% | 2% | 7% | 10% | 5% | 6% | 10% | 11% | 4% | 5% | 11% | 10% | 6% | 7% | 10% | 12% | 6% | 8% | 12% | 15% | 5% | 6% | 15% |
| | | >100 MVA | 1% | 0.1% | 1% | 1% | 13% | 6% | 4% | 13% | 20% | 10% | 11% | 20% | 21% | 7% | 10% | 21% | 19% | 11% | 13% | 19% | 22% | 10% | 14% | 22% | 21% | 8% | 11% | 21% |
| Percentage of LV Networks with Voltage Drop Issues | | All ZSS | 4% | 7% | 4% | 7% | 12% | 12% | 7% | 12% | 14% | 14% | 11% | 14% | 17% | 16% | 13% | 17% | 19% | 18% | 14% | 19% | 24% | 19% | 15% | 24% | 31% | 21% | 17% | 31% |
| | | <50 MVA | 3% | 5% | 3% | 5% | 9% | 9% | 5% | 9% | 10% | 10% | 8% | 10% | 13% | 13% | 9% | 13% | 15% | 15% | 10% | 15% | 21% | 16% | 11% | 21% | 28% | 18% | 13% | 28% |
| | | 50-100 MVA | 4% | 8% | 4% | 8% | 13% | 13% | 8% | 13% | 15% | 15% | 12% | 15% | 17% | 18% | 14% | 18% | 21% | 20% | 15% | 21% | 25% | 20% | 16% | 25% | 32% | 22% | 18% | 32% |
| | | >100 MVA | 7% | 15% | 7% | 15% | 25% | 24% | 15% | 25% | 31% | 29% | 23% | 31% | 31% | 32% | 26% | 32% | 37% | 35% | 28% | 37% | 38% | 34% | 31% | 38% | 43% | 36% | 32% | 43% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | All ZSS | 1% | 1% | 0% | 1% | 6% | 3% | 1% | 6% | 10% | 5% | 5% | 10% | 10% | 4% | 4% | 10% | 9% | 6% | 6% | 9% | 11% | 5% | 7% | 11% | 13% | 5% | 6% | 13% |
| | | <50 MVA | 1% | 1% | 0% | 1% | 4% | 2% | 1% | 4% | 7% | 3% | 4% | 7% | 7% | 4% | 4% | 7% | 7% | 5% | 5% | 7% | 8% | 4% | 6% | 8% | 11% | 4% | 5% | 11% |
| | | 50-100 MVA | 1% | 0.5% | 0% | 1% | 6% | 3% | 1% | 6% | 10% | 5% | 5% | 10% | 11% | 4% | 5% | 11% | 10% | 6% | 6% | 10% | 11% | 6% | 8% | 11% | 14% | 5% | 6% | 14% |
| | | >100 MVA | 1% | 0.1% | 0% | 1% | 13% | 6% | 2% | 13% | 20% | 10% | 10% | 20% | 21% | 7% | 9% | 21% | 19% | 11% | 11% | 19% | 21% | 10% | 14% | 21% | 21% | 8% | 11% | 21% |
| ***Thermal Assessment*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 99% | 99% | 99% | 99% | 96% | 98% | 99% | 96% | 90% | 94% | 98% | 90% | 81% | 85% | 95% | 81% | 77% | 80% | 91% | 77% | 73% | 77% | 85% | 73% | 70% | 75% | 83% | 70% |
| | | <50 MVA | 99% | 99% | 99% | 99% | 97% | 97% | 99% | 97% | 94% | 95% | 98% | 94% | 88% | 91% | 95% | 88% | 85% | 87% | 92% | 85% | 80% | 84% | 89% | 80% | 77% | 83% | 87% | 77% |
| | | 50-100 MVA | 99% | 99% | 100% | 99% | 96% | 98% | 99% | 96% | 89% | 94% | 98% | 89% | 78% | 83% | 95% | 78% | 75% | 77% | 91% | 75% | 70% | 75% | 84% | 70% | 67% | 73% | 81% | 67% |
| | | >100 MVA | 100% | 100% | 100% | 100% | 96% | 99% | 100% | 96% | 80% | 91% | 100% | 80% | 58% | 67% | 97% | 58% | 52% | 56% | 90% | 52% | 49% | 53% | 74% | 49% | 44% | 50% | 69% | 44% |
| | 100%-110% | All ZSS | 0.2% | 0.4% | 0.2% | 0.4% | 2% | 1% | 0.5% | 2% | 2% | 2% | 1% | 2% | 4% | 3% | 2% | 4% | 2% | 4% | 3% | 2% | 4% | 3% | 6% | 4% | 4% | 4% | 6% | 4% |
| | | <50 MVA | 0.2% | 0.5% | 0.3% | 0.5% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 3% | 2% | 1% | 3% | 2% | 3% | 3% | 2% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% |
| | | 50-100 MVA | 0.2% | 0.4% | 0.2% | 0.4% | 2% | 1% | 0.4% | 2% | 2% | 2% | 1% | 2% | 5% | 4% | 2% | 5% | 3% | 4% | 3% | 3% | 4% | 3% | 7% | 4% | 4% | 4% | 7% | 4% |
| | | >100 MVA | 0.0% | 0.0% | 0.0% | 0% | 4% | 1% | 0% | 4% | 5% | 4% | 0% | 5% | 9% | 7% | 3% | 9% | 5% | 7% | 5% | 5% | 5% | 3% | 14% | 5% | 4% | 3% | 13% | 4% |
| | 110%-150% | All ZSS | 1% | 0.5% | 0.2% | 0.5% | 1% | 1% | 1% | 1% | 6% | 3% | 1% | 6% | 12% | 11% | 2% | 12% | 12% | 13% | 4% | 12% | 10% | 11% | 7% | 10% | 10% | 10% | 9% | 10% |
| | | <50 MVA | 1% | 1% | 0.3% | 1% | 2% | 1% | 1% | 2% | 3% | 3% | 1% | 3% | 6% | 7% | 3% | 6% | 7% | 8% | 4% | 7% | 8% | 8% | 6% | 8% | 8% | 7% | 7% | 8% |
| | | 50-100 MVA | 1% | 0.5% | 0.2% | 0.5% | 1% | 1% | 1% | 1% | 7% | 3% | 1% | 7% | 13% | 12% | 2% | 13% | 13% | 14% | 4% | 13% | 10% | 13% | 8% | 10% | 10% | 11% | 10% | 10% |
| | | >100 MVA | 0.04% | 0.04% | 0% | 0.04% | 0.04% | 0% | 0% | 0.04% | 14% | 4% | 0.00% | 14% | 30% | 25% | 1% | 30% | 26% | 30% | 5% | 26% | 16% | 24% | 12% | 16% | 14% | 20% | 18% | 14% |
| | > 150% | All ZSS | 0.02% | 0% | 0.02% | 0% | 1% | 0.3% | 0.1% | 1% | 2% | 0% | 0.4% | 2% | 3% | 1% | 1% | 3% | 9% | 3% | 1% | 9% | 14% | 8% | 1% | 14% | 16% | 10% | 2% | 16% |
| | | <50 MVA | 0.03% | 0% | 0.03% | 0% | 1% | 0.4% | 0.2% | 1% | 2% | 1% | 0% | 2% | 3% | 1% | 1% | 3% | 6% | 2% | 1% | 6% | 8% | 4% | 2% | 8% | 10% | 5% | 2% | 10% |
| | | 50-100 MVA | 0.02% | 0% | 0.02% | 0% | 0% | 0.3% | 0.1% | 0% | 1% | 0% | 0.4% | 1% | 4% | 1% | 1% | 4% | 9% | 4% | 1% | 9% | 15% | 9% | 1% | 15% | 18% | 12% | 2% | 18% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0.04% | 0.04% | 0.00% | 0.04% | 0.1% | 0.04% | 0% | 0.1% | 4% | 1% | 0.00% | 4% | 17% | 8% | 0.00% | 17% | 31% | 20% | 0% | 31% | 37% | 27% | 0% | 37% |
| ***PV Curtailment*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 1% | 100% | 85% | 100% | 73% | 100% | 73% | 100% | 62% | 100% | 65% | 100% | 68% | 100% | 72% | 100% | 77% | 100% | 79% | 100% | 82% | 100% | 83% | 100% | 84% | 100% | 86% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 1 | 0 | 141 | 0.05 | 1 | 1 | 236 | 0.6 | 2 | 1 | 449 | 1.4 | 3 | 2 | 892 | 2 | 4 | 3 | 1193 | 3 | 5 | 4 | 1551 | 3 | 5 | 5 | 1854 |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | 6% | 0.9% | 10% | 8% | 8% | 9% | 16% | 13% | 13% | 19% | 26% | 23% | 23% | 25% | 28% | 27% | 27% | 27% | 30% | 31% | 31% | 29% | 31% | 34% | 33% |
| ***EV Management*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | - | - | - | - | - | - | 9% | 9% | 8% | 9% | 12% | 12% | 11% | 12% | 16% | 16% | 15% | 16% | 20% | 20% | 19% | 20% | 24% | 24% | 23% | 24% |
| Average EV Charging Delay (h) | | | - | - | - | - | - | - | - | - | 3.1 | 2.8 | 3.3 | 3.3 | 4.6 | 4.0 | 4.8 | 4.8 | 4.4 | 4.5 | 5.0 | 5.0 | 4.2 | 4.5 | 4.9 | 4.9 | 4.0 | 4.5 | 4.8 | 4.8 |

## Appendix 7: Full Whole-State Extrapolation Table (With DOEs) – CitiPower

| CitiPower (22 ZSS out of 45) (with DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| **Overview** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | | 0.04% | 0% | 0.1% | 0.1% | 1% | 0.2% | 0.2% | 1% | 2% | 0.3% | 0.4% | 2% | 3% | 0.5% | 1% | 3% | 3% | 1% | 1% | 3% | 4% | 1% | 1% | 4% | 3% | 1% | 1% | 3% |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 0% | 5% | 9% | 0% | 0% | 9% | 0% | 0% | 0% | 0% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 13% | 0% | 0% | 13% | 25% | 0% | 0% | 25% | 0% | 0% | 0% | 0% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Overall Residential Voltage Drop Non-Compliance | | | 1% | 1% | 0.2% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 2% | 7% | 12% | 5% | 3% | 12% | 15% | 7% | 6% | 15% | 20% | 10% | 9% | 20% | 24% | 10% | 11% | 24% |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residential Customers | | All ZSS | 0% | 0% | 0% | 0% | 5% | 5% | 0% | 5% | 100% | 23% | 0% | 100% | 100% | 14% | 5% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 13% | 13% | 0% | 13% | 100% | 50% | 0% | 100% | 100% | 25% | 13% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 7% | 0% | 100% | 100% | 7% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Total Overloaded MV Conductor Length (km) | | All | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 6 | 0 | 20 | 28 | 28 | 0 | 28 | 47 | 30 | 0 | 47 | 81 | 47 | 6 | 81 |
| | | <50 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 4 | 6 | 6 | 0 | 6 | 10 | 6 | 0 | 10 | 16 | 10 | 1 | 16 |
| | | 50-100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 4 | 0 | 16 | 22 | 22 | 0 | 22 | 37 | 24 | 0 | 37 | 65 | 37 | 4 | 65 |
| | | >100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Percentage of ZSS with LV Circuits Utilisation > 150% | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Voltage Assessment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | All ZSS | 0.04% | 0% | 0.1% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 0.3% | 0.4% | 2% | 3% | 0.5% | 1% | 3% | 3% | 1% | 1% | 3% | 4% | 1% | 1% | 4% | 3% | 1% | 1% | 3% |
| | | <50 MVA | 0.04% | 0% | 0.1% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 0.4% | 0.4% | 2% | 3% | 1% | 1% | 3% | 4% | 1% | 1% | 4% | 5% | 1% | 1% | 5% | 3% | 1% | 1% | 3% |
| | | 50-100 MVA | 0.04% | 0% | 0.1% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 0.3% | 0.4% | 2% | 2% | 0.5% | 1% | 2% | 3% | 1% | 1% | 3% | 4% | 1% | 1% | 4% | 3% | 1% | 1% | 3% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Residential Voltage Drop Non-Compliance | | All ZSS | 1% | 1% | 0.2% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 2% | 7% | 12% | 5% | 3% | 12% | 15% | 7% | 6% | 15% | 20% | 10% | 9% | 20% | 24% | 10% | 11% | 24% |
| | | <50 MVA | 1% | 2% | 0.3% | 2% | 3% | 3% | 1% | 3% | 8% | 5% | 3% | 8% | 13% | 5% | 3% | 13% | 17% | 7% | 7% | 17% | 22% | 10% | 10% | 22% | 26% | 11% | 12% | 26% |
| | | 50-100 MVA | 1% | 1% | 0.2% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 2% | 7% | 12% | 5% | 3% | 12% | 15% | 7% | 6% | 15% | 20% | 9% | 9% | 20% | 23% | 10% | 10% | 23% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Percentage of LV Networks with Voltage Rise Issues | | All ZSS | 1% | 0% | 1% | 1% | 13% | 7% | 4% | 13% | 21% | 10% | 11% | 21% | 22% | 7% | 10% | 22% | 20% | 11% | 13% | 20% | 23% | 10% | 15% | 23% | 22% | 8% | 11% | 22% |
| | | <50 MVA | 1% | 0% | 1% | 1% | 15% | 7% | 5% | 15% | 23% | 11% | 12% | 23% | 25% | 7% | 11% | 25% | 22% | 12% | 15% | 22% | 25% | 11% | 16% | 25% | 25% | 9% | 12% | 25% |
| | | 50-100 MVA | 1% | 0% | 1% | 1% | 13% | 7% | 4% | 13% | 21% | 10% | 11% | 21% | 22% | 7% | 10% | 22% | 20% | 11% | 13% | 20% | 23% | 10% | 14% | 23% | 22% | 8% | 11% | 22% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Percentage of LV Networks with Voltage Drop Issues | | All ZSS | 8% | 16% | 8% | 16% | 27% | 26% | 16% | 27% | 32% | 31% | 25% | 32% | 32% | 34% | 28% | 34% | 38% | 36% | 30% | 38% | 39% | 35% | 32% | 39% | 44% | 37% | 33% | 44% |
| | | <50 MVA | 9% | 17% | 9% | 17% | 30% | 28% | 17% | 30% | 36% | 34% | 27% | 36% | 36% | 37% | 31% | 37% | 41% | 39% | 33% | 41% | 42% | 38% | 36% | 42% | 46% | 40% | 36% | 46% |
| | | 50-100 MVA | 8% | 15% | 8% | 15% | 26% | 25% | 15% | 26% | 32% | 30% | 24% | 32% | 32% | 33% | 27% | 33% | 38% | 36% | 29% | 38% | 39% | 34% | 32% | 39% | 44% | 36% | 32% | 44% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | All ZSS | 1% | 0% | 0% | 1% | 13% | 7% | 2% | 13% | 21% | 10% | 10% | 21% | 22% | 7% | 9% | 22% | 20% | 11% | 11% | 20% | 22% | 10% | 15% | 22% | 22% | 8% | 11% | 22% |
| | | <50 MVA | 1% | 0% | 0% | 1% | 15% | 7% | 2% | 15% | 23% | 11% | 11% | 23% | 25% | 7% | 10% | 25% | 22% | 12% | 12% | 22% | 25% | 11% | 16% | 25% | 25% | 9% | 12% | 25% |
| | | 50-100 MVA | 1% | 0% | 0% | 1% | 13% | 7% | 2% | 13% | 21% | 10% | 10% | 21% | 22% | 7% | 9% | 22% | 20% | 11% | 11% | 20% | 22% | 10% | 14% | 22% | 22% | 8% | 11% | 22% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Thermal Assessment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 100% | 100% | 100% | 100% | 96% | 99% | 100% | 96% | 79% | 91% | 100% | 79% | 54% | 64% | 96% | 54% | 49% | 53% | 89% | 49% | 45% | 50% | 72% | 45% | 41% | 47% | 67% | 41% |
| | | <50 MVA | 100% | 100% | 100% | 100% | 96% | 99% | 100% | 96% | 79% | 91% | 100% | 79% | 55% | 65% | 96% | 55% | 49% | 54% | 89% | 49% | 46% | 51% | 73% | 46% | 41% | 47% | 68% | 41% |
| | | 50-100 MVA | 100% | 100% | 100% | 100% | 96% | 99% | 100% | 96% | 79% | 91% | 100% | 79% | 54% | 64% | 96% | 54% | 49% | 52% | 89% | 49% | 45% | 50% | 72% | 45% | 41% | 47% | 67% | 41% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 100%-110% | All ZSS | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 6% | 5% | 0% | 6% | 10% | 7% | 3% | 10% | 5% | 7% | 5% | 5% | 5% | 3% | 15% | 5% | 4% | 3% | 13% | 4% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 5% | 5% | 0% | 5% | 10% | 7% | 3% | 10% | 5% | 7% | 5% | 5% | 5% | 3% | 15% | 5% | 5% | 3% | 13% | 5% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 6% | 5% | 0% | 6% | 10% | 8% | 3% | 10% | 5% | 7% | 6% | 5% | 5% | 3% | 15% | 5% | 4% | 3% | 13% | 4% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 110%-150% | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 16% | 4% | 0% | 16% | 32% | 27% | 1% | 32% | 28% | 32% | 5% | 28% | 17% | 26% | 13% | 17% | 15% | 21% | 20% | 15% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 16% | 4% | 0% | 16% | 31% | 27% | 1% | 31% | 27% | 31% | 5% | 27% | 17% | 26% | 12% | 17% | 15% | 21% | 19% | 15% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 16% | 4% | 0% | 16% | 32% | 27% | 1% | 32% | 28% | 32% | 5% | 28% | 17% | 26% | 13% | 17% | 15% | 21% | 20% | 15% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | > 150% | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 19% | 8% | 0% | 19% | 33% | 21% | 0% | 33% | 40% | 29% | 0% | 40% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 18% | 8% | 0% | 18% | 33% | 21% | 0% | 33% | 39% | 29% | 0% | 39% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 19% | 8% | 0% | 19% | 33% | 21% | 0% | 33% | 40% | 29% | 0% | 40% |
| | | >100 MVA | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **PV Curtailment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0.2% | 100% | 85% | 100% | 73% | 100% | 75% | 100% | 63% | 100% | 69% | 100% | 73% | 100% | 84% | 100% | 83% | 100% | 89% | 100% | 88% | 100% | 93% | 100% | 90% | 100% | 95% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.2 | 0.1 | 51 | 0.02 | 0 | 0.3 | 87 | 0.2 | 1 | 0 | 168 | 0.5 | 1 | 1 | 325 | 0.7 | 2 | 1 | 451 | 1 | 2 | 2 | 610 | 1 | 2 | 2 | 725 |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | 6% | 1.1% | 10% | 8% | 8% | 8% | 17% | 13% | 13% | 19% | 27% | 23% | 23% | 25% | 31% | 29% | 28% | 28% | 34% | 34% | 33% | 31% | 34% | 37% | 36% |
| **EV Management** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | - | - | - | - | - | - | 9% | 9% | 9% | 9% | 13% | 13% | 12% | 13% | 16% | 16% | 16% | 16% | 21% | 20% | 20% | 21% | 24% | 24% | 23% | 24% |
| Average EV Charging Delay (h) | | | - | - | - | - | - | - | - | - | 3.9 | 3.0 | 3.5 | 3.9 | 5.1 | 4.5 | 5.3 | 5.3 | 4.8 | 4.8 | 5.7 | 5.7 | 4.6 | 4.9 | 5.7 | 5.7 | 4.5 | 4.9 | 5.5 | 5.5 |

## Appendix 8: Full Whole-State Extrapolation Table (With DOEs) – Jemena

| Jemena (26 ZSS out of 30) (with DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| *Overview* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | | 0.1% | 0.03% | 0.05% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 1% | 1% | 2% | 3.4% | 1% | 1% | 3.4% | 4% | 1% | 1% | 4% | 5% | 1.5% | 2% | 5.1% | 4% | 1% | 1% | 4.0% |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 4% | 19% | 4% | 0% | 19% | 23% | 4% | 0% | 23% | 31% | 4% | 4% | 31% | 27% | 0% | 4% | 27% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 20% | 0% | 0% | 20% | 27% | 0% | 0% | 27% | 27% | 0% | 0% | 27% | 27% | 0% | 0% | 27% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 11% | 0% | 0% | 11% | 22% | 11% | 0% | 22% | 22% | 11% | 0% | 22% | 33% | 11% | 11% | 33% | 33% | 0% | 11% | 33% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 50% | 0% | 0% | 50% | 0% | 0% | 0% | 0% |
| Overall Residential Voltage Drop Non-Compliance | | | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 3% | 7% | 12% | 5% | 4% | 12% | 15% | 7% | 7% | 15% | 20% | 10% | 10% | 20% | 24% | 11% | 11% | 24% |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residential Customers | | All ZSS | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 4% | 100% | 38% | 4% | 100% | 100% | 46% | 4% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 47% | 0% | 100% | 100% | 53% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 11% | 0% | 0% | 11% | 100% | 33% | 11% | 100% | 100% | 33% | 11% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 100% | 50% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Total Overloaded MV Conductor Length (km) | | All | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 56 | 16 | 0 | 56 | 78 | 78 | 0 | 78 | 132 | 84 | 0 | 132 | 238 | 132 | 16 | 238 |
| | | <50 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 8 | 0 | 27 | 38 | 38 | 0 | 38 | 63 | 40 | 0 | 63 | 110 | 63 | 8 | 110 |
| | | 50-100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 6 | 0 | 23 | 31 | 31 | 0 | 31 | 53 | 34 | 0 | 53 | 101 | 53 | 6 | 101 |
| | | >100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 2 | 0 | 7 | 9 | 9 | 0 | 9 | 16 | 10 | 0 | 16 | 27 | 16 | 2 | 27 |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | | All ZSS | 0% | 0% | 0% | 0% | 31% | 31% | 0% | 31% | 31% | 31% | 0% | 31% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 31% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 27% | 27% | 0% | 27% | 27% | 27% | 0% | 27% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 27% | 100% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 33% | 33% | 0% | 33% | 33% | 33% | 0% | 33% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 33% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 50% | 50% | 0% | 50% | 50% | 50% | 0% | 50% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 50% | 100% |
| Percentage of ZSS with LV Circuits Utilisation > 150% | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| *Voltage Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | All ZSS | 0.1% | 0.03% | 0.0% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 1% | 1% | 2% | 3.4% | 1% | 1% | 3.4% | 4% | 1% | 1% | 4% | 5% | 1.5% | 2% | 5% | 4% | 1% | 1% | 4% |
| | | <50 MVA | 0.1% | 0.03% | 0.1% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 1% | 1% | 2% | 3.3% | 1% | 1% | 3.3% | 4% | 1% | 1% | 4% | 5% | 1.41% | 1% | 5% | 4% | 1% | 1% | 4% |
| | | 50-100 MVA | 0.1% | 0.05% | 0.0% | 0.1% | 1% | 1% | 0.2% | 1% | 2% | 1% | 1% | 2% | 4% | 1% | 1% | 4% | 4% | 1% | 2% | 4% | 5% | 1.7% | 2% | 5% | 4% | 1% | 1% | 4% |
| | | >100 MVA | 0.1% | 0.02% | 0.1% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 1% | 0% | 2% | 3% | 1% | 1% | 3% | 4% | 1% | 1% | 4% | 5% | 1% | 1% | 5% | 3% | 1% | 1% | 3% |
| Residential Voltage Drop Non-Compliance | | All ZSS | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 3% | 7% | 12% | 5% | 4% | 12% | 15% | 7% | 7% | 15% | 20% | 10% | 10% | 20% | 24% | 11% | 11% | 24% |
| | | <50 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 8% | 5% | 3% | 8% | 12% | 5% | 4% | 12% | 16% | 7% | 7% | 16% | 21% | 10% | 10% | 21% | 24% | 11% | 11% | 24% |
| | | 50-100 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 3% | 7% | 11% | 5% | 4% | 11% | 15% | 7% | 6% | 15% | 20% | 10% | 9% | 20% | 23% | 11% | 10% | 23% |
| | | >100 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 2% | 7% | 11% | 5% | 3% | 11% | 15% | 7% | 6% | 15% | 19% | 9% | 9% | 19% | 23% | 10% | 10% | 23% |
| Percentage of LV Networks with Voltage Rise Issues | | All ZSS | 1% | 0% | 1% | 1% | 11% | 5% | 4% | 11% | 17% | 8% | 9% | 17% | 18% | 6% | 8% | 18% | 16% | 9% | 11% | 16% | 19% | 9% | 12% | 19% | 19% | 7% | 9% | 19% |
| | | <50 MVA | 1% | 0% | 1% | 1% | 12% | 6% | 4% | 12% | 19% | 9% | 10% | 19% | 21% | 7% | 9% | 21% | 19% | 10% | 13% | 19% | 21% | 9% | 14% | 21% | 21% | 7% | 10% | 21% |
| | | 50-100 MVA | 1% | 0% | 1% | 1% | 9% | 5% | 3% | 9% | 15% | 7% | 8% | 15% | 16% | 5% | 7% | 16% | 14% | 8% | 10% | 14% | 17% | 8% | 11% | 17% | 16% | 6% | 8% | 16% |
| | | >100 MVA | 1% | 0% | 1% | 1% | 13% | 6% | 4% | 13% | 20% | 9% | 11% | 20% | 21% | 6% | 10% | 21% | 19% | 11% | 13% | 19% | 22% | 10% | 14% | 22% | 21% | 7% | 11% | 21% |
| Percentage of LV Networks with Voltage Drop Issues | | All ZSS | 6% | 13% | 6% | 13% | 22% | 21% | 13% | 22% | 26% | 25% | 20% | 26% | 27% | 28% | 23% | 28% | 32% | 31% | 24% | 32% | 35% | 30% | 26% | 35% | 39% | 32% | 28% | 39% |
| | | <50 MVA | 7% | 14% | 7% | 14% | 25% | 24% | 14% | 25% | 30% | 28% | 23% | 30% | 30% | 31% | 26% | 31% | 35% | 34% | 27% | 35% | 38% | 33% | 30% | 38% | 42% | 35% | 31% | 42% |
| | | 50-100 MVA | 6% | 11% | 5% | 11% | 18% | 18% | 11% | 18% | 22% | 21% | 17% | 22% | 24% | 24% | 19% | 24% | 28% | 27% | 21% | 28% | 32% | 27% | 23% | 32% | 37% | 29% | 24% | 37% |
| | | >100 MVA | 7% | 15% | 7% | 15% | 25% | 24% | 15% | 25% | 30% | 29% | 23% | 30% | 31% | 32% | 26% | 32% | 37% | 35% | 28% | 37% | 38% | 33% | 31% | 38% | 43% | 35% | 31% | 43% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | All ZSS | 1% | 0% | 0% | 1% | 11% | 5% | 2% | 11% | 17% | 8% | 8% | 17% | 18% | 6% | 7% | 18% | 16% | 9% | 10% | 16% | 18% | 9% | 12% | 18% | 18% | 7% | 9% | 18% |
| | | <50 MVA | 1% | 0% | 0% | 1% | 12% | 6% | 2% | 12% | 19% | 9% | 9% | 19% | 20% | 7% | 8% | 20% | 19% | 10% | 11% | 19% | 21% | 9% | 14% | 21% | 21% | 7% | 10% | 21% |
| | | 50-100 MVA | 1% | 0% | 0% | 1% | 9% | 5% | 2% | 9% | 15% | 7% | 7% | 15% | 15% | 5% | 6% | 15% | 14% | 8% | 8% | 14% | 16% | 8% | 11% | 16% | 16% | 6% | 8% | 16% |
| | | >100 MVA | 1% | 0% | 0% | 1% | 13% | 6% | 2% | 13% | 20% | 9% | 9% | 20% | 21% | 6% | 8% | 21% | 19% | 11% | 11% | 19% | 21% | 10% | 14% | 21% | 21% | 7% | 11% | 21% |
| *Thermal Assessment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 100% | 100% | 100% | 100% | 97% | 99% | 100% | 97% | 84% | 93% | 100% | 84% | 65% | 72% | 97% | 65% | 60% | 63% | 91% | 60% | 56% | 60% | 78% | 56% | 52% | 58% | 74% | 52% |
| | | <50 MVA | 100% | 100% | 100% | 100% | 96% | 99% | 100% | 96% | 82% | 92% | 100% | 82% | 61% | 69% | 97% | 61% | 56% | 59% | 90% | 56% | 52% | 56% | 76% | 52% | 48% | 54% | 71% | 48% |
| | | 50-100 MVA | 100% | 100% | 100% | 100% | 97% | 99% | 100% | 97% | 86% | 93% | 100% | 86% | 70% | 76% | 97% | 70% | 65% | 67% | 92% | 65% | 62% | 65% | 80% | 62% | 58% | 63% | 76% | 58% |
| | | >100 MVA | 100% | 100% | 100% | 100% | 96% | 99% | 100% | 96% | 79% | 91% | 100% | 79% | 56% | 65% | 97% | 56% | 51% | 54% | 90% | 51% | 47% | 52% | 73% | 47% | 43% | 49% | 68% | 43% |
| | 100%-110% | All ZSS | 0% | 0% | 0% | 0% | 3% | 1% | 0% | 3% | 4% | 4% | 0% | 4% | 8% | 6% | 2% | 8% | 4% | 6% | 5% | 4% | 4% | 3% | 12% | 4% | 4% | 3% | 11% | 4% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 5% | 4% | 0% | 5% | 9% | 6% | 3% | 9% | 4% | 6% | 5% | 4% | 4% | 3% | 13% | 4% | 4% | 3% | 12% | 4% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 3% | 1% | 0% | 3% | 4% | 3% | 0% | 4% | 6% | 5% | 2% | 6% | 3% | 5% | 4% | 3% | 4% | 3% | 10% | 4% | 4% | 3% | 9% | 4% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 6% | 5% | 0% | 6% | 9% | 7% | 3% | 9% | 5% | 7% | 5% | 5% | 5% | 2.9% | 14.6% | 5% | 4% | 3% | 13% | 4% |
| | 110%-150% | All ZSS | 0.1% | 0.1% | 0.0% | 0.1% | 0.1% | 0% | 0% | 0.1% | 12% | 4% | 0% | 12% | 24% | 21% | 1% | 24% | 22% | 25% | 5% | 22% | 14% | 21% | 10% | 14% | 13% | 17% | 16% | 13% |
| | | <50 MVA | 0.1% | 0.1% | 0.0% | 0.1% | 0.1% | 0% | 0% | 0.1% | 13% | 4% | 0% | 13% | 27% | 23% | 1% | 27% | 24% | 27% | 5% | 24% | 15% | 23% | 11% | 15% | 14% | 18% | 17% | 14% |
| | | 50-100 MVA | 0.2% | 0.2% | 0.0% | 0.2% | 0.2% | 0% | 0% | 0.2% | 10% | 3% | 0% | 10% | 21% | 19% | 1% | 21% | 19% | 22% | 4% | 19% | 13% | 18% | 9% | 13% | 12% | 15% | 14% | 12% |
| | | >100 MVA | 0.02% | 0.02% | 0.0% | 0.02% | 0.0% | 0% | 0% | 0.02% | 15% | 4% | 0% | 15% | 31% | 26% | 1% | 31% | 27% | 31% | 5% | 27% | 16% | 25% | 12% | 16% | 15% | 20% | 19% | 15% |
| | > 150% | All ZSS | 0% | 0% | 0% | 0% | 0.1% | 0.1% | 0% | 0% | 0.3% | 0.1% | 0% | 0% | 3% | 1% | 0.0% | 3% | 14% | 6% | 0.0% | 14% | 26% | 16% | 0% | 26% | 31% | 22% | 0% | 31% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0.1% | 0.1% | 0% | 0% | 0.2% | 0.1% | 0% | 0% | 4% | 1% | 0.0% | 4% | 16% | 7% | 0.0% | 16% | 28% | 18% | 0% | 28% | 34% | 25% | 0% | 34% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0.2% | 0.2% | 0% | 0% | 0.4% | 0.2% | 0% | 0% | 3% | 1% | 0.0% | 3% | 12% | 6% | 0.0% | 12% | 22% | 14% | 0% | 22% | 27% | 19% | 0% | 27% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0.02% | 0.02% | 0% | 0% | 0.05% | 0.0% | 0% | 0% | 4% | 1% | 0.00% | 4% | 18% | 8% | 0.00% | 18% | 32% | 20% | 0% | 32% | 38% | 28% | 0% | 38% |
| *PV Curtailment* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0% | 100% | 85% | 100% | 73% | 100% | 74% | 100% | 63% | 100% | 68% | 100% | 72% | 100% | 82% | 100% | 82% | 100% | 88% | 100% | 87% | 100% | 91% | 100% | 88% | 100% | 93% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.3 | 0.3 | 85 | 0.04 | 1 | 0 | 146 | 0.3 | 1 | 1 | 281 | 0.8 | 2 | 2 | 548 | 1 | 3 | 2 | 754 | 2 | 3 | 3 | 1013 | 2 | 3 | 3 | 1206 |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | 6% | 1.1% | 10% | 8% | 8% | 8% | 17% | 13% | 13% | 19% | 27% | 23% | 23% | 25% | 31% | 28% | 28% | 28% | 33% | 33% | 33% | 30% | 34% | 36% | 36% |
| *EV Management* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | - | - | - | - | - | - | 9% | 9% | 8% | 9% | 13% | 12% | 12% | 13% | 16% | 16% | 15% | 16% | 21% | 20% | 20% | 21% | 24% | 24% | 23% | 24% |
| Average EV Charging Delay (h) | | | - | - | - | - | - | - | - | - | 3.7 | 2.9 | 3.4 | 3.7 | 5.0 | 4.4 | 5.2 | 5.2 | 4.8 | 4.8 | 5.6 | 5.6 | 4.5 | 4.8 | 5.5 | 5.5 | 4.4 | 4.8 | 5.4 | 5.4 |

## Appendix 9: Full Whole-State Extrapolation Table (With DOEs) – Powercor

Powercor (60 ZSS out of 68) (with DOEs)

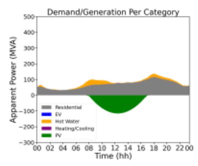
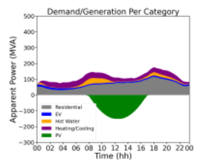
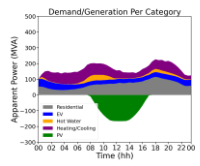
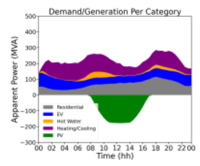
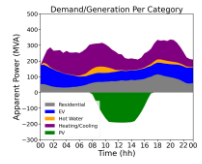
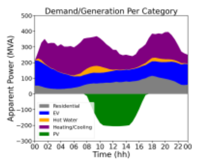
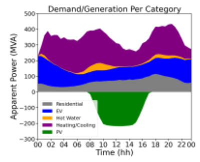
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| **Overview** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 1% | 0.2% | 2% | 4% | 2% | 1% | 4% | 6% | 2% | 2% | 6% | 6% | 3% | 2% | 6% | 7% | 3% | 3% | 7% | 11% | 2% | 3% | 11% |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 25% | 3% | 0% | 25% | 53% | 12% | 3% | 53% | 58% | 18% | 7% | 58% | 63% | 22% | 23% | 63% | 85% | 10% | 15% | 85% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 25% | 4% | 0% | 25% | 50% | 11% | 4% | 50% | 54% | 14% | 4% | 54% | 57% | 21% | 21% | 57% | 89% | 7% | 11% | 89% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 26% | 3% | 0% | 26% | 58% | 13% | 3% | 58% | 65% | 23% | 10% | 65% | 71% | 23% | 26% | 71% | 81% | 13% | 19% | 81% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% |
| Overall Residential Voltage Drop Non-Compliance | | | 1% | 2% | 1% | 2% | 4% | 3% | 1% | 4% | 7% | 4% | 3% | 7% | 10% | 6% | 4% | 10% | 13% | 7% | 6% | 13% | 18% | 9% | 9% | 18% | 24% | 11% | 10% | 24% |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residential Customers | | All ZSS | 0% | 0% | 0% | 0% | 33% | 5% | 0% | 33% | 70% | 28% | 13% | 70% | 82% | 58% | 35% | 82% | 87% | 77% | 63% | 87% | 95% | 78% | 78% | 95% | 100% | 92% | 80% | 100% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 29% | 7% | 0% | 29% | 50% | 21% | 11% | 50% | 68% | 50% | 32% | 68% | 75% | 61% | 43% | 75% | 89% | 64% | 64% | 89% | 100% | 82% | 68% | 100% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 39% | 3% | 0% | 39% | 87% | 35% | 16% | 87% | 94% | 68% | 39% | 94% | 97% | 90% | 84% | 97% | 100% | 90% | 90% | 100% | 100% | 100% | 90% | 100% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 100% | 0% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Total Overloaded MV Conductor Length (km) | | All | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 340 | 50 | 0 | 340 | 475 | 328 | 1 | 475 | 723 | 446 | 1 | 723 | 1268 | 603 | 92 | 1268 |
| | | <50 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 125 | 8 | 0 | 125 | 175 | 88 | 1 | 175 | 253 | 150 | 1 | 253 | 419 | 181 | 33 | 419 |
| | | 50-100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0.4 | 200 | 40 | 0 | 200 | 280 | 226 | 0 | 280 | 439 | 277 | 0 | 439 | 796 | 395 | 55 | 796 |
| | | >100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 | 0.04 | 14 | 2 | 0 | 14 | 20 | 14 | 0 | 20 | 31 | 19 | 0 | 31 | 53 | 26 | 4 | 53 |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | | All ZSS | 60% | 0% | 60% | 60% | 87% | 87% | 60% | 87% | 87% | 87% | 60% | 87% | 100% | 100% | 60% | 100% | 100% | 100% | 60% | 100% | 100% | 100% | 60% | 100% | 100% | 100% | 87% | 100% |
| | | <50 MVA | 79% | 0% | 79% | 79% | 89% | 89% | 79% | 89% | 89% | 89% | 79% | 89% | 100% | 100% | 79% | 100% | 100% | 100% | 79% | 100% | 100% | 100% | 79% | 100% | 100% | 100% | 89% | 100% |
| | | 50-100 MVA | 42% | 0% | 42% | 42% | 84% | 84% | 42% | 84% | 84% | 84% | 42% | 84% | 100% | 100% | 42% | 100% | 100% | 100% | 42% | 100% | 100% | 100% | 42% | 100% | 100% | 100% | 84% | 100% |
| | | >100 MVA | 100% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Percentage of ZSS with LV Circuits Utilisation > 150% | | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Voltage Assessment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | All ZSS | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 1% | 0% | 1.6% | 4% | 2% | 1% | 3.6% | 6% | 2% | 2% | 5.8% | 6% | 3% | 2% | 6.3% | 7% | 3% | 3% | 6.8% | 11% | 2% | 3% | 11.1% |
| | | <50 MVA | 0.3% | 0.2% | 0.02% | 0.3% | 2% | 1% | 0% | 1.5% | 3% | 2% | 1% | 3.5% | 6% | 2% | 2% | 5.7% | 6% | 3% | 2% | 6.0% | 6% | 3% | 3% | 6.2% | 16% | 2% | 3% | 15.7% |
| | | 50-100 MVA | 0.3% | 0.1% | 0.03% | 0.3% | 2% | 1% | 0% | 1.7% | 4% | 2% | 1% | 3.7% | 6% | 2% | 2% | 5.9% | 6% | 3% | 2% | 6.5% | 7% | 3% | 3% | 7.0% | 10% | 2% | 3% | 9.7% |
| | | >100 MVA | 0.1% | 0.1% | 0.03% | 0.1% | 1% | 1% | 0% | 1.0% | 2.3% | 1.0% | 0.6% | 2.3% | 4% | 1% | 1% | 3.6% | 4% | 2% | 1% | 4.0% | 4% | 2% | 2% | 4.5% | 11% | 1% | 2% | 11.1% |
| Residential Voltage Drop Non-Compliance | | All ZSS | 1% | 2% | 1% | 2% | 4.22% | 3.11% | 1.27% | 4% | 7% | 4% | 3% | 7% | 10% | 6% | 4% | 10% | 13% | 7% | 6% | 13% | 18% | 9% | 9% | 18% | 24% | 11% | 10% | 24% |
| | | <50 MVA | 1% | 1% | 0.5% | 1% | 4% | 3% | 1% | 4% | 6% | 3% | 3% | 6% | 8% | 5% | 4% | 8% | 10% | 6% | 5% | 10% | 14% | 7% | 7% | 14% | 25% | 10% | 8% | 25% |
| | | 50-100 MVA | 1% | 2% | 1% | 2% | 4.4% | 3.3% | 1.3% | 4% | 7% | 5% | 3% | 7% | 11% | 6% | 5% | 11% | 14% | 8% | 7% | 14% | 19% | 10% | 10% | 19% | 24% | 11% | 10% | 24% |
| | | >100 MVA | 0.4% | 1% | 0.3% | 1% | 3% | 2% | 1% | 3% | 5% | 3% | 2% | 5% | 8% | 4% | 3% | 8% | 10% | 5% | 4% | 10% | 14% | 7% | 6% | 14% | 22% | 8% | 7% | 22% |
| Percentage of LV Networks with Voltage Rise Issues | | All ZSS | 1% | 0.5% | 0.4% | 1% | 6% | 3% | 2% | 6% | 9% | 4% | 5% | 9% | 10% | 4% | 5% | 10% | 9% | 5% | 7% | 9% | 11% | 5% | 7% | 11% | 15% | 4% | 5% | 15% |
| | | <50 MVA | 0.4% | 0.4% | 0.2% | 0.4% | 3% | 2% | 1% | 3% | 5% | 2% | 3% | 5% | 5% | 3% | 3% | 5% | 5% | 3% | 4% | 5% | 6% | 3% | 4% | 6% | 13% | 3% | 3% | 13% |
| | | 50-100 MVA | 1% | 0.5% | 0.5% | 1% | 7% | 4% | 2% | 7% | 11% | 5% | 6% | 11% | 12% | 5% | 6% | 12% | 11% | 7% | 8% | 11% | 13% | 6% | 8% | 13% | 15% | 5% | 7% | 15% |
| | | >100 MVA | 1% | 0.2% | 1% | 1% | 7% | 3% | 2% | 7% | 11% | 5% | 6% | 11% | 11% | 4% | 5% | 11% | 10% | 6% | 7% | 10% | 12% | 5% | 7% | 12% | 16% | 4% | 6% | 16% |
| Percentage of LV Networks with Voltage Drop Issues | | All ZSS | 4% | 7% | 3% | 7% | 11% | 11% | 7% | 11% | 13% | 13% | 10% | 13% | 15% | 15% | 12% | 15% | 18% | 17% | 13% | 18% | 22% | 18% | 14% | 22% | 30% | 20% | 16% | 30% |
| | | <50 MVA | 2% | 4% | 2% | 4% | 6% | 6% | 4% | 6% | 8% | 7% | 6% | 8% | 10% | 9% | 7% | 10% | 12% | 11% | 7% | 12% | 16% | 11% | 8% | 16% | 26% | 13% | 9% | 26% |
| | | 50-100 MVA | 4% | 8% | 4% | 8% | 14% | 13% | 8% | 14% | 17% | 16% | 13% | 17% | 19% | 19% | 15% | 19% | 22% | 21% | 16% | 22% | 26% | 22% | 17% | 26% | 33% | 23% | 19% | 33% |
| | | >100 MVA | 4% | 8% | 4% | 8% | 13% | 13% | 8% | 13% | 16% | 15% | 12% | 16% | 17% | 17% | 14% | 17% | 21% | 19% | 15% | 21% | 23% | 19% | 16% | 23% | 33% | 21% | 17% | 33% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | All ZSS | 1% | 0.5% | 0% | 1% | 6% | 3% | 1% | 6% | 9% | 4% | 5% | 9% | 9% | 4% | 4% | 9% | 9% | 5% | 6% | 9% | 10% | 5% | 7% | 10% | 13% | 4% | 5% | 13% |
| | | <50 MVA | 0.4% | 0.4% | 0% | 0.4% | 3% | 1% | 1% | 3% | 5% | 2% | 3% | 5% | 5% | 3% | 2% | 5% | 5% | 3% | 3% | 5% | 6% | 3% | 4% | 6% | 11% | 3% | 3% | 11% |
| | | 50-100 MVA | 1% | 0.5% | 0% | 1% | 7% | 3% | 1% | 7% | 11% | 5% | 6% | 11% | 12% | 5% | 5% | 12% | 11% | 7% | 7% | 11% | 12% | 6% | 8% | 12% | 14% | 5% | 7% | 14% |
| | | >100 MVA | 1% | 0.2% | 0% | 1% | 7% | 3% | 1% | 7% | 11% | 5% | 5% | 11% | 11% | 4% | 5% | 11% | 10% | 6% | 6% | 10% | 11% | 5% | 7% | 11% | 15% | 4% | 6% | 15% |
| **Thermal Assessment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | <= 100% | All ZSS | 99% | 99% | 99% | 99% | 96% | 97% | 98% | 96% | 90% | 94% | 97% | 90% | 80% | 85% | 95% | 80% | 77% | 80% | 91% | 77% | 72% | 77% | 84% | 72% | 69% | 75% | 82% | 69% |
| | | <50 MVA | 99% | 98% | 99% | 98% | 95% | 96% | 97% | 95% | 91% | 94% | 95% | 91% | 84% | 89% | 93% | 84% | 80% | 84% | 89% | 80% | 76% | 82% | 85% | 76% | 73% | 80% | 83% | 73% |
| | | 50-100 MVA | 99% | 99% | 100% | 99% | 96% | 98% | 99% | 96% | 90% | 94% | 98% | 90% | 79% | 83% | 96% | 79% | 75% | 77% | 92% | 75% | 71% | 75% | 84% | 71% | 67% | 73% | 82% | 67% |
| | | >100 MVA | 99% | 99% | 99% | 99% | 95% | 97% | 98% | 95% | 84% | 92% | 97% | 84% | 70% | 77% | 94% | 70% | 65% | 69% | 88% | 65% | 60% | 67% | 78% | 60% | 57% | 64% | 74% | 57% |
| | 100%-110% | All ZSS | 0.3% | 1% | 0.3% | 1% | 2% | 1% | 1% | 2% | 2% | 2% | 1% | 2% | 4% | 3% | 2% | 4% | 3% | 4% | 3% | 3% | 4% | 4% | 6% | 4% | 4% | 4% | 6% | 4% |
| | | <50 MVA | 0.4% | 1% | 1% | 1% | 1% | 2% | 1% | 1% | 2% | 2% | 1% | 2% | 3% | 3% | 2% | 3% | 2% | 4% | 3% | 2% | 4% | 4% | 5% | 4% | 4% | 5% | 5% | 4% |
| | | 50-100 MVA | 0.1% | 0.3% | 0.2% | 0.3% | 2% | 1% | 0.4% | 2% | 2% | 2% | 1% | 2% | 5% | 3% | 2% | 5% | 3% | 4% | 3% | 3% | 4% | 3% | 7% | 4% | 4% | 4% | 7% | 4% |
| | | >100 MVA | 0.3% | 1% | 0.4% | 1% | 2% | 2% | 1% | 2% | 4% | 3% | 1% | 4% | 6% | 5% | 3% | 6% | 4% | 6% | 4% | 4% | 4% | 4% | 10% | 4% | 4% | 4% | 9% | 4% |
| | 110%-150% | All ZSS | 1% | 1% | 0.3% | 1% | 2% | 1% | 1% | 2% | 6% | 3% | 1% | 6% | 12% | 11% | 3% | 12% | 12% | 13% | 5% | 12% | 10% | 12% | 8% | 10% | 10% | 11% | 10% | 10% |
| | | <50 MVA | 1% | 1% | 1% | 1% | 3% | 1% | 1% | 3% | 5% | 3% | 2% | 5% | 8% | 7% | 4% | 8% | 9% | 9% | 5% | 9% | 9% | 9% | 7% | 9% | 10% | 9% | 8% | 10% |
| | | 50-100 MVA | 1% | 0.4% | 0.2% | 0.4% | 1% | 1% | 0.5% | 1% | 7% | 3% | 1% | 7% | 13% | 12% | 2% | 13% | 13% | 14% | 4% | 13% | 10% | 13% | 8% | 10% | 10% | 11% | 10% | 10% |
| | | >100 MVA | 1% | 0.5% | 0.4% | 0.5% | 2% | 1% | 1% | 2% | 10% | 4% | 2% | 10% | 20% | 16% | 3% | 20% | 18% | 20% | 6% | 18% | 13% | 17% | 10% | 13% | 13% | 15% | 14% | 13% |
| | > 150% | All ZSS | 0.03% | 0.0% | 0.03% | 0% | 1% | 0.3% | 0.2% | 1% | 2% | 0% | 1% | 2% | 4% | 1% | 1% | 4% | 9% | 3% | 1% | 9% | 14% | 8% | 2% | 14% | 17% | 10% | 3% | 17% |
| | | <50 MVA | 0.1% | 0% | 0.1% | 0% | 1% | 0.4% | 0.3% | 1% | 3% | 1% | 1% | 3% | 5% | 1% | 1% | 5% | 8% | 3% | 2% | 8% | 11% | 5% | 3% | 11% | 13% | 6% | 4% | 13% |
| | | 50-100 MVA | 0.02% | 0.0% | 0.02% | 0% | 0.4% | 0.3% | 0.1% | 0.4% | 1% | 0% | 0.3% | 1% | 3% | 1% | 0% | 3% | 9% | 4% | 1% | 9% | 15% | 9% | 1% | 15% | 18% | 12% | 2% | 18% |
| | | >100 MVA | 0.04% | 0.0% | 0.04% | 0% | 1% | 0.2% | 0.2% | 1% | 2% | 0% | 1% | 2% | 5% | 1% | 1% | 5% | 14% | 5% | 2% | 14% | 22% | 13% | 2% | 22% | 26% | 17% | 3% | 26% |
| **PV Curtailment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 1% | 100% | 85% | 100% | 72% | 100% | 73% | 100% | 62% | 100% | 64% | 100% | 67% | 100% | 70% | 100% | 77% | 100% | 77% | 100% | 82% | 100% | 82% | 100% | 84% | 100% | 85% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 1 | 0 | 141 | 0.05 | 1 | 1 | 235 | 0.5 | 2 | 1 | 437 | 1.4 | 3 | 2 | 864 | 2 | 4 | 3 | 1157 | 3 | 5 | 4 | 1511 | 3 | 5 | 5 | 1807 |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | 6% | 0.9% | 10% | 8% | 8% | 8% | 16% | 13% | 12% | 19% | 25% | 22% | 22% | 24% | 28% | 26% | 26% | 27% | 30% | 30% | 30% | 29% | 31% | 33% | 32% |
| **EV Management** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | - | - | - | - | - | - | 9% | 9% | 8% | 9% | 12% | 12% | 11% | 12% | 16% | 16% | 15% | 16% | 20% | 20% | 19% | 20% | 24% | 24% | 23% | 24% |
| Average EV Charging Delay (h) | | | - | - | - | - | - | - | - | - | 3.1 | 2.8 | 3.2 | 3.2 | 4.5 | 3.9 | 4.7 | 4.7 | 4.4 | 4.4 | 4.9 | 4.9 | 4.1 | 4.4 | 4.8 | 4.8 | 4.0 | 4.4 | 4.7 | 4.7 |

# Appendix 10: Full Whole-State Extrapolation Table (With DOEs) – United Energy

United Energy (47 ZSS out of 47) (with DOEs)

| Year | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long | Winter Peak | Summer Peak | Sping Shoulder | Year Long |
| **Overview** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Overall Residential Voltage Rise Non-Compliance | | 0.1% | 0.02% | 0.05% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 1% | 0% | 2% | 3% | 1% | 1% | 3% | 4% | 1% | 1% | 4% | 5% | 1% | 1% | 5% | 4% | 1% | 1% | 4% |
| Percentage of ZSS with Non-Compliant Voltage Rise for Residencial Customers | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 4% | 9% | 0% | 0% | 9% | 17% | 0% | 0% | 17% | 15% | 0% | 0% | 15% |
| | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 7% | 0% | 0% | 7% | 14% | 0% | 0% | 14% | 21% | 0% | 0% | 21% | 25% | 0% | 0% | 25% |
| | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 13% | 0% | 0% | 13% | 0% | 0% | 0% | 0% |
| Overall Residential Voltage Drop Non-Compliance | | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 2% | 7% | 11% | 5% | 3% | 11% | 15% | 7% | 6% | 15% | 20% | 9% | 9% | 20% | 24% | 10% | 10% | 24% |
| Percentage of ZSS with Non-Compliant Voltage Drop for Residential Customers | All ZSS | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 2% | 100% | 34% | 0% | 100% | 100% | 23% | 2% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 67% | 0% | 100% | 100% | 67% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | 50-100 MVA | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 4% | 100% | 32% | 0% | 100% | 100% | 25% | 4% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 31% | 0% | 100% | 100% | 13% | 0% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Total Overloaded MV Conductor Length (km) | All | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.1 | 120 | 28 | 0 | 120 | 167 | 148 | 0 | 167 | 272 | 172 | 0 | 272 | 466 | 256 | 33 | 466 |
| | <50 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 2 | 3 | 3 | 0 | 3 | 5 | 3 | 0 | 5 | 8 | 5 | 1 | 8 |
| | 50-100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0.1 | 83 | 17 | 0 | 83 | 116 | 97 | 0 | 116 | 186 | 117 | 0 | 186 | 318 | 170 | 23 | 318 |
| | >100 MVA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 10 | 0 | 34 | 48 | 48 | 0 | 48 | 81 | 52 | 0 | 81 | 141 | 81 | 10 | 141 |
| Percentage of ZSS with Distribution Transformer Utilisation > 150% | All ZSS | 15% | 0% | 15% | 15% | 19% | 19% | 15% | 19% | 19% | 19% | 15% | 19% | 100% | 100% | 15% | 100% | 100% | 100% | 15% | 100% | 100% | 100% | 15% | 100% | 100% | 100% | 19% | 100% |
| | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% |
| | 50-100 MVA | 25% | 0% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 25% | 100% | 100% | 25% | 100% | 100% | 100% | 25% | 100% | 100% | 100% | 25% | 100% | 100% | 100% | 25% | 100% |
| | >100 MVA | 0% | 0% | 0% | 0% | 13% | 13% | 0% | 13% | 13% | 13% | 0% | 13% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% | 100% | 100% | 13% | 100% |
| Percentage of ZSS with LV Circuits Utilisation > 150% | All ZSS | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 50-100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | >100 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Voltage Assessment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | All ZSS | 0.1% | 0.02% | 0.05% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 1% | 0% | 2% | 3% | 1% | 1% | 3% | 4% | 1% | 1% | 4% | 5% | 1% | 1% | 5% | 4% | 1% | 1% | 4% |
| | <50 MVA | 0.04% | 0% | 0.1% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 0% | 0% | 2% | 3% | 0% | 1% | 3% | 4% | 1% | 1% | 4% | 5% | 1% | 1% | 5% | 3% | 1% | 1% | 3% |
| | 50-100 MVA | 0.1% | 0.03% | 0.05% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 1% | 1% | 2% | 3.14% | 1% | 1% | 3.14% | 4% | 1% | 1% | 4% | 5% | 1% | 1% | 5% | 5% | 1% | 1% | 5% |
| | >100 MVA | 0.05% | 0.01% | 0.1% | 0.1% | 1% | 0% | 0.2% | 1% | 2% | 0% | 0% | 2% | 3% | 1% | 1% | 3% | 4% | 1% | 1% | 4% | 5% | 1% | 1.1% | 5% | 3% | 1% | 1% | 3% |
| Residential Voltage Drop Non-Compliance | All ZSS | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 2% | 7% | 11% | 5% | 3% | 11% | 15% | 7% | 6% | 15% | 20% | 9% | 9% | 20% | 24% | 10% | 10% | 24% |
| | <50 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 8% | 5% | 2% | 8% | 13% | 5% | 3% | 13% | 16% | 7% | 7% | 16% | 22% | 10% | 10% | 22% | 26% | 11% | 11% | 26% |
| | 50-100 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 2% | 7% | 11% | 5% | 3% | 11% | 14% | 7% | 6% | 14% | 19% | 9% | 9% | 19% | 24% | 10% | 10% | 24% |
| | >100 MVA | 1% | 1% | 0.3% | 1% | 3% | 3% | 1% | 3% | 7% | 5% | 2% | 7% | 12% | 5% | 3% | 12% | 15% | 7% | 6% | 15% | 20% | 9% | 9% | 20% | 24% | 10% | 10% | 24% |
| Percentage of LV Networks with Voltage Rise Issues | All ZSS | 1% | 0.2% | 1% | 1% | 11% | 5% | 3% | 11% | 17% | 8% | 9% | 17% | 17% | 6% | 8% | 17% | 16% | 9% | 11% | 16% | 18% | 8% | 12% | 18% | 20% | 6% | 9% | 20% |
| | <50 MVA | 1% | 0% | 1% | 1% | 14% | 7% | 5% | 14% | 23% | 11% | 12% | 23% | 24% | 7% | 11% | 24% | 22% | 12% | 14% | 22% | 25% | 11% | 16% | 25% | 24% | 8% | 12% | 24% |
| | 50-100 MVA | 1% | 0.2% | 1% | 1% | 10% | 5% | 3% | 10% | 15% | 7% | 8% | 15% | 16% | 5% | 7% | 16% | 14% | 8% | 10% | 14% | 17% | 7% | 10% | 17% | 19% | 6% | 8% | 19% |
| | >100 MVA | 1% | 0.03% | 1% | 1% | 13% | 7% | 4% | 13% | 21% | 10% | 11% | 21% | 22% | 7% | 10% | 22% | 20% | 11% | 13% | 20% | 22% | 10% | 14% | 22% | 22% | 8% | 11% | 22% |
| Percentage of LV Networks with Voltage Drop Issues | All ZSS | 6% | 12% | 6% | 12% | 21% | 20% | 12% | 21% | 25% | 24% | 19% | 25% | 26% | 27% | 22% | 27% | 31% | 29% | 23% | 31% | 33% | 28% | 25% | 33% | 39% | 30% | 26% | 39% |
| | <50 MVA | 8% | 17% | 8% | 17% | 29% | 28% | 17% | 29% | 35% | 33% | 26% | 35% | 35% | 36% | 30% | 36% | 40% | 38% | 32% | 40% | 41% | 37% | 35% | 41% | 46% | 39% | 35% | 46% |
| | 50-100 MVA | 6% | 11% | 5% | 11% | 19% | 18% | 11% | 19% | 23% | 22% | 17% | 23% | 24% | 24% | 20% | 24% | 28% | 26% | 21% | 28% | 30% | 26% | 23% | 30% | 37% | 28% | 24% | 37% |
| | >100 MVA | 8% | 15% | 8% | 15% | 26% | 25% | 15% | 26% | 31% | 30% | 24% | 31% | 32% | 33% | 27% | 33% | 37% | 35% | 29% | 37% | 39% | 34% | 31% | 39% | 43% | 36% | 32% | 43% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | All ZSS | 1% | 0.2% | 0% | 1% | 10% | 5% | 2% | 10% | 17% | 8% | 8% | 17% | 17% | 6% | 7% | 17% | 16% | 9% | 9% | 16% | 18% | 8% | 12% | 18% | 19% | 6% | 9% | 19% |
| | <50 MVA | 1% | 0% | 0% | 1% | 14% | 7% | 2% | 14% | 23% | 11% | 11% | 23% | 24% | 7% | 10% | 24% | 22% | 12% | 12% | 22% | 24% | 11% | 16% | 24% | 24% | 8% | 12% | 24% |
| | 50-100 MVA | 1% | 0.2% | 0% | 1% | 9% | 5% | 2% | 9% | 15% | 7% | 7% | 15% | 16% | 5% | 6% | 16% | 14% | 8% | 8% | 14% | 16% | 7% | 10% | 16% | 18% | 6% | 8% | 18% |
| | >100 MVA | 1% | 0.03% | 0% | 1% | 13% | 7% | 2% | 13% | 21% | 10% | 10% | 21% | 22% | 7% | 9% | 22% | 20% | 11% | 11% | 20% | 22% | 10% | 14% | 22% | 22% | 8% | 11% | 22% |
| **Thermal Assessment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation: <= 100% | All ZSS | 100% | 100% | 100% | 100% | 96% | 98% | 99% | 96% | 83% | 92% | 99% | 83% | 64% | 72% | 95% | 64% | 59% | 63% | 89% | 59% | 55% | 60% | 76% | 55% | 51% | 58% | 72% | 51% |
| | <50 MVA | 100% | 100% | 100% | 100% | 96% | 99% | 100% | 96% | 79% | 91% | 100% | 79% | 55% | 65% | 96% | 55% | 49% | 53% | 89% | 49% | 46% | 50% | 72% | 46% | 41% | 47% | 68% | 41% |
| | 50-100 MVA | 99% | 99% | 100% | 99% | 96% | 98% | 99% | 96% | 84% | 92% | 98% | 84% | 67% | 75% | 95% | 67% | 63% | 66% | 90% | 63% | 59% | 64% | 78% | 59% | 55% | 61% | 74% | 55% |
| | >100 MVA | 100% | 100% | 100% | 100% | 96% | 99% | 100% | 96% | 79% | 91% | 100% | 79% | 55% | 65% | 97% | 55% | 50% | 54% | 89% | 50% | 46% | 51% | 73% | 46% | 42% | 48% | 68% | 42% |
| 100%-110% | All ZSS | 0.1% | 0.3% | 0.1% | 0.3% | 3% | 1% | 0.3% | 3% | 4% | 4% | 0.4% | 4% | 8% | 6% | 3% | 8% | 4% | 6% | 5% | 4% | 4% | 3% | 12% | 4% | 4% | 3% | 11% | 4% |
| | <50 MVA | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 5% | 5% | 0% | 5% | 10% | 7% | 3% | 10% | 5% | 7% | 5% | 5% | 5% | 3% | 15% | 5% | 5% | 3% | 13% | 5% |
| | 50-100 MVA | 0.2% | 0.4% | 0.2% | 0.4% | 3% | 1% | 0.4% | 3% | 4% | 4% | 1% | 4% | 7% | 5% | 2% | 7% | 4% | 6% | 4% | 4% | 4% | 3% | 11% | 4% | 4% | 4% | 10% | 4.5% |
| | >100 MVA | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 6% | 5% | 0.01% | 6% | 9% | 7% | 3% | 9% | 5% | 7% | 5% | 5% | 4.6% | 3% | 14.9% | 5% | 4% | 3% | 13% | 4% |
| 110%-150% | All ZSS | 0.3% | 0.2% | 0.2% | 0.2% | 1% | 0% | 0.4% | 1% | 12% | 4% | 1% | 12% | 24% | 21% | 2% | 24% | 22% | 25% | 5% | 22% | 14% | 21% | 11% | 14% | 13% | 17% | 16% | 13% |
| | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 16% | 4% | 0% | 16% | 31% | 27% | 1% | 31% | 28% | 31% | 5% | 28% | 17% | 26% | 13% | 17% | 15% | 21% | 19% | 15% |
| | 50-100 MVA | 0.4% | 0.3% | 0.2% | 0.3% | 1% | 1% | 0% | 1% | 11% | 4% | 1% | 11% | 21% | 19% | 2% | 21% | 20% | 22% | 5% | 20% | 14% | 19% | 10% | 14% | 13% | 16% | 15% | 13% |
| | >100 MVA | 0.01% | 0.01% | 0% | 0.01% | 0% | 0% | 0% | 0% | 15% | 4% | 0.00% | 15% | 31% | 27% | 1% | 31% | 27% | 31% | 5% | 27% | 17% | 26% | 13% | 17% | 15% | 21% | 19% | 15% |
| > 150% | All ZSS | 0.01% | 0% | 0.01% | 0% | 0.2% | 0.1% | 0.1% | 0.2% | 1% | 0.2% | 0.2% | 1% | 4% | 1% | 0% | 4% | 15% | 7% | 1% | 15% | 26% | 16% | 1% | 26% | 31% | 22% | 1% | 31% |
| | <50 MVA | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 1% | 0% | 4% | 19% | 8% | 0% | 19% | 33% | 21% | 0% | 33% | 39% | 29% | 0% | 39% |
| | 50-100 MVA | 0.02% | 0.0% | 0.02% | 0% | 0.3% | 0.2% | 0.1% | 0.3% | 1% | 0.3% | 0.3% | 1% | 4% | 1% | 1% | 4% | 14% | 6% | 1% | 14% | 24% | 14% | 1% | 24% | 28% | 19% | 2% | 28% |
| | >100 MVA | 0% | 0% | 0% | 0% | 0.01% | 0.01% | 0% | 0.01% | 0.03% | 0.01% | 0% | 0.03% | 4% | 1% | 0.00% | 4% | 18% | 8% | 0.00% | 18% | 32% | 21% | 0% | 32% | 39% | 28% | 0% | 39% |
| **PV Curtailment** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | 0.3% | 100% | 85% | 100% | 73% | 100% | 74% | 100% | 62% | 100% | 68% | 100% | 72% | 100% | 82% | 100% | 82% | 100% | 87% | 100% | 87% | 100% | 91% | 100% | 89% | 100% | 94% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | 0 | 1 | 0 | 162 | 0.07 | 1 | 1 | 278 | 0.6 | 2 | 1 | 529 | 2 | 4 | 3 | 1027 | 2 | 5 | 4 | 1419 | 3 | 6 | 5 | 1915 | 4 | 7 | 6 | 2279 |
| | Percentage of PV Curtailment | 0% | 7% | 7% | 6% | 1.1% | 10% | 8% | 8% | 8% | 17% | 13% | 13% | 18% | 27% | 23% | 23% | 25% | 31% | 28% | 28% | 28% | 33% | 33% | 33% | 30% | 34% | 36% | 35% |
| **EV Management** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | - | - | - | - | - | - | - | - | 9% | 9% | 8% | 9% | 13% | 13% | 12% | 13% | 16% | 16% | 15% | 16% | 21% | 20% | 20% | 21% | 24% | 24% | 23% | 24% |
| Average EV Charging Delay (h) | | - | - | - | - | - | - | - | - | 3.7 | 2.9 | 3.4 | 3.7 | 5.0 | 4.4 | 5.2 | 5.2 | 4.7 | 4.7 | 5.5 | 5.5 | 4.5 | 4.8 | 5.5 | 5.5 | 4.4 | 4.8 | 5.4 | 5.4 |

# Appendix 11: Full Impact Assessment Table (Without DOE) – CBTS

| Subtransmission Network – CBTS (Without DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 483 | 465 | 433 | **483** | 543 | 521 | 444 | **543** | 625 | 608 | 494 | **625** | 732 | 703 | 554 | **732** | 861 | 818 | 626 | **861** | 1027 | 956 | 701 | **1027** | 1145 | 1070 | 753 | **1145** |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | - | - | **-** | 12% | 12% | 2% | **12%** | 15% | 17% | 11% | **15%** | 17% | 16% | 12% | **17%** | 18% | 16% | 13% | **18%** | 19% | 17% | 12% | **19%** | 11% | 12% | 7% | **11%** |
| Power Factor at Terminal Station for Max. Demand | | | 0.98 | 0.99 | 0.99 | **0.98** | 0.98 | 0.98 | 0.99 | **0.98** | 0.97 | 0.96 | 0.99 | **0.96** | 0.94 | 0.95 | 0.98 | **0.94** | 0.91 | 0.92 | 0.97 | **0.91** | 0.85 | 0.88 | 0.95 | **0.85** | 0.8 | 0.84 | 0.94 | **0.8** |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 37% | 32% | 0% | **37%** | 42% | 42% | 0% | **42%** | 63% | 47% | 5% | **63%** |
| Maximum Voltage (pu) | | | 1.06 | 1.06 | 1.06 | **1.06** | 1.05 | 1.06 | 1.06 | **1.06** | 1.06 | 1.05 | 1.04 | **1.06** | 1.05 | 1.06 | 1.06 | **1.06** | 1.03 | 1.06 | 1.06 | **1.06** | 1.02 | 1.06 | 1.03 | **1.06** | 1.02 | 1.06 | 1.03 | **1.06** |
| Minimum Voltage (pu) | | | 0.97 | 0.98 | 0.98 | **0.97** | 0.96 | 0.96 | 0.98 | **0.96** | 0.94 | 0.93 | 0.97 | **0.93** | 0.90 | 0.91 | 0.96 | **0.90** | 0.84 | 0.86 | 0.94 | **0.84** | 0.75 | 0.79 | 0.91 | **0.75** | 0.67 | 0.72 | 0.89 | **0.67** |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers | Percentage of Transformers with Maximum Utilisation | <= 100% | 83% | 92% | 100% | **83%** | 75% | 75% | 100% | **75%** | 8% | 42% | 83% | **8%** | 8% | 8% | 50% | **8%** | 8% | 8% | 33% | **8%** | 8% | 8% | 8% | **8%** | 8% | 8% | 8% | **8%** |
| | | 100%-110% | 17% | 8% | 0% | **17%** | 8% | 17% | 0% | **8%** | 50% | 25% | 17% | **50%** | 0% | 0% | 17% | **0%** | 0% | 0% | 8% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 1.5 | 0.5 | 0 | **1.5** | 5 | 1.5 | 0 | **5** | 2.2 | 1.8 | 0.5 | **2.2** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0 | **0** | 0 | 0.0 | 0 | **0** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 17% | 8% | 0% | **17%** | 42% | 33% | 0% | **42%** | 58% | 83% | 33% | **58%** | 42% | 58% | 58% | **42%** | 0% | 33% | 83% | **0%** | 0% | 0% | 58% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 2.5 | 1 | 0 | **2.5** | 5.5 | 3 | 0 | **5.5** | 5.9 | 3.3 | 0.8 | **5.9** | 9.7 | 4.1 | 3.6 | **9.7** | 0 | 4.8 | 4.6 | **0** | 0 | 0 | 3.4 | **0** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 33% | 8% | 0% | **33%** | 50% | 33% | 0% | **50%** | 92% | 58% | 8% | **92%** | 92% | 92% | 33% | **92%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 2.6 | 1 | 0 | **2.6** | 6.2 | 2.9 | 0 | **6.2** | 8.4 | 3.8 | 0.5 | **8.4** | 10.7 | 4.1 | 0.5 | **10.7** |
| | Max. Utilisation of the Worst Performing Transformer | | 106% | 100% | 90% | **106%** | 119% | 113% | 93% | **119%** | 138% | 132% | 103% | **138%** | 158% | 152% | 120% | **158%** | 195% | 184% | 136% | **195%** | 219% | 218% | 160% | **219%** | 228% | 215% | 176% | **228%** |
| HV Lines | Percentage of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 85% | 85% | 100% | **85%** | 77% | 77% | 92% | **77%** | 38% | 54% | 85% | **38%** | 38% | 38% | 77% | **38%** | 38% | 38% | 69% | **38%** |
| | | 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 8% | 0% | **0%** | 0% | 8% | 8% | **0%** | 15% | 15% | 0% | **15%** | 0% | 0% | 8% | **0%** | 0% | 0% | 8% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 2 | 0 | **0** | 0 | 2 | 0.5 | **0** | 1.8 | 2 | 0 | **1.8** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0.5 | **0** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 15% | 8% | 0% | **15%** | 23% | 15% | 0% | **23%** | 31% | 15% | 15% | **31%** | 31% | 38% | 15% | **31%** | 0% | 15% | 8% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 3.3 | 1.5 | 0 | **3.3** | 7.2 | 3.5 | 0 | **7.2** | 4.9 | 2 | 0.5 | **4.9** | 6.6 | 2.6 | 3.3 | **6.6** | 0 | 3 | 0.5 | **0** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 15% | 15% | 0% | **15%** | 31% | 23% | 0% | **31%** | 62% | 46% | 15% | **62%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 7 | 2.8 | 0 | **7** | 9.8 | 3.5 | 0 | **9.8** | 8.6 | 2.8 | 0.5 | **8.6** |
| | Max. Utilisation of the Worst Performing Line | | 82% | 78% | 70% | **82%** | 98% | 92% | 74% | **98%** | 119% | 115% | 86% | **119%** | 148% | 140% | 101% | **148%** | 187% | 174% | 119% | **187%** | 245% | 223% | 141% | **245%** | 280% | 255% | 157% | **280%** |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0% | 0% | 0% | **0%** | 2% | 2% | 0% | **2%** | 6% | 3% | 2% | **6%** | 9% | 5.2% | 5.3% | **9%** | 12% | 7% | 8% | **12%** | 14% | 9% | 10% | **14%** | 18% | 10% | 13% | **18%** |
| Residential Voltage Drop Non-Compliance | | | 1% | 2% | 1% | **2%** | 5.3% | 4% | 2% | **5.3%** | 10% | 7% | 5.2% | **10%** | 14% | 10% | 9% | **14%** | 18% | 15% | 13% | **18%** | 23% | 19% | 17% | **23%** | 27% | 21% | 19% | **27%** |
| Percentage of LV Networks with Voltage Rise Issues | | | 0.8% | 0.5% | 0.6% | **1%** | 9% | 8% | 3% | **9%** | 15% | 9% | 11% | **15%** | 18% | 14% | 11% | **18%** | 19% | 15% | 14% | **19%** | 21% | 17% | 15% | **21%** | 22% | 19% | 18% | **22%** |
| Percentage of LV Networks with Voltage Drop Issues | | | 5% | 9% | 5% | **9%** | 16% | 17% | 10% | **17%** | 19% | 20% | 15% | **20%** | 23% | 23% | 19% | **23%** | 27% | 28% | 21% | **28%** | 33% | 33% | 25% | **33%** | 39% | 34% | 28% | **39%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | | 0.8% | 0.5% | 0% | **1%** | 9% | 8% | 2% | **9%** | 15% | 9% | 10% | **15%** | 18% | 14% | 11% | **18%** | 19% | 15% | 14% | **19%** | 21% | 17% | 15% | **21%** | 22% | 19% | 16% | **22%** |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | | <= 100% | 100% | 100% | 100% | **100%** | 97% | 98% | 100% | **97%** | 86% | 91% | 99% | **86%** | 75% | 78% | 95% | **75%** | 70% | 72% | 86% | **70%** | 64% | 66% | 77% | **64%** | 62% | 65% | 72% | **62%** |
| | | 100%-110% | 0.04% | 0.1% | 0.1% | **0.1%** | 2% | 1% | 0.1% | **2%** | 5% | 4% | 0.4% | **5%** | 4% | 5% | 3% | **4%** | 3% | 4% | 5% | **3%** | 3% | 5% | 4% | **3%** | 2% | 3% | 4% | **2%** |
| | | 110%-150% | 0.3% | 0.3% | 0.1% | **0.3%** | 0.5% | 1% | 0.1% | **0.5%** | 8% | 5% | 0.6% | **8%** | 16% | 15% | 2% | **16%** | 14% | 15% | 9% | **14%** | 10% | 11% | 16% | **10%** | 10% | 10% | 19% | **10%** |
| | | > 150% | 0.01% | 0% | 0.01% | **0%** | 0.3% | 0.3% | 0.04% | **0.3%** | 0.8% | 0.3% | 0.1% | **0.8%** | 5% | 2% | 0.4% | **5%** | 14% | 9% | 0.6% | **14%** | 23% | 17% | 3% | **23%** | 26% | 22% | 5% | **26%** |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 1% | 100% | 85% | **100%** | 86% | 100% | 86% | **100%** | 85% | 100% | 85% | **100%** | 85% | 100% | 85% | **100%** | 84% | 100% | 100% | **100%** | 83% | 100% | 100% | **100%** | 82% | 100% | 100% | **100%** |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.1 | 0.04 | **15** | 0 | 0.1 | 0.1 | **29** | 0.01 | 0.2 | 0.1 | **45** | 0.04 | 0.4 | 0.2 | **70** | 0.1 | 0.3 | 0.2 | **86** | 0.1 | 0.4 | 0.3 | **114** | 0.1 | 0.5 | 0.4 | **142** |
| | Percentage of PV Curtailment | | 0.01% | 7% | 7% | **6%** | 0.4% | 10% | 10% | **9%** | 2% | 14% | 13% | **12%** | 5% | 17% | 16% | **15%** | 7% | 20% | 19% | **18%** | 10% | 23% | 22% | **21%** | 13% | 25% | 24% | **24%** |

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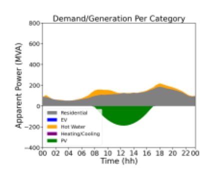
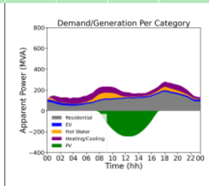
# Appendix 12: Full Impact Assessment Table (Without DOE) – ERTS

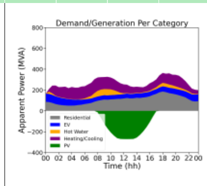
**Subtransmission Network – ERTS (Without DOEs)**

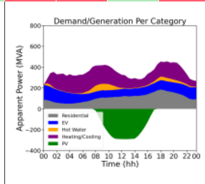
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | | | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 504 | 475 | 424 | 504 | 653 | 609 | 461 | 653 | 906 | 837 | 602 | 906 | 1254 | 1106 | 785 | 1254 | 1631 | 1434 | 993 | 1631 | 2049 | 1854 | 1226 | 2049 | 2350 | 2116 | 1375 | 2350 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | - | - | - | 30% | 28% | 9% | 30% | 39% | 37% | 31% | 39% | 38% | 32% | 30% | 38% | 30% | 30% | 27% | 30% | 26% | 29% | 23% | 26% | 15% | 14% | 12% | 15% |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 1.00 | 1.00 | 1.00 | 0.97 | 0.98 | 1.00 | 0.97 | 0.91 | 0.94 | 0.98 | 0.91 | 0.83 | 0.90 | 0.94 | 0.83 | 0.77 | 0.83 | 0.90 | 0.77 | 0.69 | 0.75 | 0.85 | 0.69 | 0.64 | 0.69 | 0.83 | 0.64 |

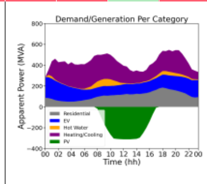
**Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day**

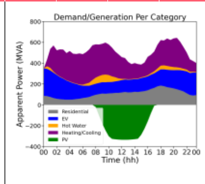
2023: 

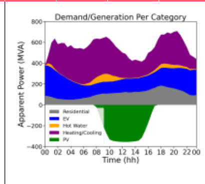

2028: 


2033: 


2038: 

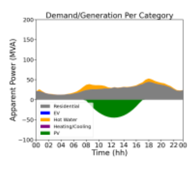
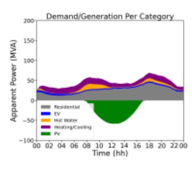
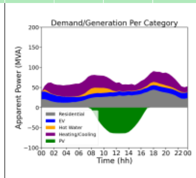
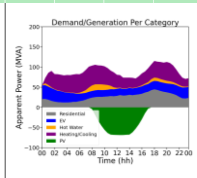
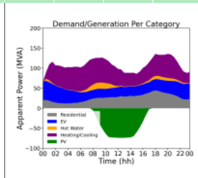
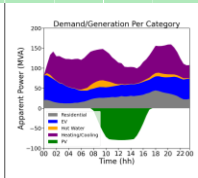
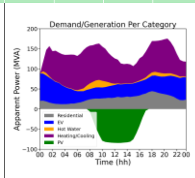

2043: 


2048: 

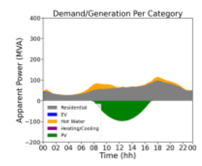
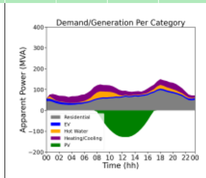
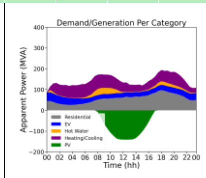
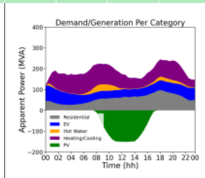
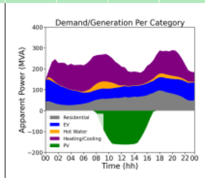
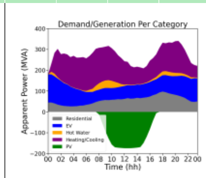
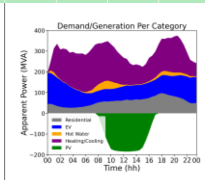

2053: 


| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Percentage of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 26% | 9% | 0% | 26% | 43% | 26% | 0% | 43% |
| Maximum Voltage (pu) | | | 1.06 | 1.06 | 1.06 | 1.06 | 1.08 | 1.08 | 1.06 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 |
| Minimum Voltage (pu) | | | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.97 | 0.97 | 0.98 | 0.97 | 0.94 | 0.94 | 0.98 | 0.94 | 0.75 | 0.81 | 0.97 | 0.75 | 0.71 | 0.75 | 0.97 | 0.71 |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers | Percentage of Transformers with Maximum Utilisation | <= 100% | 88% | 94% | 100% | 88% | 88% | 88% | 100% | 88% | 65% | 71% | 88% | 65% | 47% | 53% | 76% | 47% | 47% | 47% | 65% | 47% | 47% | 47% | 47% | 47% | 47% | 47% | 47% | 47% |
| | | 100%-110% | 12% | 6% | 0% | 12% | 0% | 0% | 0% | 0% | 12% | 6% | 0% | 12% | 6% | 12% | 6% | 6% | 0% | 0% | 6% | 0% | 0% | 0% | 6% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) 3 | 3 | 0.5 | 0 | 3 | 0 | 0 | 0 | 0 | 3.3 | 0.5 | 0.0 | 3.3 | 4 | 2 | 0.5 | 4 | 0 | 0 | 4.5 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 12% | 12% | 0% | 12% | 12% | 12% | 12% | 12% | 24% | 18% | 6% | 24% | 29% | 29% | 18% | 29% | 0% | 6% | 24% | 0% | 0% | 0% | 29% | 0% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 5.5 | 2.5 | 0 | 5.5 | 5 | 2.3 | 1.5 | 5 | 6.6 | 2.7 | 0.5 | 6.6 | 13.5 | 3.4 | 4 | 13.5 | 0 | 4 | 2.8 | 0 | 0 | 0 | 3.3 | 0 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 12% | 12% | 0% | 12% | 24% | 18% | 12% | 24% | 24% | 24% | 12% | 24% | 53% | 47% | 24% | 53% | 53% | 53% | 24% | 53% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.5 | 3 | 0 | 4.5 | 6 | 8.5 | 0.5 | 6 | 13.9 | 9.1 | 1 | 13.9 | 10.2 | 6.6 | 3.3 | 10.2 | 14.2 | 8.2 | 5.1 | 14.2 |
| | Max. Utilisation of the Worst Performing Transformer | | 110% | 100% | 83% | 110% | 150% | 124% | 93% | 150% | 187% | 182% | 145% | 187% | 282% | 262% | 191% | 282% | 302% | 302% | 206% | 302% | 307% | 304% | 283% | 307% | 318% | 295% | 309% | 318% |
| HV Lines | Percentage of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 94% | 100% | 100% | 94% | 75% | 81% | 100% | 75% | 75% | 75% | 88% | 75% | 62% | 75% | 81% | 62% | 44% | 56% | 75% | 44% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 6% | 0% | 0% | 6% | 6% | 0% | 0% | 6% | 0% | 0% | 6% | 0% | 12% | 0% | 0% | 12% | 12% | 19% | 6% | 12% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 4 | 2.5 | 0 | 0 | 2.5 | 0 | 0 | 0.5 | 0 | 1 | 0 | 0 | 1 | 0.5 | 1.2 | 0.5 | 0.5 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 19% | 19% | 0% | 19% | 12% | 12% | 6% | 12% | 0% | 6% | 19% | 0% | 19% | 0% | 19% | 19% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.8 | 2.2 | 0 | 5.8 | 6.8 | 3 | 0.5 | 6.8 | 0 | 3.5 | 0.5 | 0 | 1.2 | 0 | 4.2 | 1.2 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 12% | 12% | 0% | 12% | 25% | 19% | 0% | 25% | 25% | 25% | 0% | 25% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.3 | 1.3 | 0 | 4.3 | 9 | 3 | 0 | 9 | 12.1 | 3.4 | 0 | 12.1 |
| | Max. Utilisation of the Worst Performing Line | | 66% | 62% | 56% | 66% | 81% | 76% | 58% | 81% | 108% | 100% | 74% | 108% | 133% | 127% | 92% | 133% | 168% | 157% | 112% | 168% | 205% | 198% | 131% | 205% | 241% | 212% | 144% | 241% |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 1% | 3% | 1% | 1% | 3% | 5.3% | 2% | 2% | 5.3% | 9% | 4% | 5% | 9% | 12% | 5.1% | 6% | 12% | 14% | 6% | 8% | 14% |
| Residential Voltage Drop Non-Compliance | | | 1% | 1% | 0% | 1% | 3% | 3% | 1% | 3% | 9% | 7% | 3% | 9% | 14% | 9% | 7% | 14% | 19% | 13% | 11% | 19% | 23% | 18% | 15% | 23% | 26% | 19% | 18% | 26% |
| Percentage of LV Networks with Voltage Rise Issues | | | 1% | 0.3% | 0.8% | 1% | 12% | 10% | 4% | 12% | 20% | 12% | 14% | 20% | 24% | 17% | 14% | 24% | 26% | 20% | 19% | 26% | 28% | 22% | 20% | 28% | 28% | 25% | 23% | 28% |
| Percentage of LV Networks with Voltage Drop Issues | | | 6% | 12% | 6% | 12% | 21% | 22% | 13% | 22% | 26% | 26% | 20% | 26% | 30% | 29% | 25% | 30% | 33% | 34% | 27% | 34% | 41% | 40% | 30% | 41% | 45% | 40% | 34% | 45% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | | 1% | 0.3% | 0% | 1% | 12% | 10% | 3% | 12% | 20% | 12% | 13% | 20% | 24% | 17% | 14% | 24% | 25% | 20% | 19% | 25% | 28% | 22% | 20% | 28% | 28% | 25% | 22% | 28% |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | | <= 100% | 100% | 100% | 100% | 100% | 97% | 98% | 100% | 97% | 82% | 89% | 100% | 82% | 67% | 72% | 95% | 67% | 61% | 64% | 83% | 61% | 56% | 57% | 73% | 56% | 54% | 56% | 67% | 54% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 3% | 1% | 0% | 3% | 7% | 5% | 0.2% | 7% | 4% | 6% | 3% | 4% | 4% | 4% | 6% | 4% | 3% | 6% | 5% | 3% | 2% | 3% | 5% | 2% |
| | | 110%-150% | 0.2% | 0.2% | 0% | 0.2% | 0.2% | 1.0% | 0% | 0.2% | 11% | 6% | 0.2% | 11% | 22% | 19% | 1% | 22% | 17% | 19% | 10% | 17% | 11% | 13% | 20% | 11% | 11% | 12% | 24% | 11% |
| | | > 150% | 0% | 0% | 0% | 0% | 0.2% | 0.2% | 0% | 0.2% | 0.3% | 0.2% | 0% | 0.3% | 6% | 3% | 0.2% | 6% | 18% | 12% | 0.2% | 18% | 30% | 23% | 3% | 30% | 33% | 29% | 5% | 33% |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0.4% | 100% | 85% | 100% | 86% | 100% | 86% | 100% | 85% | 100% | 85% | 100% | 85% | 100% | 85% | 100% | 84% | 100% | 100% | 100% | 83% | 100% | 100% | 100% | 82% | 100% | 100% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.1 | 0.1 | 28 | 0 | 0.2 | 0.2 | 55 | 0.03 | 0.3 | 0.2 | 84 | 0.1 | 0.4 | 0.3 | 120 | 0.1 | 0.5 | 0.5 | 163 | 0.2 | 0.7 | 0.6 | 216 | 0.3 | 0.9 | 0.8 | 268 |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | 6% | 0.3% | 10% | 10% | 9% | 2% | 13% | 13% | 12% | 5% | 16% | 16% | 15% | 7% | 19% | 19% | 18% | 10% | 23% | 22% | 21% | 13% | 25% | 24% | 24% |

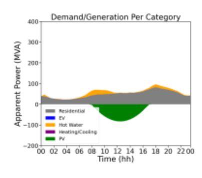
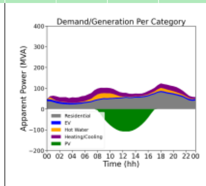
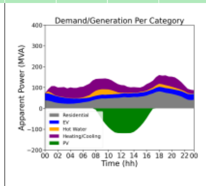
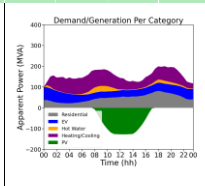
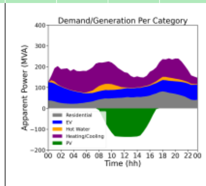
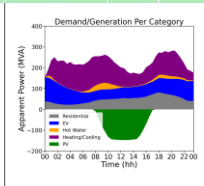
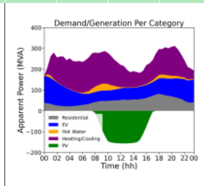
# Appendix 13: Full Impact Assessment Table (Without DOE) – GNTS-MBTS

| Subtransmission Network – GNTS + MBTS (Without DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Stations Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at GN Terminal Station (MVA) | 104 | 98 | 92 | **104** | 136 | 122 | 104 | **136** | 184 | 157 | 124 | **184** | 239 | 199 | 156 | **239** | 287 | 248 | 184 | **287** | 344 | 284 | 213 | **344** | 380 | 311 | 236 | **380** |
| Maximum Demand at MB Terminal Station (MVA) | 23 | 22 | 20 | **23** | 28 | 27 | 22 | **28** | 36 | 33 | 26 | **36** | 44 | 42 | 31 | **44** | 52 | 49 | 37 | **52** | 62 | 57 | 43 | **62** | 70 | 63 | 47 | **70** |
| Increase of Max. Demand at Terminal Stations (MVA) | - | - | - | **-** | 29% | 25% | 11% | **29%** | 34% | 28% | 20% | **34%** | 29% | 26% | 25% | **29%** | 20% | 24% | 18% | **20%** | 20% | 15% | 16% | **20%** | 11% | 10% | 10% | **11%** |
| Power Factor at GN Terminal Station for Max. Demand | 0.97 | 0.97 | 0.97 | **0.97** | 0.93 | 0.95 | 0.96 | **0.93** | 0.91 | 0.94 | 0.94 | **0.91** | 0.87 | 0.91 | 0.90 | **0.87** | 0.85 | 0.87 | 0.89 | **0.85** | 0.82 | 0.86 | 0.89 | **0.82** | 0.80 | 0.84 | 0.88 | **0.80** |
| Power Factor at MB Terminal Station for Max. Demand | 1.00 | 1.00 | 1.00 | **1.00** | 1.00 | 1.00 | 1.00 | **1.00** | 0.98 | 0.99 | 1.00 | **0.98** | 0.97 | 0.98 | 1.00 | **0.97** | 0.97 | 0.97 | 0.99 | **0.97** | 0.95 | 0.96 | 0.98 | **0.95** | 0.94 | 0.95 | 0.98 | **0.94** |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of Buses with Voltage Drop Issues | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 7% | 0% | 0% | **7%** | 13% | 7% | 0% | **13%** | 13% | 13% | 7% | **13%** | 20% | 13% | 13% | **20%** | 20% | 20% | 13% | **20%** |
| Maximum Voltage (pu) | 1.07 | 1.07 | 1.07 | **1.07** | 1.07 | 1.07 | 1.07 | **1.07** | 1.07 | 1.07 | 1.07 | **1.07** | 1.06 | 1.07 | 1.07 | **1.07** | 1.07 | 1.07 | 1.07 | **1.07** | 1.07 | 1.07 | 1.07 | **1.07** | 1.07 | 1.07 | 1.07 | **1.07** |
| Minimum Voltage (pu) | 0.99 | 0.99 | 0.99 | **0.99** | 0.95 | 0.97 | 0.99 | **0.95** | 0.86 | 0.91 | 0.95 | **0.86** | 0.76 | 0.84 | 0.90 | **0.76** | 0.71 | 0.76 | 0.85 | **0.71** | 0.66 | 0.72 | 0.80 | **0.66** | 0.63 | 0.70 | 0.77 | **0.63** |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – <= 100% | 95% | 95% | 95% | **95%** | 91% | 95% | 95% | **91%** | 64% | 82% | 95% | **64%** | 50% | 55% | 86% | **50%** | 45% | 50% | 59% | **45%** | 45% | 45% | 50% | **45%** | 45% | 45% | 50% | **45%** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | **0%** | 5% | 0% | 0% | **5%** | 18% | 9% | 0% | **18%** | 0% | 9% | 9% | **0%** | 9% | 0% | 14% | **9%** | 0% | 5% | 9% | **0%** | 0% | 5% | 0% | **0%** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0.5 | 0 | 0 | **0.5** | 0.9 | 0 | 0 | **0.9** | 0 | 0.2 | 0.5 | **0** | 0.5 | 0 | 0.3 | **0.5** | 0 | 0.5 | 0.1 | **0** | 0 | 0.1 | 0 | **0** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – 110%-150% | 5% | 5% | 5% | **5%** | 0% | 5% | 5% | **0%** | 14% | 9% | 5% | **14%** | 41% | 36% | 0% | **41%** | 18% | 41% | 23% | **18%** | 18% | 23% | 36% | **18%** | 18% | 14% | 45% | **18%** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – Avg. Overloading Duration (hr) 3 | 1.1 | 1.1 | 1.1 | **1.1** | 0 | 1.1 | 1.1 | **0** | 0.7 | 1 | 0.4 | **0.7** | 4.2 | 1.8 | 0 | **4.2** | 3 | 1.5 | 0.4 | **3** | 3.1 | 1.4 | 2.4 | **3.1** | 3.4 | 1.3 | 3.2 | **3.4** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – > 150% | 0% | 0% | 0% | **0%** | 5% | 0% | 0% | **5%** | 5% | 0% | 0% | **5%** | 9% | 0% | 5% | **9%** | 27% | 9% | 5% | **27%** | 36% | 27% | 5% | **36%** | 36% | 36% | 5% | **36%** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0.3 | 0 | 0 | **0.3** | 0.9 | 0 | 0 | **0.9** | 1.3 | 0 | 0.4 | **1.3** | 2.6 | 1 | 0.8 | **2.6** | 4.9 | 1.7 | 1.1 | **4.9** | 5.8 | 2.1 | 1.1 | **5.8** |
| HV Transformers – Max. Utilisation of the Worst Performing Transformer | 123% | 122% | 120% | **123%** | 156% | 129% | 124% | **156%** | 171% | 131% | 131% | **171%** | 211% | 137% | 163% | **211%** | 223% | 214% | 172% | **223%** | 268% | 220% | 204% | **268%** | 286% | 218% | 209% | **286%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 95% | 100% | 100% | **95%** | 95% | 95% | 100% | **95%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 5% | 0% | **0%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0.3 | 0 | **0** |
| HV Lines – Percentage of Lines with Maximum Utilisation – 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 5% | 0% | 0% | **5%** | 5% | 0% | 0% | **5%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0.2 | 0 | 0 | **0.2** | 0.7 | 0 | 0 | **0.7** |
| HV Lines – Percentage of Lines with Maximum Utilisation – > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** |
| HV Lines – Max. Utilisation of the Worst Performing Line | 47% | 45% | 42% | **47%** | 55% | 53% | 45% | **55%** | 68% | 63% | 50% | **68%** | 81% | 75% | 58% | **81%** | 93% | 86% | 66% | **93%** | 111% | 98% | 74% | **111%** | 124% | 108% | 81% | **124%** |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | 0% | 0% | 0% | **0%** | 2% | 2% | 0% | **2%** | 5% | 3% | 2% | **5%** | 8% | 5% | 5.1% | **8%** | 10% | 6% | 6% | **10%** | 12% | 8% | 8% | **12%** | 22% | 9% | 11% | **22%** |
| Residential Voltage Drop Non-Compliance | 1% | 1% | 1% | **1%** | 4% | 3% | 1% | **4%** | 6% | 4% | 4% | **6%** | 8% | 7% | 6% | **8%** | 12% | 10% | 9% | **12%** | 15% | 12% | 11% | **15%** | 26% | 15% | 13% | **26%** |
| Percentage of LV Networks with Voltage Rise Issues | 0.4% | 0.5% | 0.2% | **0.5%** | 4% | 3% | 1% | **4%** | 6% | 3% | 4% | **6%** | 7% | 6% | 5% | **7%** | 8% | 6% | 6% | **8%** | 9% | 7% | 6% | **9%** | 15% | 7% | 8% | **15%** |
| Percentage of LV Networks with Voltage Drop Issues | 2% | 4% | 2% | **4%** | 7% | 7% | 4% | **7%** | 7% | 8% | 6% | **8%** | 10% | 10% | 8% | **10%** | 14% | 13% | 9% | **14%** | 16% | 16% | 12% | **16%** | 28% | 18% | 14% | **28%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | 0.4% | 0.5% | 0% | **0.5%** | 4% | 3% | 1% | **4%** | 6% | 3% | 4% | **6%** | 6% | 6% | 5% | **6%** | 7% | 6% | 6% | **7%** | 9% | 7% | 6% | **9%** | 13% | 7% | 6% | **13%** |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation – <= 100% | 99% | 98% | 99% | **98%** | 95% | 96% | 98% | **95%** | 90% | 92% | 95% | **90%** | 84% | 86% | 91% | **84%** | 78% | 82% | 86% | **78%** | 72% | 77% | 81% | **72%** | 70% | 75% | 78% | **70%** |
| Percentage of Distribution Transformers with Maximum Utilisation – 100%-110% | 0.4% | 0.9% | 0.5% | **0.9%** | 1% | 2% | 1% | **1%** | 2% | 2% | 1% | **2%** | 3% | 4% | 2% | **3%** | 3% | 4% | 3% | **3%** | 3% | 5% | 3% | **3%** | 3% | 4% | 3% | **3%** |
| Percentage of Distribution Transformers with Maximum Utilisation – 110%-150% | 0.9% | 0.7% | 0.5% | **0.7%** | 3% | 2% | 1% | **3%** | 5% | 5% | 3% | **5%** | 8% | 8% | 4% | **8%** | 9% | 10% | 8% | **9%** | 11% | 10% | 10% | **11%** | 11% | 9% | 12% | **11%** |
| Percentage of Distribution Transformers with Maximum Utilisation – > 150% | 0.04% | 0% | 0.04% | **0%** | 0.8% | 0.4% | 0.3% | **0.8%** | 3% | 1% | 1% | **3%** | 5% | 2% | 1.9% | **5%** | 9% | 5% | 3% | **9%** | 14% | 9% | 6% | **14%** | 16% | 12% | 8% | **16%** |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | 1% | 100% | 85% | **100%** | 86% | 100% | 86% | **100%** | 85% | 100% | 85% | **100%** | 85% | 100% | 85% | **100%** | 84% | 100% | 100% | **100%** | 83% | 100% | 100% | **100%** | 82% | 100% | 100% | **100%** |
| Aggregate Export – Total PV Curtailment (GWh) | 0 | 0.02 | 0.01 | **5** | 0 | 0.03 | 0.03 | **9** | 0 | 0.05 | 0.04 | **14** | 0.01 | 0.1 | 0.1 | **20** | 0.02 | 0.1 | 0.1 | **27** | 0.03 | 0.1 | 0.1 | **35** | 0.04 | 0.1 | 0.1 | **44** |
| Aggregate Export – Percentage of PV Curtailment | 0% | 7% | 7% | **6%** | 0.3% | 10% | 10% | **9%** | 2% | 14% | 13% | **12%** | 5% | 17% | 16% | **15%** | 7% | 20% | 19% | **18%** | 10% | 23% | 22% | **21%** | 13% | 25% | 24% | **23%** |

# Appendix 14: Full Impact Assessment Table (Without DOE) – SMTS

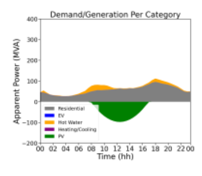
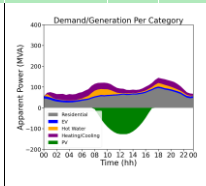
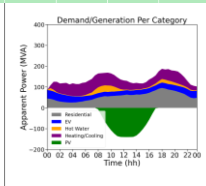
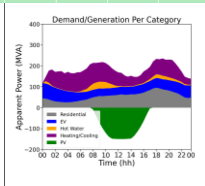
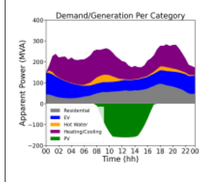
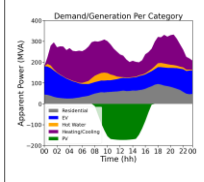
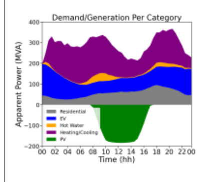
| Subtransmission Network – SMTS (Without DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 274 | 257 | 234 | **274** | 338 | 316 | 251 | **338** | 430 | 403 | 306 | **430** | 546 | 502 | 369 | **546** | 646 | 602 | 440 | **646** | 756 | 695 | 513 | **756** | 832 | 760 | 565 | **832** |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | - | - | **-** | 23% | 23% | 7% | **23%** | 27% | 28% | 22% | **27%** | 27% | 24% | 21% | **27%** | 18% | 20% | 19% | **18%** | 17% | 15% | 17% | **17%** | 10% | 9% | 10% | **10%** |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 1.00 | 1.00 | **1.00** | 0.99 | 0.99 | 1.00 | **0.99** | 0.98 | 0.98 | 0.99 | **0.98** | 0.96 | 0.96 | 0.99 | **0.96** | 0.94 | 0.95 | 0.98 | **0.94** | 0.92 | 0.93 | 0.97 | **0.92** | 0.91 | 0.92 | 0.96 | **0.91** |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 21% | 3% | 0% | **21%** | 39% | 27% | 3% | **39%** | 45% | 39% | 18% | **45%** | 48% | 45% | 27% | **48%** | 48% | 45% | 39% | **48%** |
| Maximum Voltage (pu) | | | 1.04 | 1.04 | 1.04 | **1.04** | 1.04 | 1.04 | 1.04 | **1.04** | 1.05 | 1.04 | 1.04 | **1.05** | 1.05 | 1.04 | 1.06 | **1.06** | 1.05 | 1.05 | 1.05 | **1.05** | 1.05 | 1.05 | 1.06 | **1.06** | 1.05 | 1.05 | 1.06 | **1.06** |
| Minimum Voltage (pu) | | | 0.93 | 0.94 | 0.95 | **0.93** | 0.92 | 0.90 | 0.94 | **0.90** | 0.86 | 0.90 | 0.90 | **0.86** | 0.75 | 0.83 | 0.92 | **0.75** | 0.70 | 0.75 | 0.88 | **0.70** | 0.65 | 0.70 | 0.83 | **0.65** | 0.62 | 0.68 | 0.79 | **0.62** |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers | Percentage of Transformers with Maximum Utilisation | <= 100% | 95% | 100% | 100% | **95%** | 85% | 90% | 100% | **85%** | 65% | 65% | 90% | **65%** | 60% | 60% | 85% | **60%** | 60% | 60% | 65% | **60%** | 50% | 50% | 60% | **50%** | 50% | 50% | 60% | **50%** |
| | | 100%-110% | 5% | 0% | 0% | **5%** | 5% | 5% | 0% | **5%** | 0% | 20% | 5% | **0%** | 0% | 5% | 5% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 5% | **0%** | 0% | 0% | 0% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 1.5 | 0 | 0 | **1.5** | 3 | 0.5 | 0 | **3** | 0.0 | 2.1 | 2.5 | **0** | 0 | 2 | 1 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0 | **0** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 10% | 5% | 0% | **10%** | 30% | 10% | 5% | **30%** | 30% | 30% | 5% | **30%** | 5% | 15% | 30% | **5%** | 15% | 15% | 30% | **15%** | 10% | 10% | 15% | **10%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 2 | 0.5 | 0 | **2** | 3.3 | 2.8 | 3.5 | **3.3** | 10 | 4.7 | 2 | **10** | 7 | 5.2 | 1.6 | **7** | 5 | 2 | 7 | **5** | 4.5 | 2 | 4.8 | **4.5** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 5% | 5% | 0% | **5%** | 10% | 5% | 5% | **10%** | 35% | 25% | 5% | **35%** | 35% | 35% | 5% | **35%** | 40% | 40% | 25% | **40%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 13.5 | 3.5 | 0 | **13.5** | 12 | 17 | 7 | **12** | 7.9 | 6 | 13 | **7.9** | 13.5 | 6.3 | 15 | **13.5** | 14.1 | 6.1 | 3.4 | **14.1** |
| | Max. Utilisation of the Worst Performing Transformer | | 104% | 98% | 90% | **104%** | 118% | 110% | 95% | **118%** | 209% | 194% | 140% | **209%** | 306% | 298% | 206% | **306%** | 383% | 361% | 272% | **383%** | 422% | 406% | 354% | **422%** | 441% | 432% | 394% | **441%** |
| HV Lines | Percentage of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 96% | 100% | 100% | **96%** | 84% | 92% | 100% | **84%** | 84% | 84% | 100% | **84%** | 64% | 64% | 92% | **64%** | 60% | 64% | 84% | **60%** |
| | | 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 4% | 0% | 0% | **4%** | 4% | 4% | 0% | **4%** | 0% | 4% | 0% | **0%** | 8% | 20% | 0% | **8%** | 4% | 8% | 4% | **4%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 3 | 0 | 0 | **3** | 5.5 | 1.5 | 0 | **5.5** | 0 | 2.5 | 0 | **0** | 5 | 1.5 | 0 | **5** | 5 | 2 | 0.5 | **5** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 12% | 4% | 0% | **12%** | 8% | 12% | 0% | **8%** | 20% | 8% | 8% | **20%** | 24% | 20% | 12% | **24%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 6.2 | 1.5 | 0 | **6.2** | 8.5 | 3.2 | 0 | **8.5** | 6.9 | 3.5 | 0.8 | **6.9** | 7.3 | 2.9 | 2.3 | **7.3** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 8% | 0% | 0% | **8%** | 8% | 8% | 0% | **8%** | 12% | 8% | 0% | **12%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 3.3 | 0 | 0 | **3.3** | 10 | 1.5 | 0 | **10** | 10.5 | 2.8 | 0 | **10.5** |
| | Max. Utilisation of the Worst Performing Line | | 66% | 62% | 57% | **66%** | 81% | 77% | 63% | **81%** | 106% | 95% | 77% | **106%** | 138% | 118% | 85% | **138%** | 158% | 145% | 100% | **158%** | 172% | 162% | 119% | **172%** | 181% | 171% | 136% | **181%** |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0% | 0% | 0% | **0%** | 2% | 2% | 0% | **2%** | 5% | 3% | 2% | **5%** | 8% | 4% | 4% | **8%** | 11% | 6% | 6% | **11%** | 13% | 8% | 8% | **13%** | 18% | 9% | 11% | **18%** |
| Residential Voltage Drop Non-Compliance | | | 1% | 2% | 1% | **2%** | 4% | 3% | 1% | **4%** | 8% | 6% | 4% | **8%** | 12% | 9% | 7% | **12%** | 16% | 13% | 11% | **16%** | 20% | 16% | 14% | **20%** | 26% | 18% | 16% | **26%** |
| Percentage of LV Networks with Voltage Rise Issues | | | 0.5% | 0.5% | 0.3% | **0.5%** | 5% | 4% | 2% | **5%** | 9% | 5% | 6% | **9%** | 10% | 8% | 6% | **10%** | 11% | 9% | 8% | **11%** | 13% | 10% | 9% | **13%** | 17% | 11% | 11% | **17%** |
| Percentage of LV Networks with Voltage Drop Issues | | | 3% | 5% | 3% | **5%** | 9% | 10% | 6% | **10%** | 11% | 12% | 9% | **12%** | 14% | 14% | 11% | **14%** | 18% | 18% | 13% | **18%** | 22% | 22% | 16% | **22%** | 32% | 23% | 18% | **32%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | | 0.5% | 0.5% | 0% | **0.5%** | 5% | 4% | 1% | **5%** | 9% | 5% | 6% | **9%** | 10% | 8% | 6% | **10%** | 11% | 9% | 8% | **11%** | 12% | 10% | 9% | **12%** | 16% | 11% | 9% | **16%** |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | | <= 100% | 99% | 99% | 99% | **99%** | 96% | 97% | 98% | **96%** | 88% | 92% | 96% | **88%** | 80% | 82% | 93% | **80%** | 75% | 77% | 85% | **75%** | 69% | 72% | 79% | **69%** | 67% | 71% | 75% | **67%** |
| | | 100%-110% | 0.2% | 0.6% | 0.3% | **0.6%** | 1% | 1% | 0.6% | **1%** | 4% | 3% | 1% | **4%** | 3% | 4% | 3% | **3%** | 3% | 4% | 4% | **3%** | 3% | 5% | 4% | **3%** | 3% | 4% | 3% | **3%** |
| | | 110%-150% | 0.7% | 0.6% | 0.3% | **0.6%** | 2% | 2% | 0.8% | **2%** | 6% | 5% | 2% | **6%** | 12% | 11% | 4% | **12%** | 11% | 12% | 8% | **11%** | 11% | 10% | 12% | **11%** | 10% | 9% | 15% | **10%** |
| | | > 150% | 0.03% | 0% | 0.03% | **0%** | 0.6% | 0.4% | 0.2% | **0.6%** | 2% | 0.8% | 0.6% | **2%** | 5% | 2% | 1% | **5%** | 11% | 7% | 2% | **11%** | 18% | 13% | 5% | **18%** | 20% | 16% | 6% | **20%** |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0.9% | 100% | 85% | **100%** | 86% | 100% | 86% | **100%** | 85% | 100% | 85% | **100%** | 85% | 100% | 85% | **100%** | 84% | 100% | 100% | **100%** | 83% | 100% | 100% | **100%** | 82% | 100% | 100% | **100%** |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.04 | 0.04 | **12** | 0 | 0.1 | 0.1 | **24** | 0.01 | 0.1 | 0.1 | **37** | 0.03 | 0.2 | 0.2 | **52** | 0.1 | 0.2 | 0.2 | **71** | 0.1 | 0.3 | 0.3 | **94** | 0.1 | 0.4 | 0.3 | **117** |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | **6%** | 0.3% | 10% | 10% | **9%** | 2% | 14% | 13% | **12%** | 5% | 17% | 16% | **15%** | 7% | 20% | 19% | **18%** | 10% | 23% | 22% | **21%** | 13% | 25% | 24% | **24%** |

## Appendix 15: Full Impact Assessment Table (Without DOE) – TSTS

| Subtransmission Network – TSTS (Without DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | 359 | 344 | 317 | **359** | 433 | 413 | 336 | **433** | 538 | 519 | 409 | **538** | 659 | 632 | 490 | **659** | 781 | 746 | 576 | **781** | 912 | 859 | 656 | **912** | 1002 | 940 | 708 | **1002** |
| Increase of Max. Demand at Terminal Station (MVA) | - | - | - | **-** | 20% | 20% | 6% | **20%** | 24% | 26% | 22% | **24%** | 22% | 22% | 20% | **22%** | 19% | 18% | 17% | **19%** | 17% | 15% | 14% | **17%** | 10% | 9% | 8% | **10%** |
| Power Factor at Terminal Station for Max. Demand | 0.99 | 0.99 | 1.00 | **0.99** | 0.99 | 0.99 | 0.99 | **0.99** | 0.98 | 0.98 | 0.99 | **0.98** | 0.97 | 0.97 | 0.98 | **0.97** | 0.96 | 0.97 | 0.98 | **0.96** | 0.96 | 0.96 | 0.98 | **0.96** | 0.95 | 0.95 | 0.97 | **0.95** |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of Buses with Voltage Drop Issues | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Maximum Voltage (pu) | 1.01 | 1.01 | 1.01 | **1.01** | 1.01 | 1.01 | 1.01 | **1.01** | 1.01 | 1.01 | 1.01 | **1.01** | 1.01 | 1.01 | 1.01 | **1.01** | 1.01 | 1.01 | 1.01 | **1.01** | 1.01 | 1.01 | 1.01 | **1.01** | 1.01 | 1.01 | 1.01 | **1.01** |
| Minimum Voltage (pu) | 0.99 | 0.99 | 0.99 | **0.99** | 0.99 | 0.99 | 0.99 | **0.99** | 0.99 | 0.99 | 0.99 | **0.99** | 0.99 | 0.99 | 0.99 | **0.99** | 0.99 | 0.99 | 0.99 | **0.99** | 0.99 | 0.99 | 0.99 | **0.99** | 0.98 | 0.98 | 0.99 | **0.98** |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 0% | 33% | 100% | **0%** | 0% | 0% | 100% | **0%** | 0% | 0% | 33% | **0%** | 0% | 0% | 33% | **0%** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 67% | 0% | **100%** | 0% | 0% | 0% | **0%** | 0% | 0% | 67% | **0%** | 0% | 0% | 67% | **0%** |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 3.5 | 2 | 0 | **3.5** | 0 | 0.0 | 0 | **0** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0.5 | **0** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 100% | 100% | 0% | **100%** | 100% | 100% | 0% | **100%** | 100% | 100% | 0% | **100%** |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 4.3 | 1.5 | 0 | **4.3** | 7 | 3.2 | 0 | **7** | 10.8 | 3.8 | 0 | **10.8** |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** |
| HV Transformers – Max. Utilisation of the Worst Performing Transformer | 77% | 73% | 66% | **77%** | 86% | 81% | 67% | **86%** | 97% | 94% | 73% | **97%** | 110% | 106% | 82% | **110%** | 122% | 119% | 92% | **122%** | 134% | 131% | 101% | **134%** | 143% | 140% | 107% | **143%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 67% | 67% | 100% | **67%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 33% | 33% | 0% | **33%** |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 3 | 0.5 | 0 | **3** |
| HV Lines – Percentage of Lines with Maximum Utilisation – 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** |
| HV Lines – Percentage of Lines with Maximum Utilisation – > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** |
| HV Lines – Max. Utilisation of the Worst Performing Line | 52% | 50% | 44% | **52%** | 59% | 56% | 46% | **59%** | 67% | 64% | 49% | **67%** | 77% | 74% | 56% | **77%** | 85% | 83% | 63% | **85%** | 96% | 93% | 69% | **96%** | 103% | 100% | 74% | **103%** |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | 0% | 0% | 0% | **0%** | 1% | 1% | 0% | **1%** | 4% | 2% | 1% | **4%** | 6% | 3% | 3% | **6%** | 10% | 5.01% | 5.4% | **10%** | 12% | 6% | 7% | **12%** | 15% | 7% | 9% | **15%** |
| Residential Voltage Drop Non-Compliance | 1% | 2% | 0% | **2%** | 4% | 4% | 1% | **4%** | 9% | 7% | 4% | **9%** | 14% | 9% | 7% | **14%** | 18% | 14% | 12% | **18%** | 23% | 18% | 15% | **23%** | 26% | 20% | 18% | **26%** |
| Percentage of LV Networks with Voltage Rise Issues | 0.8% | 0.5% | 0.6% | **0.8%** | 10% | 8% | 3% | **10%** | 16% | 10% | 11% | **16%** | 18% | 14% | 12% | **18%** | 20% | 16% | 15% | **20%** | 22% | 18% | 16% | **22%** | 23% | 19% | 19% | **23%** |
| Percentage of LV Networks with Voltage Drop Issues | 5% | 10% | 5% | **10%** | 17% | 18% | 11% | **18%** | 20% | 21% | 16% | **21%** | 24% | 24% | 20% | **24%** | 29% | 30% | 22% | **30%** | 36% | 35% | 26% | **36%** | 41% | 36% | 30% | **41%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | 0.8% | 0.5% | 0% | **0.8%** | 10% | 8% | 2% | **10%** | 16% | 10% | 10% | **16%** | 18% | 14% | 12% | **18%** | 20% | 16% | 15% | **20%** | 22% | 18% | 16% | **22%** | 23% | 19% | 17% | **23%** |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation – <= 100% | 100% | 100% | 100% | **100%** | 97% | 98% | 100% | **97%** | 84% | 90% | 100% | **84%** | 72% | 75% | 95% | **72%** | 66% | 68% | 85% | **66%** | 61% | 63% | 75% | **61%** | 59% | 61% | 70% | **59%** |
| Percentage of Distribution Transformers with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | **0%** | 2% | 0.8% | 0% | **2%** | 6% | 5% | 0.2% | **6%** | 4% | 6% | 3% | **4%** | 3% | 4% | 6% | **3%** | 3% | 5% | 4% | **3%** | 2% | 3% | 4% | **2%** |
| Percentage of Distribution Transformers with Maximum Utilisation – 110%-150% | 0.2% | 0.2% | 0% | **0.2%** | 0.2% | 0.8% | 0% | **0.2%** | 9% | 5% | 0.2% | **9%** | 19% | 17% | 1% | **19%** | 15% | 18% | 9% | **15%** | 11% | 12% | 18% | **11%** | 10% | 10% | 21% | **10%** |
| Percentage of Distribution Transformers with Maximum Utilisation – > 150% | 0% | 0% | 0% | **0%** | 0.2% | 0.2% | 0% | **0.2%** | 0.5% | 0.2% | 0% | **0.5%** | 5% | 2% | 0.2% | **5%** | 15% | 10% | 0.2% | **15%** | 26% | 20% | 3% | **26%** | 29% | 25% | 4% | **29%** |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | 0.6% | 100% | 85% | **100%** | 86% | 100% | 86% | **100%** | 85% | 100% | 85% | **100%** | 85% | 100% | 85% | **100%** | 84% | 100% | 100% | **100%** | 83% | 100% | 100% | **100%** | 82% | 100% | 100% | **100%** |
| Aggregate Export – Total PV Curtailment (GWh) | 0 | 0.04 | 0.03 | **12** | 0 | 0.1 | 0.1 | **23** | 0.01 | 0.1 | 0.1 | **35** | 0.03 | 0.2 | 0.1 | **50** | 0.1 | 0.2 | 0.2 | **69** | 0.1 | 0.3 | 0.3 | **91** | 0.1 | 0.4 | 0.3 | **113** |
| Aggregate Export – Percentage of PV Curtailment | 0% | 7% | 7% | **6%** | 0.3% | 10% | 10% | **9%** | 2% | 13% | 13% | **12%** | 5% | 17% | 16% | **15%** | 7% | 20% | 19% | **18%** | 10% | 23% | 22% | **21%** | 13% | 25% | 24% | **24%** |

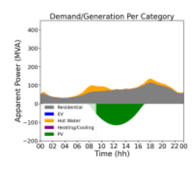
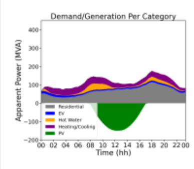
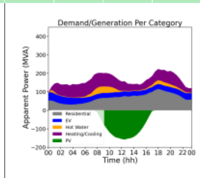
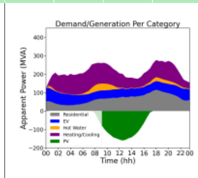
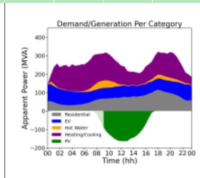
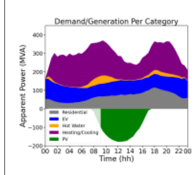
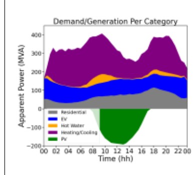
## Appendix 16: Full Impact Assessment Table (Without DOE) – TTS

**Subtransmission Network – TTS (Without DOEs)**

| Year | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | 254 | 240 | 215 | **254** | 340 | 319 | 241 | **340** | 475 | 450 | 325 | **475** | 640 | 602 | 423 | **640** | 820 | 773 | 533 | **820** | 983 | 916 | 646 | **983** | 1120 | 1015 | 728 | **1120** |
| Increase of Max. Demand at Terminal Station (MVA) | - | - | - | **-** | 34% | 33% | 12% | **34%** | 40% | 41% | 35% | **40%** | 35% | 34% | 30% | **35%** | 28% | 28% | 26% | **28%** | 20% | 19% | 21% | **20%** | 14% | 11% | 13% | **14%** |
| Power Factor at Terminal Station for Max. Demand | 1.00 | 1.00 | 1.00 | **1.00** | 0.98 | 0.99 | 1.00 | **0.98** | 0.95 | 0.96 | 0.99 | **0.95** | 0.92 | 0.92 | 0.97 | **0.92** | 0.87 | 0.88 | 0.95 | **0.87** | 0.83 | 0.84 | 0.92 | **0.83** | 0.79 | 0.82 | 0.90 | **0.79** |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of Buses with Voltage Drop Issues | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 8% | 0% | 0% | **8%** | 31% | 23% | 0% | **31%** | 54% | 54% | 8% | **54%** | 85% | 77% | 8% | **85%** |
| Maximum Voltage (pu) | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** |
| Minimum Voltage (pu) | 0.99 | 0.99 | 0.99 | **0.99** | 0.97 | 0.98 | 0.99 | **0.97** | 0.95 | 0.96 | 0.98 | **0.95** | 0.92 | 0.93 | 0.97 | **0.92** | 0.82 | 0.83 | 0.95 | **0.82** | 0.76 | 0.78 | 0.93 | **0.76** | 0.73 | 0.75 | 0.87 | **0.73** |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – <= 100% | 100% | 100% | 100% | **100%** | 43% | 57% | 100% | **43%** | 14% | 14% | 57% | **14%** | 14% | 14% | 29% | **14%** | 0% | 0% | 14% | **0%** | 0% | 0% | 14% | **0%** | 0% | 0% | 0% | **0%** |
| HV Transformers – 100%-110% | 0% | 0% | 0% | **0%** | 14% | 43% | 0% | **14%** | 0% | 14% | 43% | **0%** | 0% | 0% | 14% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 1.5 | 2 | 0 | **1.5** | 0 | 2 | 0.5 | **0** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** |
| HV Transformers – 110%-150% | 0% | 0% | 0% | **0%** | 43% | 0% | 0% | **43%** | 71% | 71% | 0% | **71%** | 29% | 29% | 57% | **29%** | 0% | 29% | 43% | **0%** | 0% | 0% | 29% | **0%** | 0% | 0% | 29% | **0%** |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 1.5 | 0 | 0 | **1.5** | 6.6 | 3.6 | 0 | **6.6** | 13.8 | 4.3 | 3.1 | **13.8** | 0 | 9.5 | 3 | **0** | 0 | 0 | 8 | **0** | 0 | 0 | 6.8 | **0** |
| HV Transformers – > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 14% | 0% | 0% | **14%** | 57% | 57% | 0% | **57%** | 100% | 71% | 43% | **100%** | 100% | 100% | 57% | **100%** | 100% | 100% | 71% | **100%** |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 2 | 0 | 0 | **2** | 8.8 | 2.9 | 0 | **8.8** | 11.1 | 5.8 | 0.7 | **11.1** | 16.3 | 8.6 | 3.6 | **16.3** | 18.1 | 11.2 | 6 | **18.1** |
| HV Transformers – Max. Utilisation of the Worst Performing Transformer | 92% | 88% | 80% | **92%** | 114% | 107% | 84% | **114%** | 154% | 142% | 107% | **154%** | 202% | 187% | 134% | **202%** | 239% | 233% | 165% | **239%** | 267% | 255% | 195% | **267%** | 297% | 275% | 213% | **297%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 90% | 90% | 100% | **90%** | 80% | 80% | 100% | **80%** | 60% | 60% | 80% | **60%** | 60% | 60% | 80% | **60%** | 60% | 60% | 60% | **60%** |
| HV Lines – 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 10% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 10% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 20% | **0%** |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 2 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0.5 | **0** |
| HV Lines – 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 10% | 0% | 0% | **10%** | 10% | 20% | 0% | **10%** | 20% | 20% | 10% | **20%** | 0% | 20% | 20% | **0%** | 0% | 0% | 10% | **0%** |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 3 | 0 | 0 | **3** | 5 | 2.8 | 0 | **5** | 4.5 | 1.5 | 0.5 | **4.5** | 0 | 3 | 4 | **0** | 0 | 0 | 1 | **0** |
| HV Lines – > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 10% | 0% | 0% | **10%** | 20% | 20% | 0% | **20%** | 40% | 20% | 0% | **40%** | 40% | 40% | 10% | **40%** |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0.5 | 0 | 0 | **0.5** | 7.5 | 2.5 | 0 | **7.5** | 7.4 | 3.8 | 0 | **7.4** | 10.5 | 4.6 | 0.5 | **10.5** |
| HV Lines – Max. Utilisation of the Worst Performing Line | 65% | 62% | 55% | **65%** | 85% | 79% | 60% | **85%** | 114% | 109% | 78% | **114%** | 151% | 141% | 98% | **151%** | 194% | 184% | 123% | **194%** | 226% | 215% | 149% | **226%** | 244% | 231% | 171% | **244%** |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | 0% | 0% | 0% | **0%** | 1% | 0.5% | 0.2% | **1%** | 3% | 0.9% | 0.6% | **3%** | 4% | 2% | 1% | **4%** | 8% | 3% | 4% | **8%** | 11% | 4% | 5.02% | **11%** | 12% | 5.3% | 6% | **12%** |
| Residential Voltage Drop Non-Compliance | 0% | 1% | 0% | **1%** | 3% | 3% | 1% | **3%** | 9% | 6% | 3% | **9%** | 13% | 8% | 6% | **13%** | 18% | 12% | 11% | **18%** | 22% | 16% | 14% | **22%** | 24% | 18% | 16% | **24%** |
| Percentage of LV Networks with Voltage Rise Issues | 1% | 0% | 1% | **1%** | 15% | 13% | 5% | **15%** | 25% | 15% | 17% | **25%** | 29% | 20% | 17% | **29%** | 31% | 23% | 22% | **31%** | 34% | 26% | 25% | **34%** | 34% | 30% | 27% | **34%** |
| Percentage of LV Networks with Voltage Drop Issues | 7% | 15% | 7% | **15%** | 26% | 27% | 16% | **27%** | 31% | 31% | 25% | **31%** | 35% | 34% | 30% | **35%** | 39% | 41% | 32% | **41%** | 50% | 48% | 35% | **50%** | 53% | 47% | 40% | **53%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | 1% | 0% | 0% | **1%** | 15% | 13% | 3% | **15%** | 25% | 15% | 16% | **25%** | 29% | 20% | 17% | **29%** | 31% | 23% | 22% | **31%** | 34% | 26% | 25% | **34%** | 34% | 30% | 27% | **34%** |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation – <= 100% | 100% | 100% | 100% | **100%** | 96% | 98% | 100% | **96%** | 73% | 84% | 100% | **73%** | 53% | 59% | 94% | **53%** | 46% | 49% | 78% | **46%** | 41% | 42% | 63% | **41%** | 40% | 42% | 55% | **40%** |
| Percentage of Distribution Transformers with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | **0%** | 4% | 1% | 0% | **4%** | 10% | 8% | 0% | **10%** | 6% | 9% | 5% | **6%** | 4% | 5% | 9% | **4%** | 4% | 7% | 6% | **4%** | 2% | 2% | 7% | **2%** |
| Percentage of Distribution Transformers with Maximum Utilisation – 110%-150% | 0% | 0% | 0% | **0%** | 0% | 1% | 0% | **0%** | 16% | 8% | 0% | **16%** | 33% | 28% | 1% | **33%** | 24% | 28% | 13% | **24%** | 13% | 17% | 27% | **13%** | 12% | 14% | 32% | **12%** |
| Percentage of Distribution Transformers with Maximum Utilisation – > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 8% | 4% | 0% | **8%** | 26% | 18% | 0% | **26%** | 43% | 33% | 4% | **43%** | 47% | 42% | 6% | **47%** |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | 0.2% | 100% | 85% | **100%** | 86% | 100% | 86% | **100%** | 85% | 100% | 85% | **100%** | 85% | 100% | 85% | **100%** | 84% | 100% | 100% | **100%** | 83% | 100% | 100% | **100%** | 82% | 100% | 100% | **100%** |
| Aggregate Export – Total PV Curtailment (GWh) | 0 | 0.1 | 0.04 | **15** | 0 | 0.1 | 0.1 | **29** | 0.01 | 0.1 | 0.1 | **44** | 0.03 | 0.2 | 0.2 | **63** | 0.1 | 0.3 | 0.2 | **85** | 0.1 | 0.4 | 0.3 | **113** | 0.1 | 0.4 | 0.4 | **140** |
| Aggregate Export – Percentage of PV Curtailment | 0% | 7% | 7% | **6%** | 0.3% | 10% | 10% | **9%** | 2% | 13% | 13% | **12%** | 5% | 16% | 16% | **15%** | 7% | 19% | 19% | **18%** | 10% | 22% | 22% | **21%** | 13% | 25% | 24% | **24%** |

# Appendix 17: Full Impact Assessment Table (With DOE) – CBTS

**Subtransmission Network – CBTS (With DOEs)**

| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | | | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 483 | 464 | 433 | 483 | 543 | 520 | 444 | 543 | 620 | 599 | 489 | 620 | 721 | 681 | 541 | 721 | 836 | 773 | 595 | 836 | 970 | 863 | 650 | 970 | 1078 | 942 | 689 | 1078 |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | - | - | - | 12% | 12% | 2% | 12% | 14% | 15% | 10% | 14% | 16% | 14% | 10% | 16% | 16% | 13% | 10% | 16% | 16% | 12% | 9% | 16% | 11% | 9% | 6% | 11% |
| Power Factor at Terminal Station for Max. Demand | | | 0.98 | 0.99 | 0.99 | 0.98 | 0.98 | 0.98 | 0.99 | 0.98 | 0.96 | 0.96 | 0.99 | 0.96 | 0.94 | 0.95 | 0.98 | 0.94 | 0.90 | 0.93 | 0.97 | 0.90 | 0.86 | 0.90 | 0.95 | 0.86 | 0.83 | 0.87 | 0.94 | 0.83 |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day | | |   | | | |   | | | |   | | | |   | | | |   | | | |   | | | |   | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Percentage of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 0% | 5% | 37% | 16% | 0% | 37% | 42% | 37% | 0% | 42% | 47% | 42% | 0% | 47% |
| Maximum Voltage (pu) | | | 1.06 | 1.06 | 1.06 | 1.06 | 1.05 | 1.06 | 1.06 | 1.06 | 1.06 | 1.05 | 1.04 | 1.06 | 1.04 | 1.06 | 1.05 | 1.06 | 1.05 | 1.06 | 1.06 | 1.06 | 1.04 | 1.06 | 1.05 | 1.06 | 1.04 | 1.06 | 1.05 | 1.06 |
| Minimum Voltage (pu) | | | 0.97 | 0.98 | 0.98 | 0.97 | 0.96 | 0.96 | 0.98 | 0.96 | 0.93 | 0.94 | 0.97 | 0.93 | 0.89 | 0.92 | 0.96 | 0.89 | 0.84 | 0.88 | 0.94 | 0.84 | 0.78 | 0.84 | 0.92 | 0.78 | 0.70 | 0.80 | 0.90 | 0.70 |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers | Percentage of Transformers with Maximum Utilisation | <= 100% | 83% | 92% | 100% | 83% | 75% | 75% | 100% | 75% | 33% | 42% | 92% | 33% | 8% | 8% | 67% | 8% | 8% | 8% | 42% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% | 8% |
| | | 100%-110% | 17% | 8% | 0% | 17% | 8% | 17% | 0% | 8% | 33% | 25% | 8% | 33% | 0% | 25% | 25% | 0% | 0% | 0% | 25% | 0% | 0% | 0% | 33% | 0% | 0% | 0% | 33% | 0% |
| | | Avg. Overloading Duration (hr) 3 | 1.5 | 0.5 | 0 | 1.5 | 5 | 1.5 | 0 | 5 | 4.5 | 0.8 | 0.5 | 4.5 | 0 | 2.5 | 2.5 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 17% | 8% | 0% | 17% | 33% | 33% | 0% | 33% | 75% | 67% | 8% | 75% | 50% | 58% | 33% | 50% | 33% | 50% | 58% | 33% | 0% | 33% | 50% | 0% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 2.5 | 1 | 0 | 2.5 | 6.8 | 2.6 | 0 | 6.8 | 7.7 | 5.2 | 0.5 | 7.7 | 10.3 | 4.1 | 2.8 | 10.3 | 14.5 | 6.5 | 5.1 | 14.5 | 0 | 8 | 5.2 | 0 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 17% | 0% | 0% | 17% | 42% | 33% | 0% | 42% | 58% | 42% | 0% | 58% | 92% | 58% | 8% | 92% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 6.3 | 2.5 | 0 | 6.3 | 8.8 | 4.6 | 0 | 8.8 | 8.6 | 5.2 | 1.5 | 8.6 |
| | Max. Utilisation of the Worst Performing Transformer | | 106% | 100% | 90% | 106% | 119% | 113% | 93% | 119% | 136% | 130% | 102% | 136% | 155% | 148% | 114% | 155% | 187% | 169% | 126% | 187% | 218% | 194% | 144% | 218% | 218% | 211% | 156% | 218% |
| HV Lines | Percentage of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 85% | 85% | 100% | 85% | 77% | 77% | 100% | 77% | 46% | 54% | 85% | 46% | 38% | 46% | 85% | 38% | 38% | 38% | 77% | 38% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 8% | 0% | 0% | 0% | 8% | 0% | 0% | 8% | 23% | 8% | 8% | 0% | 8% | 0% | 0% | 0% | 0% | 8% | 0% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0.5 | 0.8 | 2 | 0.5 | 0 | 1.5 | 0 | 0 | 0 | 0 | 1.5 | 0 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 15% | 8% | 0% | 15% | 23% | 15% | 0% | 23% | 31% | 8% | 8% | 31% | 38% | 31% | 15% | 38% | 15% | 38% | 15% | 15% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.5 | 0 | 3 | 6.3 | 3.8 | 0 | 6.3 | 2.8 | 3 | 1 | 2.8 | 5.9 | 2.9 | 2 | 5.9 | 7.3 | 2.5 | 3 | 7.3 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 15% | 15% | 0% | 15% | 23% | 15% | 0% | 23% | 46% | 23% | 0% | 46% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 2 | 0 | 6 | 10.5 | 4.3 | 0 | 10.5 | 7.4 | 4.7 | 0 | 7.4 |
| | Max. Utilisation of the Worst Performing Line | | 82% | 77% | 70% | 82% | 98% | 91% | 74% | 98% | 118% | 112% | 85% | 118% | 146% | 134% | 98% | 146% | 180% | 159% | 112% | 180% | 228% | 188% | 127% | 228% | 259% | 216% | 139% | 259% |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.3% | 0.2% | 0.03% | 0.3% | 2% | 2% | 0.2% | 2% | 4% | 2% | 1% | 4% | 7% | 3% | 3% | 7% | 8% | 4% | 3% | 8% | 8% | 4% | 4% | 8% | 10% | 3% | 3% | 10% |
| Residential Voltage Drop Non-Compliance | | | 0.8% | 2% | 0.6% | 2% | 5.1% | 4% | 2% | 5.1% | 8% | 5% | 4% | 8% | 12% | 7% | 5.3% | 12% | 15% | 8% | 7% | 15% | 20% | 11% | 10% | 20% | 25% | 12% | 11% | 25% |
| Percentage of LV Networks with Voltage Rise Issues | | | 0.8% | 0.5% | 0.6% | 0.8% | 8% | 4% | 3% | 8% | 13% | 6% | 7% | 13% | 14% | 5% | 7% | 14% | 13% | 7% | 9% | 13% | 15% | 7% | 9% | 15% | 16% | 6% | 7% | 16% |
| Percentage of LV Networks with Voltage Drop Issues | | | 5% | 9% | 5% | 9% | 16% | 16% | 9% | 16% | 19% | 19% | 15% | 19% | 21% | 22% | 17% | 22% | 25% | 24% | 18% | 25% | 30% | 25% | 20% | 30% | 34% | 26% | 22% | 34% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | | 0.8% | 0.5% | 0% | 0.8% | 8% | 4% | 1% | 8% | 13% | 6% | 6% | 13% | 13% | 5% | 6% | 13% | 13% | 7% | 8% | 13% | 14% | 7% | 9% | 14% | 15% | 6% | 7% | 15% |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | | <= 100% | 100% | 100% | 100% | 100% | 97% | 98% | 100% | 97% | 89% | 94% | 99% | 89% | 76% | 81% | 97% | 76% | 73% | 74% | 92% | 73% | 68% | 72% | 84% | 68% | 65% | 70% | 81% | 65% |
| | | 100%-110% | 0.04% | 0.1% | 0.1% | 0.1% | 2% | 1% | 0.1% | 2% | 3% | 2% | 0.4% | 3% | 5% | 4% | 2% | 5% | 3% | 4% | 4% | 3% | 4% | 3% | 8% | 4% | 4% | 3% | 8% | 4% |
| | | 110%-150% | 0.3% | 0.3% | 0.1% | 0.3% | 0.5% | 0.4% | 0.1% | 0.5% | 8% | 3% | 0.2% | 8% | 16% | 15% | 1% | 16% | 15% | 17% | 4% | 15% | 11% | 14% | 8% | 11% | 10% | 12% | 11% | 10% |
| | | > 150% | 0.01% | 0% | 0.01% | 0% | 0.3% | 0.3% | 0.03% | 0.3% | 0.7% | 0.3% | 0.1% | 0.7% | 3% | 0.9% | 0.1% | 3% | 10% | 4% | 0.2% | 10% | 17% | 11% | 0.3% | 17% | 21% | 15% | 0.7% | 21% |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 1% | 100% | 85% | 100% | 73% | 100% | 73% | 100% | 64% | 100% | 66% | 100% | 68% | 100% | 73% | 100% | 77% | 100% | 79% | 100% | 82% | 100% | 83% | 100% | 83% | 100% | 86% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.1 | 0.1 | 23 | 0.01 | 0.1 | 0.1 | 38 | 0.09 | 0.3 | 0.2 | 74 | 0.2 | 0.5 | 0.4 | 150 | 0.3 | 0.6 | 0.6 | 198 | 0.4 | 0.8 | 0.7 | 255 | 0.5 | 0.9 | 0.9 | 304 |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | 6% | 1% | 10% | 8% | 8% | 9% | 17% | 13% | 13% | 20% | 27% | 24% | 24% | 25% | 29% | 28% | 28% | 27% | 31% | 32% | 31% | 29% | 31% | 34% | 34% |
| *EV Management Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | - | - | - | - | - | - | 9% | 9% | 8% | 9% | 12% | 12% | 11% | 12% | 16% | 16% | 15% | 16% | 20% | 20% | 19% | 20% | 24% | 24% | 23% | 24% |
| Average EV Charging Delay (h) | | | - | - | - | - | - | - | - | - | 3.1 | 2.8 | 3.3 | 3.3 | 4.6 | 4 | 4.9 | 4.9 | 4.5 | 4.5 | 5 | 5 | 4.2 | 4.5 | 4.9 | 4.9 | 4 | 4.4 | 4.8 | 4.8 |

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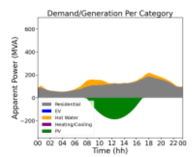
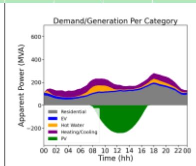
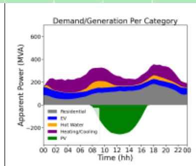
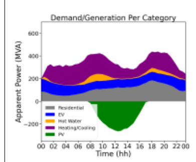
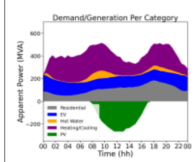
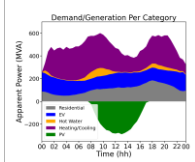
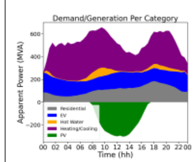
# Appendix 18: Full Impact Assessment Table (With DOE) – ERTS

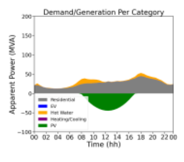
| Subtransmission Network – ERTS (With DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | | | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 504 | 474 | 424 | **504** | 653 | 608 | 461 | **653** | 896 | 810 | 590 | **896** | 1189 | 1039 | 746 | **1189** | 1462 | 1294 | 904 | **1462** | 1858 | 1570 | 1054 | **1858** | 2032 | 1774 | 1154 | **2032** |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | - | - | **-** | 30% | 28% | 9% | **30%** | 37% | 33% | 28% | **37%** | 33% | 28% | 26% | **33%** | 23% | 25% | 21% | **23%** | 27% | 21% | 17% | **27%** | 9% | 13% | 9% | **9%** |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 1.00 | 1.00 | **1.00** | 0.97 | 0.98 | 1.00 | **0.97** | 0.90 | 0.95 | 0.98 | **0.90** | 0.84 | 0.91 | 0.94 | **0.84** | 0.80 | 0.85 | 0.90 | **0.80** | 0.74 | 0.80 | 0.87 | **0.74** | 0.71 | 0.75 | 0.85 | **0.71** |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 17% | 0% | 0% | **17%** | 26% | 9% | 0% | **26%** |
| Maximum Voltage (pu) | | | 1.06 | 1.06 | 1.06 | **1.06** | 1.07 | 1.08 | 1.06 | **1.08** | 1.08 | 1.08 | 1.08 | **1.08** | 1.08 | 1.08 | 1.08 | **1.08** | 1.08 | 1.08 | 1.08 | **1.08** | 1.08 | 1.08 | 1.08 | **1.08** | 1.08 | 1.08 | 1.08 | **1.08** |
| Minimum Voltage (pu) | | | 0.98 | 0.98 | 0.98 | **0.98** | 0.98 | 0.98 | 0.98 | **0.98** | 0.98 | 0.98 | 0.98 | **0.98** | 0.97 | 0.97 | 0.98 | **0.97** | 0.96 | 0.96 | 0.98 | **0.96** | 0.80 | 0.92 | 0.98 | **0.80** | 0.74 | 0.83 | 0.97 | **0.74** |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers | Percentage of Transformers with Maximum Utilisation | <= 100% | 88% | 94% | 100% | **88%** | 88% | 88% | 100% | **88%** | 71% | 76% | 88% | **71%** | 47% | 53% | 76% | **47%** | 47% | 47% | 65% | **47%** | 47% | 47% | 53% | **47%** | 47% | 47% | 47% | **47%** |
| | | 100%-110% | 12% | 6% | 0% | **12%** | 0% | 0% | 0% | **0%** | 6% | 0% | 0% | **6%** | 6% | 18% | 12% | **6%** | 0% | 0% | 6% | **0%** | 0% | 0% | 12% | **0%** | 0% | 0% | 6% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 3 | 0.5 | 0 | **3** | 0.0 | 0.0 | 0 | **0.0** | 3 | 0 | 0 | **3** | 1 | 1.8 | 1.8 | **1** | 0 | 0 | 2 | **0** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0.5 | **0** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 12% | 12% | 0% | **12%** | 12% | 12% | 12% | **12%** | 24% | 18% | 0% | **24%** | 29% | 29% | 18% | **29%** | 12% | 29% | 18% | **12%** | 0% | 12% | 24% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 4.5 | 2.5 | 0 | **4.5** | 5.5 | 1.5 | 1.5 | **5.5** | 3.5 | 5.7 | 0 | **3.5** | 10.5 | 2.8 | 2 | **10.5** | 17.3 | 6 | 2.8 | **17.3** | 0 | 6.8 | 1.5 | **0** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 12% | 12% | 0% | **12%** | 24% | 12% | 12% | **24%** | 24% | 24% | 12% | **24%** | 41% | 24% | 18% | **41%** | 53% | 41% | 24% | **53%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 6 | 3 | 0 | **6** | 5.9 | 14 | 0.5 | **5.9** | 13.5 | 9 | 0.5 | **13.5** | 10 | 12.8 | 1.5 | **10** | 10.2 | 8.9 | 2.1 | **10.2** |
| | Max. Utilisation of the Worst Performing Transformer | | 110% | 100% | 83% | **110%** | 137% | 124% | 93% | **137%** | 194% | 180% | 144% | **194%** | 232% | 244% | 177% | **232%** | 271% | 282% | 196% | **271%** | 303% | 299% | 242% | **303%** | 313% | 297% | 262% | **313%** |
| HV Lines | Percentage of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 94% | 100% | 100% | **94%** | 81% | 81% | 100% | **81%** | 75% | 75% | 94% | **75%** | 75% | 75% | 81% | **75%** | 62% | 75% | 81% | **62%** |
| | | 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 6% | 0% | 0% | **6%** | 0% | 0% | 0% | **0%** | 0% | 6% | 6% | **0%** | 0% | 0% | 6% | **0%** | 12% | 0% | 0% | **12%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 4 | 0 | 0 | **4** | 0 | 0 | 0 | **0** | 0 | 2.5 | 1.5 | **0** | 0 | 0 | 1.5 | **0** | 1 | 0 | 0 | **1** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 19% | 19% | 0% | **19%** | 12% | 19% | 0% | **12%** | 0% | 6% | 12% | **0%** | 0% | 6% | 19% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 5.8 | 1.5 | 0 | **5.8** | 5.8 | 5 | 0 | **5.8** | 0 | 3 | 1.3 | **0** | 0 | 4.5 | 1.7 | **0** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 12% | 0% | 0% | **12%** | 25% | 19% | 0% | **25%** | 25% | 19% | 0% | **25%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 1.8 | 0 | 0 | **1.8** | 5.6 | 2.2 | 0 | **5.6** | 9.4 | 3 | 0 | **9.4** |
| | Max. Utilisation of the Worst Performing Line | | 66% | 62% | 56% | **66%** | 81% | 76% | 58% | **81%** | 106% | 97% | 72% | **106%** | 129% | 120% | 91% | **129%** | 156% | 143% | 102% | **156%** | 204% | 171% | 117% | **204%** | 207% | 195% | 126% | **207%** |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.1% | 0.03% | 0.05% | **0.1%** | 1% | 0.5% | 0.2% | **1%** | 2% | 0.7% | 0.5% | **2%** | 3% | 0.9% | 0.9% | **3%** | 4% | 1% | 1% | **4%** | 5.1% | 1% | 2% | **5.1%** | 4% | 1% | 1% | **4%** |
| Residential Voltage Drop Non-Compliance | | | 0.6% | 1% | 0.3% | **1%** | 3% | 3% | 1% | **3%** | 8% | 5% | 3% | **8%** | 12% | 5.1% | 4% | **12%** | 15% | 7% | 7% | **15%** | 20% | 10% | 10% | **20%** | 24% | 11% | 11% | **24%** |
| Percentage of LV Networks with Voltage Rise Issues | | | 1% | 0.3% | 0.8% | **1%** | 11% | 5% | 3% | **11%** | 17% | 8% | 9% | **17%** | 18% | 6% | 8% | **18%** | 16% | 9% | 11% | **16%** | 19% | 9% | 12% | **19%** | 19% | 7% | 9% | **19%** |
| Percentage of LV Networks with Voltage Drop Issues | | | 6% | 12% | 6% | **12%** | 21% | 20% | 12% | **21%** | 26% | 25% | 20% | **26%** | 27% | 28% | 22% | **28%** | 31% | 30% | 24% | **31%** | 35% | 30% | 26% | **35%** | 39% | 32% | 27% | **39%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | | 1% | 0.3% | 0% | **1%** | 11% | 5% | 2% | **11%** | 17% | 8% | 8% | **17%** | 18% | 6% | 7% | **18%** | 16% | 9% | 10% | **16%** | 18% | 9% | 12% | **18%** | 18% | 7% | 9% | **18%** |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | | <= 100% | 100% | 100% | 100% | **100%** | 97% | 99% | 100% | **97%** | 85% | 93% | 100% | **85%** | 68% | 75% | 97% | **68%** | 64% | 66% | 91% | **64%** | 60% | 64% | 80% | **60%** | 56% | 62% | 76% | **56%** |
| | | 100%-110% | 0% | 0% | 0% | **0%** | 3% | 1% | 0% | **3%** | 4% | 3% | 0.2% | **4%** | 7% | 5% | 2% | **7%** | 3% | 5% | 4% | **3%** | 4% | 3% | 11% | **4%** | 4% | 3% | 10% | **4%** |
| | | 110%-150% | 0.2% | 0.2% | 0% | **0.2%** | 0.2% | 0.2% | 0% | **0.2%** | 11% | 3% | 0% | **11%** | 22% | 19% | 0.9% | **22%** | 19% | 22% | 4% | **19%** | 13% | 19% | 9% | **13%** | 12% | 15% | 14% | **12%** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0.2% | 0.2% | 0% | **0.2%** | 0.3% | 0.2% | 0% | **0.3%** | 3% | 1% | 0% | **3%** | 13% | 6% | 0% | **13%** | 23% | 15% | 0% | **23%** | 28% | 20% | 0.2% | **28%** |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0.4% | 100% | 85% | **100%** | 73% | 100% | 74% | **100%** | 63% | 100% | 68% | **100%** | 72% | 100% | 82% | **100%** | 82% | 100% | 88% | **100%** | 87% | 100% | 91% | **100%** | 88% | 100% | 93% | **100%** |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.1 | 0.1 | **38** | 0.02 | 0.2 | 0.2 | **65** | 0.1 | 0.5 | 0.3 | **125** | 0.4 | 0.9 | 0.7 | **244** | 0.6 | 1.1 | 0.9 | **336** | 0.7 | 1.4 | 1.3 | **450** | 0.8 | 1.5 | 1.5 | **536** |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | **6%** | 1% | 10% | 8% | **8%** | 8% | 17% | 13% | **13%** | 19% | 27% | 23% | **23%** | 25% | 31% | 28% | **28%** | 28% | 33% | 34% | **33%** | 30% | 34% | 36% | **36%** |
| *EV Management Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | - | - | - | - | - | - | 9% | 9% | 8% | **9%** | 13% | 12% | 12% | **13%** | 16% | 16% | 15% | **16%** | 21% | 20% | 20% | **21%** | 24% | 24% | 23% | **24%** |
| Average EV Charging Delay (h) | | | - | - | - | - | - | - | - | - | 3.7 | 2.9 | 3.4 | **3.7** | 5 | 4.4 | 5.2 | **5.2** | 4.8 | 4.8 | 5.6 | **5.6** | 4.5 | 4.8 | 5.5 | **5.5** | 4.4 | 4.8 | 5.4 | **5.4** |

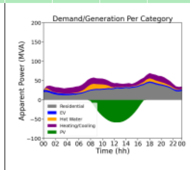
# Appendix 19: Full Impact Assessment Table (With DOE) – GNTS-MBTS

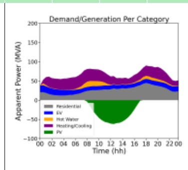
**Subtransmission Network – GNTS + MBTS (With DOEs)**

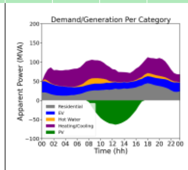
| | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | | | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at GN Terminal Station (MVA) | | | 104 | 96 | 92 | 104 | 133 | 121 | 104 | 133 | 185 | 154 | 129 | 185 | 239 | 195 | 161 | 239 | 276 | 235 | 191 | 276 | 320 | 265 | 225 | 320 | 341 | 284 | 237 | 341 |
| Maximum Demand at MB Terminal Station (MVA) | | | 23 | 22 | 20 | 23 | 28 | 27 | 22 | 28 | 36 | 33 | 26 | 36 | 44 | 40 | 32 | 44 | 52 | 47 | 37 | 52 | 59 | 53 | 41 | 59 | 67 | 57 | 44 | 67 |
| Increase of Max. Demand at Terminal Stations (MVA) | | | - | - | - | - | 28% | 25% | 12% | 28% | 39% | 27% | 24% | 39% | 29% | 27% | 25% | 29% | 15% | 21% | 19% | 15% | 16% | 13% | 18% | 16% | 7% | 7% | 6% | 7% |
| Power Factor at GN Terminal Station for Max. Demand | | | 0.97 | 0.97 | 0.97 | 0.97 | 0.95 | 0.95 | 0.96 | 0.95 | 0.90 | 0.94 | 0.92 | 0.90 | 0.87 | 0.90 | 0.91 | 0.87 | 0.86 | 0.87 | 0.90 | 0.86 | 0.83 | 0.86 | 0.86 | 0.83 | 0.83 | 0.85 | 0.85 | 0.83 |
| Power Factor at MB Terminal Station for Max. Demand | | | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.98 | 0.99 | 1.00 | 0.98 | 0.97 | 0.98 | 0.99 | 0.97 | 0.97 | 0.97 | 0.98 | 0.97 | 0.95 | 0.96 | 0.97 | 0.95 | 0.93 | 0.96 | 0.96 | 0.93 |

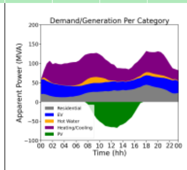
Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day

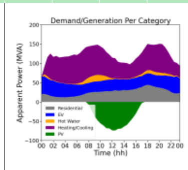
2023: 

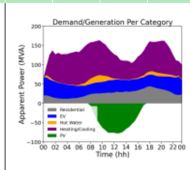

2028: 


2033: 


2038: 


2043: 

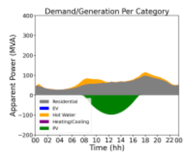
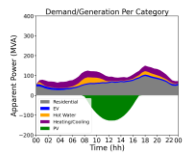
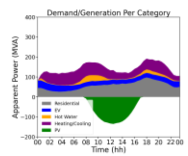
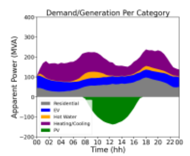
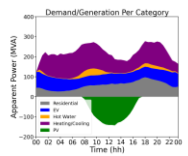
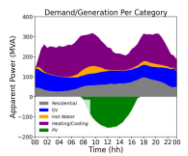
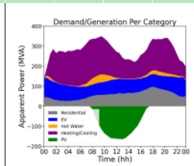

2048: 


2053: 

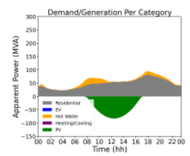
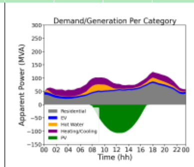
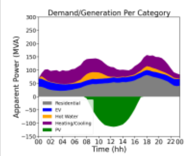
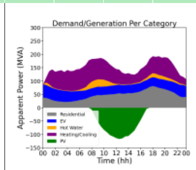
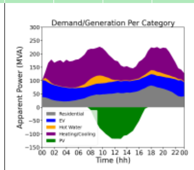
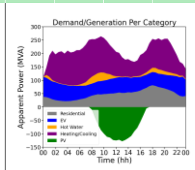
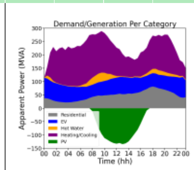

| | | | 2023 WP | 2023 SP | 2023 SS | 2023 YL | 2028 WP | 2028 SP | 2028 SS | 2028 YL | 2033 WP | 2033 SP | 2033 SS | 2033 YL | 2038 WP | 2038 SP | 2038 SS | 2038 YL | 2043 WP | 2043 SP | 2043 SS | 2043 YL | 2048 WP | 2048 SP | 2048 SS | 2048 YL | 2053 WP | 2053 SP | 2053 SS | 2053 YL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Percentage of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 7% | 0% | 0% | 7% | 13% | 7% | 7% | 13% | 13% | 13% | 7% | 13% | 20% | 13% | 13% | 20% | 20% | 13% | 13% | 20% |
| Maximum Voltage (pu) | | | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.06 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.06 | 1.06 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 | 1.07 |
| Minimum Voltage (pu) | | | 0.99 | 0.99 | 0.99 | 0.99 | 0.95 | 0.97 | 0.99 | 0.95 | 0.86 | 0.92 | 0.95 | 0.86 | 0.77 | 0.85 | 0.89 | 0.77 | 0.72 | 0.78 | 0.83 | 0.72 | 0.68 | 0.74 | 0.77 | 0.68 | 0.65 | 0.72 | 0.76 | 0.65 |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers | Percentage of Transformers with Maximum Utilisation | <= 100% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 95% | 64% | 91% | 91% | 64% | 50% | 50% | 77% | 50% | 50% | 50% | 64% | 50% | 45% | 45% | 50% | 45% | 50% | 45% | 50% | 45% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 18% | 5% | 5% | 18% | 0% | 14% | 14% | 0% | 5% | 0% | 9% | 5% | 5% | 5% | 0% | 5% | 0% | 5% | 0% | 5% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0.1 | 0.7 | 0.8 | 0 | 0.1 | 0.4 | 0 | 0.05 | 0 | 0.1 | 0.05 | 0.2 | 0.1 | 0 | 0.2 | 0 | 0.8 | 0 | 0.8 |
| | | 110%-150% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 14% | 5% | 0% | 14% | 41% | 32% | 5% | 41% | 18% | 45% | 27% | 18% | 14% | 32% | 45% | 14% | 14% | 23% | 41% | 23% |
| | | Avg. Overloading Duration (hr) 3 | 1.1 | 1.1 | 1.1 | 1.1 | 0.6 | 1.1 | 1.1 | 0.6 | 0.7 | 1 | 0 | 0.7 | 3.8 | 0.6 | 0.02 | 3.8 | 2.7 | 2 | 1.2 | 2.7 | 2.1 | 1.9 | 2 | 2.1 | 2.5 | 1.5 | 2.2 | 1.5 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 5% | 5% | 9% | 5% | 5% | 9% | 27% | 5% | 0% | 27% | 36% | 18% | 5% | 36% | 36% | 27% | 9% | 27% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 0.2 | 0.9 | 1.1 | 0.8 | 0.4 | 1.1 | 2 | 0.8 | 0 | 2 | 4.4 | 1.4 | 1.1 | 4.4 | 5.2 | 1.8 | 1.1 | 1.8 |
| | Max. Utilisation of the Worst Performing Transformer | | 123% | 121% | 120% | 123% | 132% | 129% | 124% | 132% | 171% | 131% | 155% | 171% | 211% | 174% | 165% | 211% | 183% | 210% | 135% | 183% | 223% | 220% | 208% | 223% | 223% | 221% | 212% | 221% |
| HV Lines | Percentage of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 95% | 100% | 100% | 95% | 95% | 100% | 100% | 95% |
| | | 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 0% | 5% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0 |
| | | 110%-150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 0% | 5% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0.8 |
| | | > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Max. Utilisation of the Worst Performing Line | | 47% | 45% | 42% | 47% | 55% | 53% | 45% | 55% | 69% | 62% | 51% | 69% | 81% | 73% | 60% | 81% | 93% | 82% | 68% | 93% | 107% | 93% | 75% | 107% | 119% | 99% | 79% | 119% |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.3% | 0.2% | 0.01% | 0.3% | 2% | 2% | 0.2% | 2% | 4% | 2% | 1% | 4% | 7% | 3% | 2% | 7% | 7% | 4% | 3% | 7% | 7% | 4% | 4% | 7% | 18% | 3% | 3% | 18% |
| Residential Voltage Drop Non-Compliance | | | 0.6% | 1% | 0.6% | 1% | 4% | 2% | 1% | 4% | 5.2% | 3% | 3% | 5.2% | 7% | 5.1% | 4% | 7% | 9% | 6% | 5% | 9% | 13% | 7% | 7% | 13% | 24% | 9% | 7% | 24% |
| Percentage of LV Networks with Voltage Rise Issues | | | 0.4% | 1% | 0.2% | 0.5% | 3% | 2% | 0.9% | 3% | 5% | 2% | 3% | 5% | 5% | 3% | 3% | 5% | 5% | 3% | 4% | 5% | 7% | 3% | 4% | 7% | 12% | 3% | 3% | 12% |
| Percentage of LV Networks with Voltage Drop Issues | | | 2% | 4% | 2% | 4% | 6% | 6% | 4% | 6% | 7% | 7% | 6% | 7% | 10% | 9% | 7% | 10% | 12% | 11% | 7% | 12% | 16% | 12% | 8% | 16% | 26% | 14% | 10% | 26% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | | 0.4% | 0.5% | 0% | 0.5% | 3% | 1% | 0.6% | 3% | 5% | 2% | 3% | 5% | 5% | 3% | 3% | 5% | 5% | 3% | 4% | 5% | 6% | 3% | 4% | 6% | 10% | 3% | 3% | 10% |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | | <= 100% | 99% | 98% | 99% | 98% | 95% | 97% | 98% | 95% | 92% | 95% | 96% | 92% | 86% | 90% | 93% | 86% | 82% | 85% | 90% | 82% | 77% | 83% | 86% | 77% | 75% | 81% | 84% | 75% |
| | | 100%-110% | 0.4% | 0.9% | 0.5% | 0.9% | 1% | 2% | 0.9% | 1% | 2% | 2% | 1.3% | 2% | 3% | 3% | 2% | 3% | 2% | 4% | 3% | 2% | 4% | 4% | 4% | 4% | 4% | 4% | 4% | 4% |
| | | 110%-150% | 0.9% | 0.7% | 0.5% | 0.7% | 3% | 1% | 1% | 3% | 4% | 3% | 2% | 4% | 7% | 7% | 4% | 7% | 8% | 8% | 5% | 8% | 9% | 8% | 7% | 9% | 9% | 9% | 8% | 9% |
| | | > 150% | 0.04% | 0% | 0.04% | 0% | 0.8% | 0.4% | 0.3% | 0.8% | 3% | 0.6% | 0.7% | 3% | 4% | 1% | 1% | 4% | 7% | 2% | 2% | 7% | 10% | 5% | 3% | 10% | 12% | 6% | 4% | 12% |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 1% | 100% | 85% | 100% | 71% | 100% | 72% | 100% | 58% | 100% | 59% | 100% | 60% | 100% | 58% | 100% | 71% | 100% | 67% | 100% | 78% | 100% | 72% | 100% | 81% | 100% | 78% | 100% |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.03 | 0.02 | 8 | 0 | 0.1 | 0.04 | 14 | 0.03 | 0.1 | 0.1 | 23 | 0.1 | 0.2 | 0.1 | 45 | 0.1 | 0.2 | 0.2 | 59 | 0.1 | 0.2 | 0.2 | 77 | 0.2 | 0.3 | 0.3 | 93 |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | 6% | 0.6% | 9% | 8% | 7% | 8% | 13% | 11% | 11% | 17% | 21% | 19% | 19% | 22% | 23% | 22% | 22% | 25% | 25% | 25% | 25% | 26% | 27% | 28% | 27% |
| *EV Management Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | - | - | - | - | - | - | 8% | 8% | 7% | 8% | 12% | 12% | 11% | 12% | 15% | 16% | 15% | 16% | 20% | 20% | 19% | 20% | 23% | 24% | 23% | 24% |
| Average EV Charging Delay (h) | | | - | - | - | - | - | - | - | - | 2.5 | 2.7 | 3 | 3 | 3.9 | 3.5 | 4.1 | 4.1 | 3.9 | 4 | 4.2 | 4.2 | 3.7 | 4.1 | 4.1 | 4.1 | 3.5 | 4.1 | 4.1 | 4.1 |

# Appendix 20: Full Impact Assessment Table (With DOE) – SMTS

**Subtransmission Network – SMTS (With DOEs)**

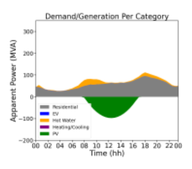
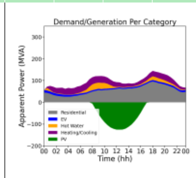
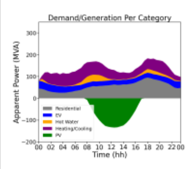
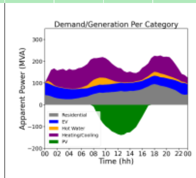
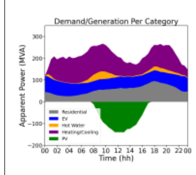
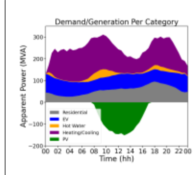
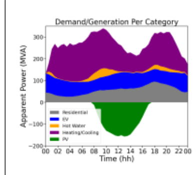
| Year | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| ***Terminal Station Assessment (model-based simulations)*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | 274 | 255 | 234 | **274** | 338 | 314 | 251 | **338** | 431 | 395 | 301 | **431** | 540 | 481 | 364 | **540** | 627 | 569 | 429 | **627** | 713 | 637 | 488 | **713** | 776 | 684 | 525 | **776** |
| Increase of Max. Demand at Terminal Station (MVA) | - | - | - | **-** | 23% | 23% | 7% | **23%** | 28% | 26% | 20% | **28%** | 25% | 22% | 21% | **25%** | 16% | 18% | 18% | **16%** | 14% | 12% | 14% | **14%** | 9% | 7% | 8% | **9%** |
| Power Factor at Terminal Station for Max. Demand | 1.00 | 1.00 | 1.00 | **1.00** | 0.99 | 0.99 | 1.00 | **0.99** | 0.97 | 0.98 | 0.99 | **0.97** | 0.95 | 0.97 | 0.98 | **0.95** | 0.93 | 0.95 | 0.97 | **0.93** | 0.93 | 0.94 | 0.96 | **0.93** | 0.91 | 0.93 | 0.95 | **0.91** |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| ***HV Voltage Assessment (model-based simulations)*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of Buses with Voltage Drop Issues | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 18% | 0% | 9% | **18%** | 39% | 21% | 9% | **39%** | 42% | 33% | 21% | **42%** | 42% | 39% | 24% | **42%** | 45% | 42% | 33% | **45%** |
| Maximum Voltage (pu) | 1.04 | 1.04 | 1.04 | **1.04** | 1.04 | 1.04 | 1.04 | **1.04** | 1.05 | 1.04 | 1.04 | **1.05** | 1.05 | 1.04 | 1.05 | **1.05** | 1.05 | 1.05 | 1.06 | **1.06** | 1.05 | 1.05 | 1.05 | **1.05** | 1.05 | 1.05 | 1.05 | **1.05** |
| Minimum Voltage (pu) | 0.93 | 0.94 | 0.95 | **0.93** | 0.92 | 0.90 | 0.94 | **0.90** | 0.85 | 0.90 | 0.89 | **0.85** | 0.75 | 0.85 | 0.89 | **0.75** | 0.70 | 0.76 | 0.86 | **0.70** | 0.66 | 0.72 | 0.79 | **0.66** | 0.64 | 0.70 | 0.76 | **0.64** |
| ***HV Thermal Assessment (model-based simulations)*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – <= 100% | 95% | 100% | 100% | **95%** | 85% | 90% | 100% | **85%** | 65% | 65% | 90% | **65%** | 60% | 60% | 85% | **60%** | 60% | 60% | 65% | **60%** | 50% | 50% | 65% | **50%** | 50% | 50% | 60% | **50%** |
| 100%-110% | 5% | 0% | 0% | **5%** | 5% | 10% | 0% | **5%** | 15% | 20% | 5% | **15%** | 5% | 5% | 5% | **5%** | 0% | 0% | 0% | **0%** | 10% | 10% | 0% | **10%** | 0% | 0% | 5% | **0%** |
| Avg. Overloading Duration (hr) 3 | 1.5 | 0 | 0 | **1.5** | 3 | 1.5 | 0 | **3** | 4.5 | 2.1 | 3 | **4.5** | 6 | 1.5 | 1 | **6** | 0 | 0 | 0 | **0** | 5.5 | 2 | 0 | **5.5** | 0 | 0 | 1 | **0** |
| 110%-150% | 0% | 0% | 0% | **0%** | 10% | 0% | 0% | **10%** | 15% | 10% | 5% | **15%** | 25% | 30% | 5% | **25%** | 5% | 15% | 30% | **5%** | 5% | 5% | 30% | **5%** | 10% | 15% | 30% | **10%** |
| Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 2 | 0 | 0 | **2** | 5.7 | 2.8 | 4 | **5.7** | 10.1 | 4.9 | 2 | **10.1** | 6.5 | 6 | 1.8 | **6.5** | 10.5 | 3.5 | 3.3 | **10.5** | 2.5 | 2 | 4.3 | **2.5** |
| > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 5% | 5% | 0% | **5%** | 10% | 5% | 5% | **10%** | 35% | 25% | 5% | **35%** | 35% | 35% | 5% | **35%** | 40% | 35% | 5% | **40%** |
| Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 14 | 3.5 | 0 | **14** | 12.3 | 16.5 | 5 | **12.3** | 7.6 | 5.5 | 12.5 | **7.6** | 12.6 | 6.1 | 15.5 | **12.6** | 13 | 7.1 | 15.5 | **13** |
| Max. Utilisation of the Worst Performing Transformer | 104% | 97% | 90% | **104%** | 118% | 110% | 95% | **118%** | 212% | 192% | 137% | **212%** | 305% | 281% | 200% | **305%** | 370% | 348% | 262% | **370%** | 414% | 381% | 329% | **414%** | 425% | 408% | 365% | **425%** |
| HV Lines – Percentage of Lines with Maximum Utilisation – <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 96% | 100% | 100% | **96%** | 84% | 92% | 100% | **84%** | 84% | 84% | 92% | **84%** | 64% | 84% | 88% | **64%** | 60% | 64% | 84% | **60%** |
| 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 4% | 0% | 0% | **4%** | 4% | 4% | 0% | **4%** | 0% | 4% | 8% | **0%** | 20% | 0% | 4% | **20%** | 4% | 20% | 4% | **4%** |
| Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 2.5 | 0 | 0 | **2.5** | 5 | 1 | 0 | **5** | 0 | 2 | 0.5 | **0** | 2.8 | 0 | 1 | **2.8** | 2 | 0.9 | 1 | **2** |
| 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 12% | 4% | 0% | **12%** | 12% | 12% | 0% | **12%** | 8% | 12% | 8% | **8%** | 24% | 8% | 12% | **24%** |
| Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 6.3 | 0.5 | 0 | **6.3** | 9.8 | 3 | 0 | **9.8** | 14 | 3.7 | 1.3 | **14** | 4 | 3.8 | 1.7 | **4** |
| > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 4% | 0% | 0% | **4%** | 8% | 4% | 0% | **8%** | 12% | 8% | 0% | **12%** |
| Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 4.5 | 0 | 0 | **4.5** | 8.5 | 1.5 | 0 | **8.5** | 8.7 | 1.8 | 0 | **8.7** |
| Max. Utilisation of the Worst Performing Line | 66% | 61% | 57% | **66%** | 81% | 76% | 63% | **81%** | 106% | 93% | 78% | **106%** | 139% | 113% | 92% | **139%** | 156% | 140% | 107% | **156%** | 168% | 154% | 126% | **168%** | 176% | 162% | 136% | **176%** |
| ***MV-LV Voltage Assessment (extrapolation of metrics)*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | 0.3% | 0.1% | 0.03% | **0.3%** | 2% | 1% | 0.2% | **2%** | 4% | 2% | 1% | **4%** | 6% | 2% | 2% | **6%** | 6% | 3% | 2% | **6%** | 7% | 3% | 3% | **7%** | 11% | 2% | 3% | **11%** |
| Residential Voltage Drop Non-Compliance | 0.7% | 2% | 0.5% | **2%** | 4% | 3% | 1% | **4%** | 7% | 4% | 3% | **7%** | 10% | 6% | 4% | **10%** | 13% | 7% | 6% | **13%** | 18% | 9% | 9% | **18%** | 24% | 11% | 10% | **24%** |
| Percentage of LV Networks with Voltage Rise Issues | 0.5% | 0.5% | 0.3% | **0.5%** | 5% | 2% | 1% | **5%** | 7% | 3% | 4% | **7%** | 8% | 3% | 4% | **8%** | 7% | 5% | 6% | **7%** | 9% | 4% | 6% | **9%** | 13% | 4% | 5% | **13%** |
| Percentage of LV Networks with Voltage Drop Issues | 3% | 5% | 3% | **5%** | 9% | 9% | 5% | **9%** | 11% | 11% | 8% | **11%** | 13% | 13% | 10% | **13%** | 16% | 15% | 10% | **16%** | 20% | 16% | 11% | **20%** | 29% | 18% | 13% | **29%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | 0.5% | 0.5% | 0% | **0.5%** | 5% | 2% | 0.8% | **5%** | 7% | 3% | 4% | **7%** | 8% | 3% | 3% | **8%** | 7% | 5% | 5% | **7%** | 8% | 4% | 6% | **8%** | 11% | 4% | 5% | **11%** |
| ***MV-LV Thermal Assessment (extrapolation of metrics)*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation – <= 100% | 99% | 99% | 99% | **99%** | 96% | 97% | 98% | **96%** | 90% | 94% | 97% | **90%** | 82% | 86% | 95% | **82%** | 78% | 81% | 91% | **78%** | 74% | 78% | 85% | **74%** | 71% | 77% | 82% | **71%** |
| 100%-110% | 0.2% | 0.6% | 0.3% | **0.6%** | 1% | 1% | 0.6% | **1%** | 2% | 2% | 1.0% | **2%** | 4% | 3% | 2% | **4%** | 2% | 4% | 3% | **2%** | 4% | 4% | 6% | **4%** | 4% | 4% | 6% | **4%** |
| 110%-150% | 0.7% | 0.6% | 0.3% | **0.6%** | 2% | 1% | 0.8% | **2%** | 6% | 3% | 1% | **6%** | 11% | 10% | 3% | **11%** | 11% | 12% | 4% | **11%** | 10% | 11% | 7% | **10%** | 10% | 10% | 9% | **10%** |
| > 150% | 0.03% | 0% | 0.03% | **0%** | 0.6% | 0.3% | 0.2% | **0.6%** | 2% | 0.5% | 0.5% | **2%** | 4% | 1% | 0.8% | **4%** | 8% | 3% | 1% | **8%** | 13% | 7% | 2% | **13%** | 16% | 9% | 3% | **16%** |
| ***PV Curtailment Assessment (extrapolation of metrics)*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | 0.9% | 100% | 85% | **100%** | 72% | 100% | 73% | **100%** | 61% | 100% | 64% | **100%** | 66% | 100% | 70% | **100%** | 76% | 100% | 77% | **100%** | 82% | 100% | 81% | **100%** | 83% | 100% | 85% | **100%** |
| Aggregate Export – Total PV Curtailment (GWh) | 0 | 0.1 | 0.1 | **19** | 0.01 | 0.1 | 0.1 | **32** | 0.07 | 0.2 | 0.2 | **59** | 0.2 | 0.4 | 0.3 | **117** | 0.3 | 0.5 | 0.4 | **156** | 0.3 | 0.6 | 0.6 | **204** | 0.4 | 0.7 | 0.7 | **244** |
| Aggregate Export – Percentage of PV Curtailment | 0% | 7% | 7% | **6%** | 0.8% | 10% | 8% | **8%** | 8% | 15% | 12% | **12%** | 19% | 25% | 22% | **22%** | 24% | 28% | 26% | **26%** | 27% | 30% | 30% | **30%** | 28% | 31% | 33% | **32%** |
| ***EV Management Assessment (extrapolation of metrics)*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | - | - | - | - | - | - | - | - | 9% | 9% | 8% | **9%** | 12% | 12% | 11% | **12%** | 16% | 16% | 15% | **16%** | 20% | 20% | 19% | **20%** | 24% | 24% | 23% | **24%** |
| Average EV Charging Delay (h) | - | - | - | - | - | - | - | - | 3.1 | 2.8 | 3.2 | **3.2** | 4.5 | 3.9 | 4.7 | **4.7** | 4.4 | 4.4 | 4.9 | **4.9** | 4.1 | 4.5 | 4.8 | **4.8** | 4 | 4.4 | 4.7 | **4.7** |

# Appendix 21: Full Impact Assessment Table (With DOE) – TSTS

| Subtransmission Network – TSTS (With DOEs) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
| Day Type | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | 359 | 343 | 317 | 359 | 433 | 413 | 336 | 433 | 530 | 509 | 404 | 530 | 647 | 606 | 471 | 647 | 755 | 696 | 535 | 755 | 861 | 781 | 597 | 861 | 936 | 836 | 639 | 936 |
| Increase of Max. Demand at Terminal Station (MVA) | - | - | - | - | 20% | 20% | 6% | 20% | 23% | 23% | 20% | 23% | 22% | 19% | 17% | 22% | 17% | 15% | 14% | 17% | 14% | 12% | 12% | 14% | 9% | 7% | 7% | 9% |
| Power Factor at Terminal Station for Max. Demand | 0.99 | 0.99 | 1.00 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.97 | 0.98 | 0.99 | 0.97 | 0.97 | 0.97 | 0.98 | 0.97 | 0.96 | 0.96 | 0.97 | 0.96 | 0.95 | 0.96 | 0.96 | 0.95 | 0.95 | 0.95 | 0.96 | 0.95 |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Percentage of Buses with Voltage Drop Issues | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Maximum Voltage (pu) | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 |
| Minimum Voltage (pu) | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.98 | 0.98 | 0.99 | 0.98 |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – <= 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 0% | 33% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 67% | 0% | 100% | 33% | 33% | 0% | 33% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.2 | 1.5 | 0 | 3.2 | 5.5 | 2.5 | 0 | 5.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – 110%-150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 67% | 67% | 0% | 67% | 100% | 100% | 0% | 100% | 100% | 100% | 0% | 100% |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.5 | 1.5 | 0 | 4.5 | 7 | 2.7 | 0 | 7 | 8.3 | 3.5 | 0 | 8.3 |
| HV Transformers – Percentage of Transformers with Maximum Utilisation – > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HV Transformers – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HV Transformers – Max. Utilisation of the Worst Performing Transformer | 77% | 73% | 66% | 77% | 86% | 81% | 67% | 86% | 96% | 92% | 73% | 96% | 108% | 104% | 80% | 108% | 118% | 114% | 88% | 118% | 130% | 124% | 95% | 130% | 138% | 130% | 99% | 138% |
| HV Lines – Percentage of Lines with Maximum Utilisation – <= 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| HV Lines – Percentage of Lines with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HV Lines – Percentage of Lines with Maximum Utilisation – 110%-150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HV Lines – Percentage of Lines with Maximum Utilisation – > 150% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| HV Lines – Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HV Lines – Max. Utilisation of the Worst Performing Line | 52% | 50% | 44% | 52% | 59% | 56% | 46% | 59% | 66% | 64% | 49% | 66% | 76% | 73% | 55% | 76% | 84% | 80% | 60% | 84% | 93% | 88% | 65% | 93% | 100% | 93% | 68% | 100% |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | 0.2% | 0.1% | 0.04% | 0.2% | 1% | 0.8% | 0.2% | 1% | 3% | 1% | 0.7% | 3% | 4% | 2% | 1% | 4% | 5.1% | 2% | 2% | 5.1% | 6% | 2% | 2% | 6% | 5.5% | 2% | 2% | 5.5% |
| Residential Voltage Drop Non-Compliance | 0.6% | 2% | 0.4% | 2% | 4% | 3% | 1% | 4% | 8% | 5% | 3% | 8% | 12% | 5% | 4% | 12% | 15% | 7% | 7% | 15% | 20% | 10% | 10% | 20% | 24% | 11% | 11% | 24% |
| Percentage of LV Networks with Voltage Rise Issues | 0.8% | 0.5% | 0.6% | 0.8% | 9% | 4% | 3% | 9% | 13% | 6% | 7% | 13% | 14% | 5% | 7% | 14% | 13% | 8% | 9% | 13% | 15% | 7% | 10% | 15% | 15% | 6% | 8% | 15% |
| Percentage of LV Networks with Voltage Drop Issues | 5% | 10% | 5% | 10% | 17% | 16% | 10% | 17% | 20% | 19% | 15% | 20% | 22% | 22% | 18% | 22% | 26% | 25% | 19% | 26% | 31% | 26% | 21% | 31% | 35% | 27% | 22% | 35% |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | 0.8% | 0.5% | 0% | 0.8% | 8% | 4% | 1% | 8% | 13% | 6% | 7% | 13% | 14% | 5% | 6% | 14% | 13% | 8% | 8% | 13% | 15% | 7% | 10% | 15% | 15% | 6% | 8% | 15% |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation – <= 100% | 100% | 100% | 100% | 100% | 97% | 99% | 100% | 97% | 87% | 94% | 100% | 87% | 73% | 78% | 97% | 73% | 69% | 71% | 92% | 69% | 65% | 68% | 82% | 65% | 62% | 66% | 79% | 62% |
| Percentage of Distribution Transformers with Maximum Utilisation – 100%-110% | 0% | 0% | 0% | 0% | 2% | 0.8% | 0% | 2% | 3% | 3% | 0.2% | 3% | 6% | 4% | 2% | 6% | 3% | 5% | 4% | 3% | 4% | 3% | 9% | 4% | 4% | 3% | 9% | 4% |
| Percentage of Distribution Transformers with Maximum Utilisation – 110%-150% | 0.2% | 0.2% | 0% | 0.2% | 0.2% | 0.2% | 0% | 0.2% | 9% | 3% | 0% | 9% | 19% | 17% | 1% | 19% | 17% | 20% | 4% | 17% | 12% | 16% | 8% | 12% | 11% | 13% | 13% | 11% |
| Percentage of Distribution Transformers with Maximum Utilisation – > 150% | 0% | 0% | 0% | 0% | 0.2% | 0.2% | 0% | 0.2% | 0.5% | 0.2% | 0% | 0.5% | 3% | 0.8% | 0% | 3% | 11% | 5% | 0% | 11% | 19% | 13% | 0% | 19% | 24% | 17% | 0.2% | 24% |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | 0.6% | 100% | 85% | 100% | 73% | 100% | 74% | 100% | 62% | 100% | 67% | 100% | 71% | 100% | 80% | 100% | 81% | 100% | 85% | 100% | 86% | 100% | 89% | 100% | 87% | 100% | 91% | 100% |
| Aggregate Export – Total PV Curtailment (GWh) | 0 | 0.1 | 0.05 | 17 | 0.01 | 0.1 | 0.1 | 28 | 0.06 | 0.2 | 0.2 | 54 | 0.2 | 0.4 | 0.3 | 106 | 0.2 | 0.5 | 0.4 | 145 | 0.3 | 0.6 | 0.5 | 193 | 0.4 | 0.7 | 0.7 | 230 |
| Aggregate Export – Percentage of PV Curtailment | 0% | 7% | 7% | 6% | 1% | 10% | 8% | 8% | 8% | 17% | 13% | 13% | 19% | 27% | 23% | 23% | 25% | 30% | 28% | 28% | 28% | 33% | 33% | 32% | 30% | 33% | 36% | 35% |
| *EV Management Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | - | - | - | - | - | - | - | - | 9% | 9% | 8% | 9% | 12% | 12% | 11% | 12% | 16% | 16% | 15% | 16% | 20% | 20% | 20% | 20% | 24% | 24% | 23% | 24% |
| Average EV Charging Delay (h) | - | - | - | - | - | - | - | - | 3.5 | 2.9 | 3.4 | 3.5 | 4.9 | 4.3 | 5.1 | 5.1 | 4.7 | 4.7 | 5.4 | 5.4 | 4.4 | 4.8 | 5.4 | 5.4 | 4.3 | 4.7 | 5.3 | 5.3 |

# Appendix 22: Full Impact Assessment Table (With DOE) – TTS

**Subtransmission Network – TTS (With DOEs)**

| Year | | | 2023 | | | | 2028 | | | | 2033 | | | | 2038 | | | | 2043 | | | | 2048 | | | | 2053 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day Type | | | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long | Winter Peak | Summer Peak | Spring Shoulder | Year Long |
| *Terminal Station Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Maximum Demand at Terminal Station (MVA) | | | 254 | 239 | 215 | **254** | 340 | 318 | 241 | **340** | 468 | 437 | 319 | **468** | 626 | 572 | 401 | **626** | 785 | 705 | 484 | **785** | 918 | 815 | 570 | **918** | 1013 | 886 | 631 | **1013** |
| Increase of Max. Demand at Terminal Station (MVA) | | | - | - | - | **-** | 34% | 33% | 12% | **34%** | 38% | 37% | 32% | **38%** | 34% | 31% | 26% | **34%** | 25% | 23% | 21% | **25%** | 17% | 16% | 18% | **17%** | 10% | 9% | 11% | **10%** |
| Power Factor at Terminal Station for Max. Demand | | | 1.00 | 1.00 | 1.00 | **1.00** | 0.98 | 0.99 | 1.00 | **0.98** | 0.95 | 0.96 | 0.99 | **0.95** | 0.92 | 0.92 | 0.97 | **0.92** | 0.87 | 0.89 | 0.94 | **0.87** | 0.84 | 0.86 | 0.92 | **0.84** | 0.81 | 0.84 | 0.90 | **0.81** |
| Aggregated Demand/Generation Per Technology (MVA) During Peak Demand Day | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |  | | | |
| *HV Voltage Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Buses with Voltage Rise Issues | | | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** |
| Percentage of Buses with Voltage Drop Issues | | | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 8% | 8% | 0% | **8%** | 54% | 31% | 0% | **54%** | 54% | 54% | 0% | **54%** |
| Maximum Voltage (pu) | | | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** | 1.02 | 1.02 | 1.02 | **1.02** |
| Minimum Voltage (pu) | | | 0.99 | 0.99 | 0.99 | **0.99** | 0.97 | 0.98 | 0.99 | **0.97** | 0.95 | 0.96 | 0.98 | **0.95** | 0.93 | 0.94 | 0.96 | **0.93** | 0.82 | 0.87 | 0.95 | **0.82** | 0.78 | 0.81 | 0.94 | **0.78** | 0.75 | 0.78 | 0.91 | **0.75** |
| *HV Thermal Assessment (model-based simulations)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| HV Transformers | Percentage of Transformers with Maximum Utilisation | <= 100% | 100% | 100% | 100% | **100%** | 43% | 57% | 100% | **43%** | 14% | 14% | 57% | **14%** | 14% | 14% | 29% | **14%** | 0% | 0% | 14% | **0%** | 0% | 0% | 14% | **0%** | 0% | 0% | 0% | **0%** |
| | | 100%-110% | 0% | 0% | 0% | **0%** | 14% | 43% | 0% | **14%** | 0% | 14% | 43% | **0%** | 0% | 0% | 14% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 14% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 1.5 | 2.0 | 0 | **1.5** | 0 | 1.5 | 0.5 | **0** | 0 | 0 | 0.5 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 3.5 | **0** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 43% | 0% | 0% | **43%** | 86% | 71% | 0% | **86%** | 29% | 29% | 57% | **29%** | 14% | 29% | 71% | **14%** | 0% | 14% | 43% | **0%** | 0% | 0% | 29% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 1.5 | 0 | 0 | **1.5** | 7.4 | 3.5 | 0 | **7.4** | 11.3 | 4.5 | 2.4 | **11.3** | 17.0 | 9.3 | 4.8 | **17.0** | 0 | 16.5 | 4.5 | **0** | 0 | 0 | 4 | **0** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 57% | 57% | 0% | **57%** | 86% | 71% | 14% | **86%** | 100% | 86% | 43% | **100%** | 100% | 100% | 57% | **100%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 7.8 | 2.8 | 0 | **7.8** | 11.6 | 6.1 | 2.0 | **11.6** | 15.1 | 11.0 | 2 | **15.1** | 16.9 | 10.7 | 2.5 | **16.9** |
| | Max. Utilisation of the Worst Performing Transformer | | 92% | 88% | 80% | **92%** | 114% | 107% | 84% | **114%** | 149% | 140% | 105% | **149%** | 198% | 178% | 130% | **198%** | 232% | 216% | 158% | **232%** | 252% | 240% | 181% | **252%** | 273% | 246% | 196% | **273%** |
| HV Lines | Percentage of Lines with Maximum Utilisation | <= 100% | 100% | 100% | 100% | **100%** | 100% | 100% | 100% | **100%** | 90% | 90% | 100% | **90%** | 80% | 80% | 100% | **80%** | 60% | 60% | 90% | **60%** | 60% | 60% | 80% | **60%** | 60% | 60% | 80% | **60%** |
| | | 100%-110% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 10% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 20% | 0% | **0%** | 0% | 0% | 10% | **0%** | 0% | 0% | 0% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 2.0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 1.5 | 0 | **0** | 0 | 0 | 2.0 | **0** | 0 | 0 | 0 | **0** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 10% | 0% | 0% | **10%** | 20% | 20% | 0% | **20%** | 20% | 10% | 10% | **20%** | 20% | 20% | 10% | **20%** | 0% | 20% | 20% | **0%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 1.5 | 0 | 0 | **1.5** | 7.3 | 3.0 | 0 | **7.3** | 1.0 | 4.5 | 1.0 | **1.0** | 8.5 | 2.5 | 2.0 | **8.5** | 0 | 4.0 | 2.5 | **0** |
| | | > 150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 20% | 10% | 0% | **20%** | 20% | 20% | 0% | **20%** | 40% | 20% | 0% | **40%** |
| | | Avg. Overloading Duration (hr) 3 | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 0 | 0 | 0 | **0** | 4.5 | 3.0 | 0 | **4.5** | 11.8 | 4.0 | 0 | **11.8** | 7.9 | 9.3 | 0 | **7.9** |
| | Max. Utilisation of the Worst Performing Line | | 65% | 61% | 55% | **65%** | 85% | 79% | 60% | **85%** | 112% | 106% | 77% | **112%** | 147% | 136% | 95% | **147%** | 186% | 168% | 112% | **186%** | 214% | 193% | 132% | **214%** | 229% | 208% | 147% | **229%** |
| *MV-LV Voltage Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Residential Voltage Rise Non-Compliance | | | 0.04% | 0% | 0.1% | **0.1%** | 0.8% | 0.2% | 0.2% | **0.8%** | 2% | 0.3% | 0.4% | **2%** | 2% | 0.4% | 0.5% | **2%** | 3% | 0.5% | 1% | **3%** | 4% | 0.9% | 0.9% | **4%** | 3% | 0.6% | 0.7% | **3%** |
| Residential Voltage Drop Non-Compliance | | | 0.5% | 1% | 0.2% | **1%** | 3% | 3% | 1% | **3%** | 7% | 5% | 2% | **7%** | 11% | 4% | 3% | **11%** | 15% | 7% | 6% | **15%** | 19% | 9% | 9% | **19%** | 23% | 10% | 10% | **23%** |
| Percentage of LV Networks with Voltage Rise Issues | | | 1% | 0% | 1% | **1%** | 13% | 6% | 4% | **13%** | 20% | 10% | 11% | **20%** | 21% | 6% | 10% | **21%** | 19% | 11% | 13% | **19%** | 22% | 10% | 14% | **22%** | 21% | 7% | 11% | **21%** |
| Percentage of LV Networks with Voltage Drop Issues | | | 7% | 15% | 7% | **15%** | 26% | 25% | 15% | **26%** | 31% | 30% | 23% | **31%** | 31% | 32% | 27% | **32%** | 37% | 35% | 28% | **37%** | 38% | 34% | 31% | **38%** | 43% | 36% | 32% | **43%** |
| Percentage of LV Networks with Both Voltage Rise&Drop Issues | | | 1% | 0% | 0% | **1%** | 13% | 6% | 2% | **13%** | 20% | 10% | 10% | **20%** | 21% | 6% | 9% | **21%** | 19% | 11% | 11% | **19%** | 21% | 10% | 14% | **21%** | 21% | 7% | 11% | **21%** |
| *MV-LV Thermal Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of Distribution Transformers with Maximum Utilisation | | <= 100% | 100% | 100% | 100% | **100%** | 96% | 99% | 100% | **96%** | 78% | 91% | 100% | **78%** | 54% | 64% | 96% | **54%** | 48% | 52% | 89% | **48%** | 45% | 49% | 72% | **45%** | 41% | 47% | 67% | **41%** |
| | | 100%-110% | 0% | 0% | 0% | **0%** | 4% | 1% | 0% | **4%** | 6% | 5% | 0% | **6%** | 10% | 8% | 3% | **10%** | 5% | 7% | 6% | **5%** | 5% | 3% | 15% | **5%** | 4% | 3% | 14% | **4%** |
| | | 110%-150% | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 16% | 4% | 0% | **16%** | 32% | 28% | 0.7% | **32%** | 28% | 32% | 5% | **28%** | 17% | 26% | 13% | **17%** | 15% | 21% | 20% | **15%** |
| | | > 150% | 0.0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 0% | 0% | 0% | **0%** | 4% | 1% | 0% | **4%** | 19% | 8% | 0% | **19%** | 33% | 21% | 0% | **33%** | 40% | 29% | 0% | **40%** |
| *PV Curtailment Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of PV Customers Curtailed | | | 0% | 100% | 85% | **100%** | 73% | 100% | 74% | **100%** | 61% | 100% | 68% | **100%** | 72% | 100% | 83% | **100%** | 83% | 100% | 89% | **100%** | 88% | 100% | 93% | **100%** | 89% | 100% | 95% | **100%** |
| Aggregate Export | Total PV Curtailment (GWh) | | 0 | 0.1 | 0.1 | **20** | 0.01 | 0.1 | 0.1 | **34** | 0.07 | 0.2 | 0.2 | **63** | 0.2 | 0.4 | 0.3 | **122** | 0.3 | 0.6 | 0.5 | **170** | 0.4 | 0.7 | 0.7 | **232** | 0.4 | 0.8 | 0.8 | **276** |
| | Percentage of PV Curtailment | | 0% | 7% | 7% | **6%** | 1% | 10% | 8% | **8%** | 7% | 17% | 13% | **13%** | 18% | 27% | 22% | **22%** | 24% | 31% | 27% | **27%** | 28% | 34% | 33% | **33%** | 30% | 34% | 36% | **35%** |
| *EV Management Assessment (extrapolation of metrics)* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of EVs Affected | | | - | - | - | - | - | - | - | - | 9% | 9% | 9% | **9%** | 13% | 13% | 12% | **13%** | 16% | 16% | 16% | **16%** | 21% | 20% | 20% | **21%** | 24% | 24% | 23% | **24%** |
| Average EV Charging Delay (h) | | | - | - | - | - | - | - | - | - | 3.8 | 2.9 | 3.4 | **3.8** | 5.1 | 4.5 | 5.2 | **5.2** | 4.8 | 4.8 | 5.7 | **5.7** | 4.6 | 4.9 | 5.7 | **5.7** | 4.5 | 4.9 | 5.5 | **5.5** |