Islanding Design and Cost Analysis for Donald and Tarnagulla Microgrid Feasibility Study

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Project Overview

Task 1: Developing D&T Microgrid Model

A. Microgrid power system and power electronics modelling

B. Microgrid economic modelling

Task 2: Assessing Islanding Design (Options)

A. Identifying the potential islanding options and requirements

B. Assessing islanding impacts

Task 3: Performing Cost Estimation and Reliability Analysis

A. Cost estimation for all shortlisted islanded options

B. Microgrid reliability analysis

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Research Methodology

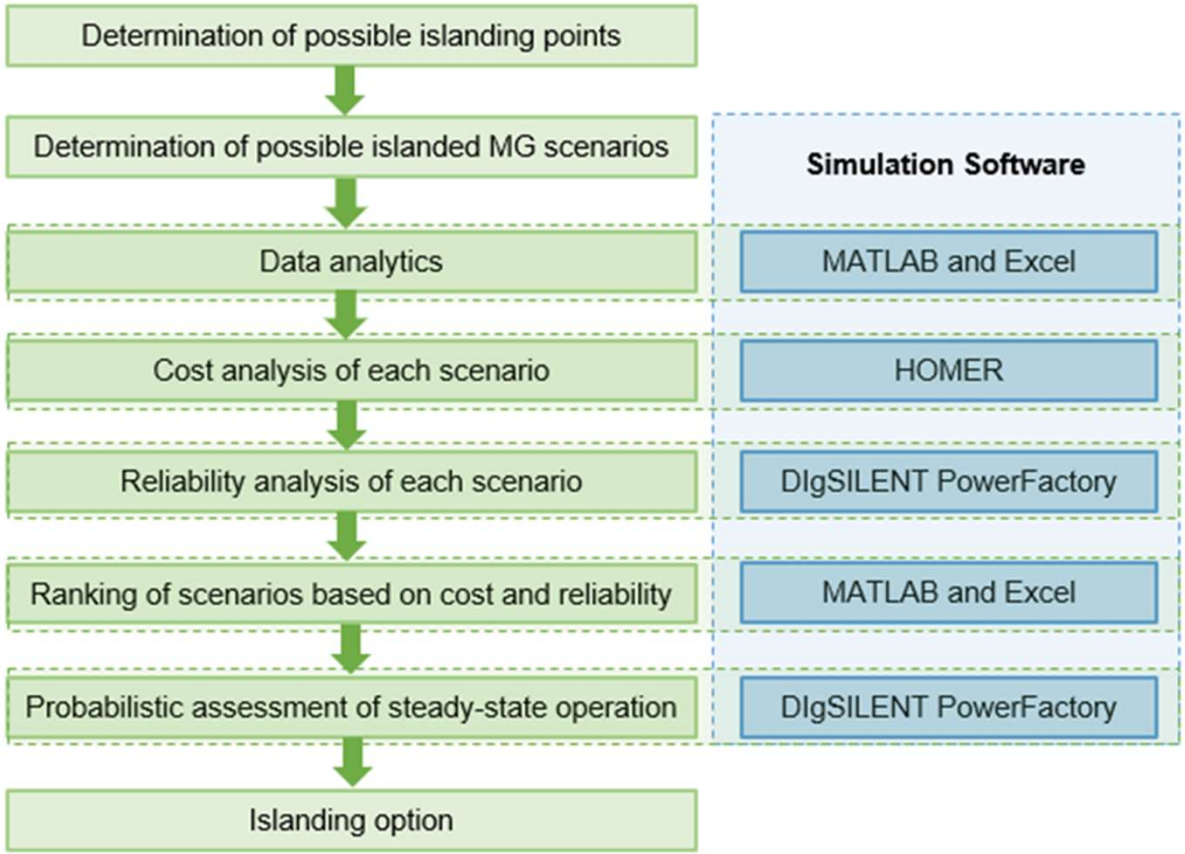

Figure: Research methodology to identify optimal islanding option(s).

This research has taken a progressive approach to identify the optimal islanding design options.

The optimal islanding options has been chosen based on the

(1) cost analysis only,
(2) reliability analysis only, and
(3) combined reliability and cost analysis.

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1

System Modelling for Islanding Design

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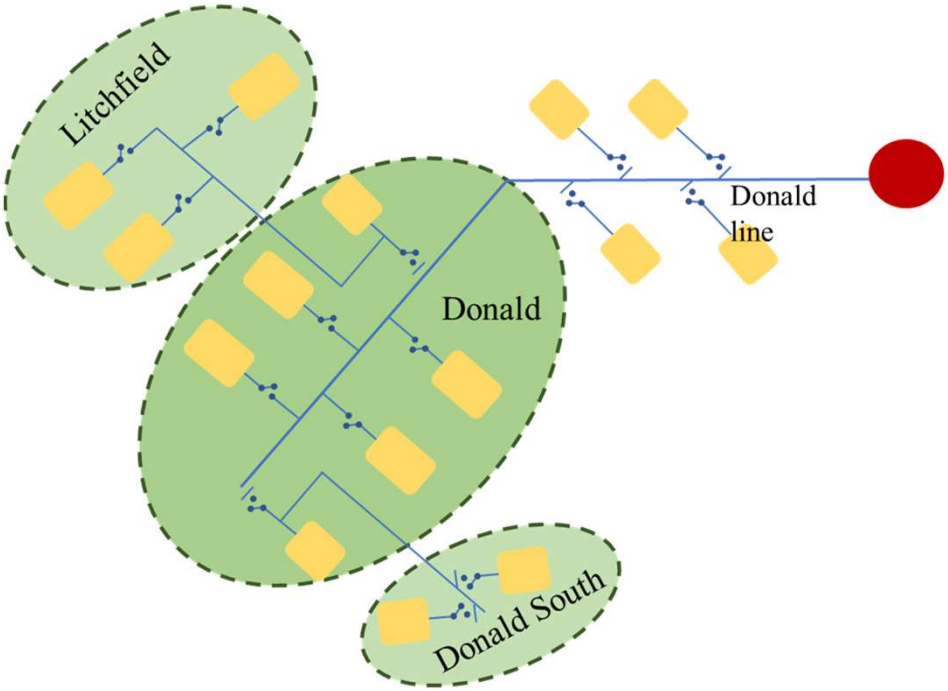
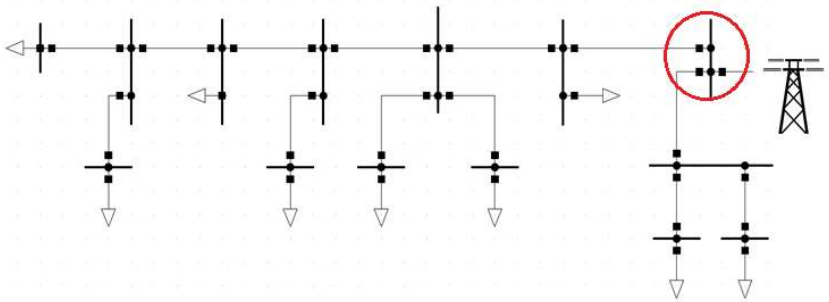
Donald and Tarnagulla Networks



Donald Network



Tarnagulla Network

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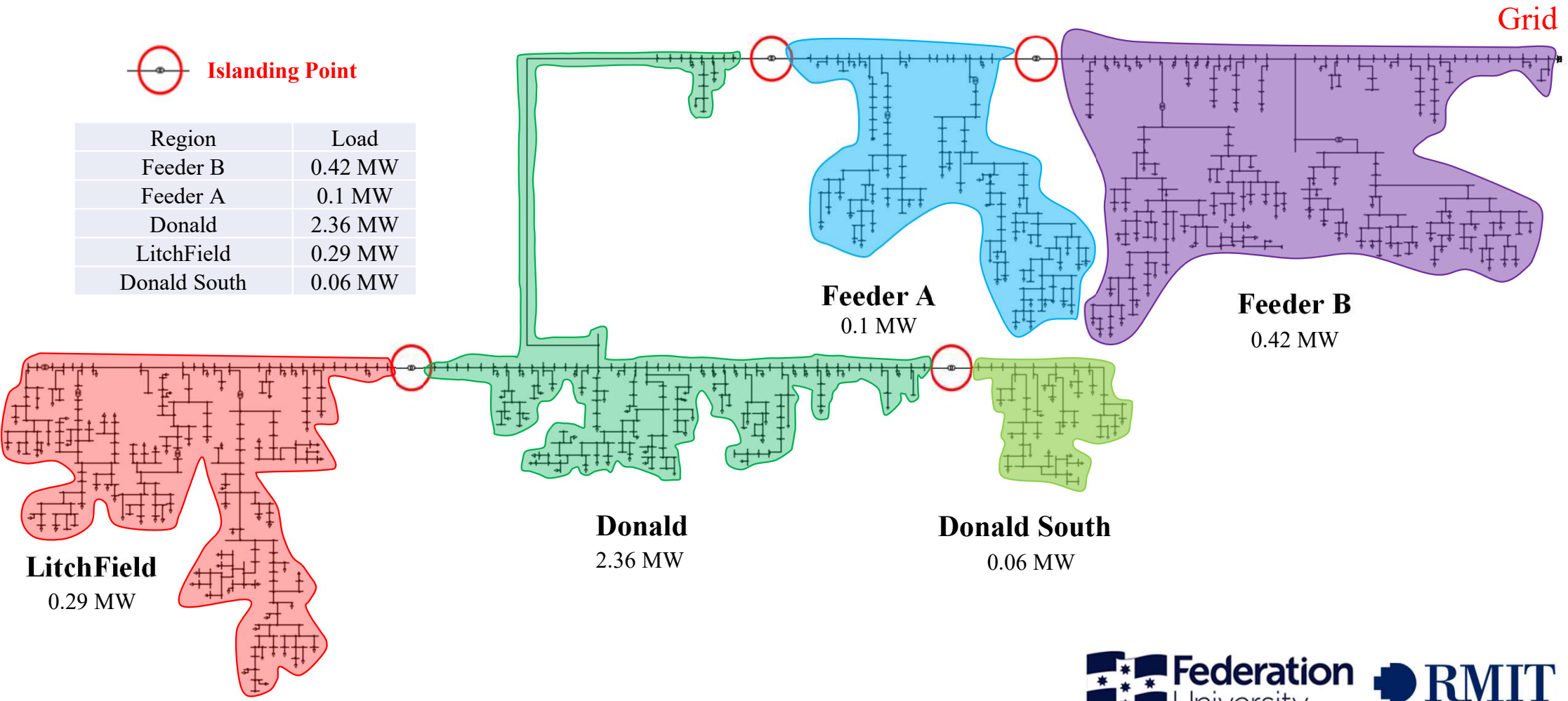
Possible Islanding Option (1): Donald Network



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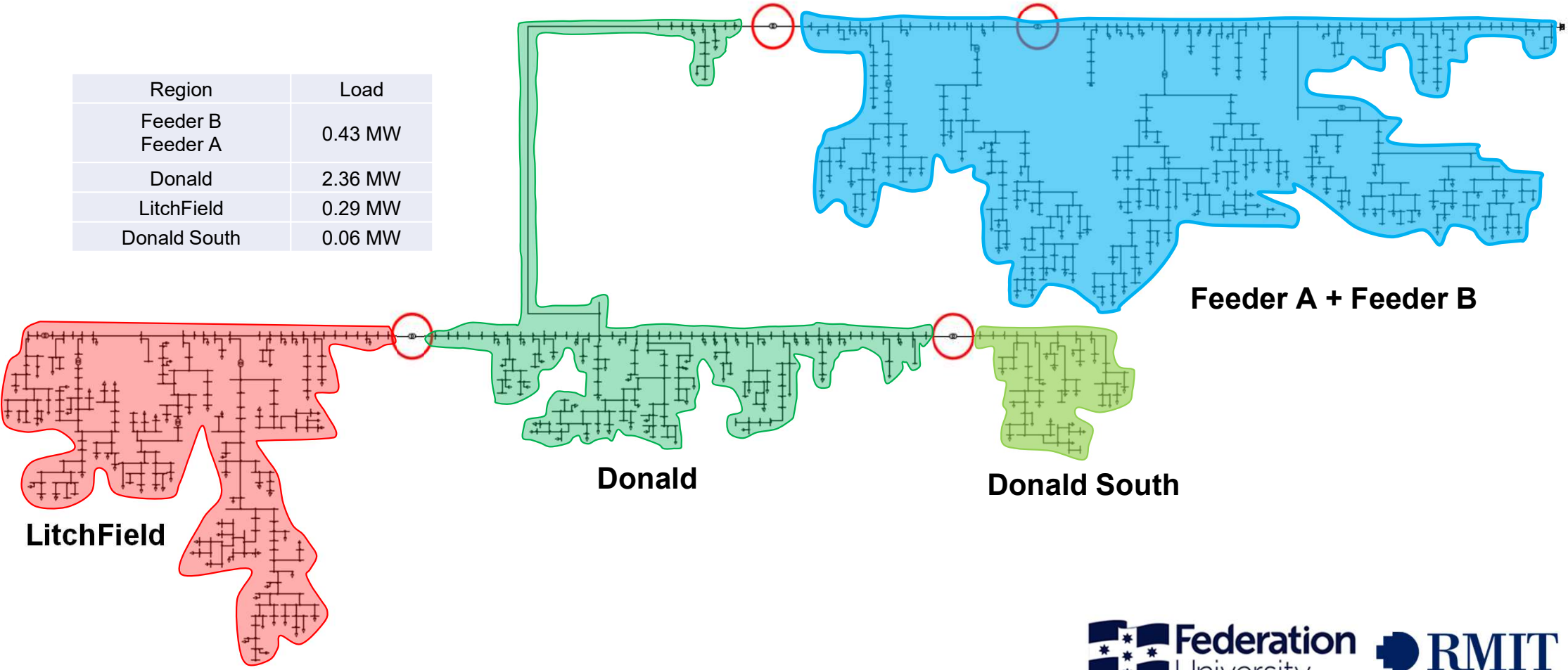
Possible Islanding Option (2): Donald Network

Region	Load
Feeder B Feeder A	0.43 MW
Donald	2.36 MW
LitchField	0.29 MW
Donald South	0.06 MW



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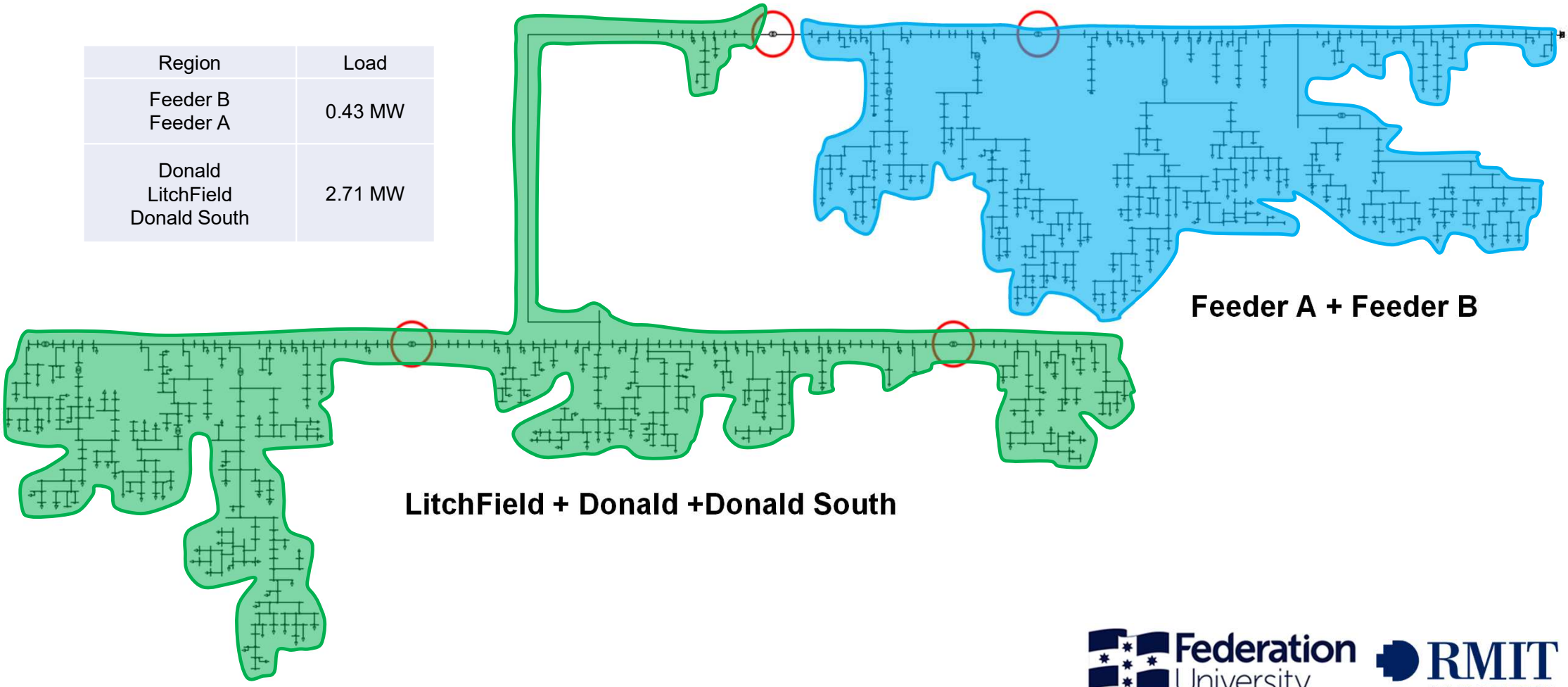
Possible Islanding Option (3): Donald Network

Region	Load
Feeder B Feeder A	0.43 MW
Donald LitchField Donald South	2.71 MW



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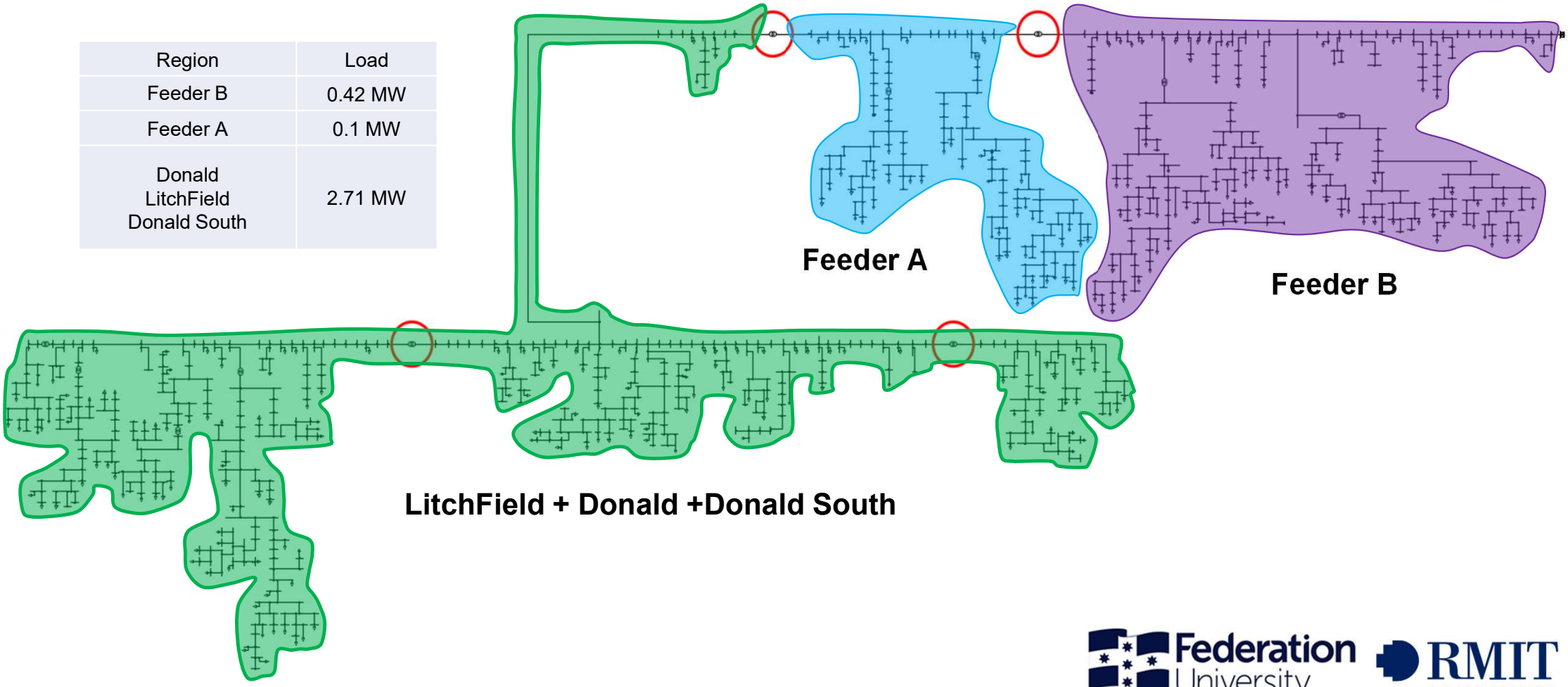
Possible Islanding Option (4): Donald Network

Region	Load
Feeder B	0.42 MW
Feeder A	0.1 MW
Donald LitchField Donald South	2.71 MW



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Totally off-grid

All Possible Islanding Scenarios: Donald Network

Scenario	Grid	Feeder B	Feeder A	Donald	Donald South	Litchfield
S1	0	0	0	0	0	0
S2	0	0	0	1	1	0
S3	0	0	0	1	0	1
S4	0	0	0	1	1	1
S5	0	1	1	0	0	0
S6	0	2	2	1	1	0
S7	0	2	2	1	0	1
S8	0	2	2	1	1	1
S9	0	0	1	1	0	0
S10	0	0	1	1	1	0
S11	0	0	1	1	0	1
S12	0	0	1	1	1	1
S13	0	1	1	1	0	0
S14	0	1	1	1	1	0
S15	0	1	1	1	0	1
S16	0	1	1	1	1	1

Number & Colour	Description
0	Individual feeder islanded
1	Area islanded scenarios
2	Different area islanded scenarios

- **16 possible islanded scenarios have been considered for cost estimation and reliability analysis.**
- **Scenarios represent single islands and/or clusters of islands.**
- **All of these islands are designed to (electrically) operate independently.**

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Partially grid-connected

All Possible Islanding Scenarios: Donald Network

Scenario	Grid	Feeder	Feeder	Donald	Donald	Litchfield
S17	1	1	0	0	0	0
S18	1	1	0	2	2	0
S19	1	1	0	2	0	2
S20	1	1	0	2	2	2
S21	1	1	2	2	0	0
S22	1	1	2	2	2	0
S23	1	1	2	2	0	2
S24	1	1	2	2	2	2
S25	1	1	1	0	0	0
S26	1	1	1	2		2
S27	1	1	1	2	2	0
S28	1	1	1	2	2	2
S29	1	1	1	1	0	0
S30	1	1	1	1	0	1
S31	1	1	1	1	1	0
S32	1	1	1	1	1	1

Number & Colour	Description
0	Individual feeder islanded
1	Area islanded scenarios
2	Different area islanded scenarios

- 16 possible (partially grid-connected) islanded scenarios have been considered for cost estimation and reliability analysis.
- Scenarios represent single islands and/or clusters of islands.
- All of these islands are designed to (electrically) operate independently.

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All Possible Islanding Scenarios: Donald Network

Totally off-grid Islanded Scenarios

Scenario	Grid	Feeder B	Feeder A	Donald	Donald South	Litchfield
S1	0	0	0	0	0	0
S2	0	0	0	1	1	0
S3	0	0	0	1	0	1
S4	0	0	0	1	1	1
S5	0	1	1	0	0	0
S6	0	2	2	1	1	0
S7	0	2	2	1	0	1
S8	0	2	2	1	1	1
S9	0	0	1	1	0	0
S10	0	0	1	1	1	0
S11	0	0	1	1	0	1
S12	0	0	1	1	1	1
S13	0	1	1	1	0	0
S14	0	1	1	1	1	0
S15	0	1	1	1	0	1
S16	0	1	1	1	1	1

Number & Colour	Description
0	Individual feeder islanded
1	Area islanded scenarios
2	Different area islanded scenarios

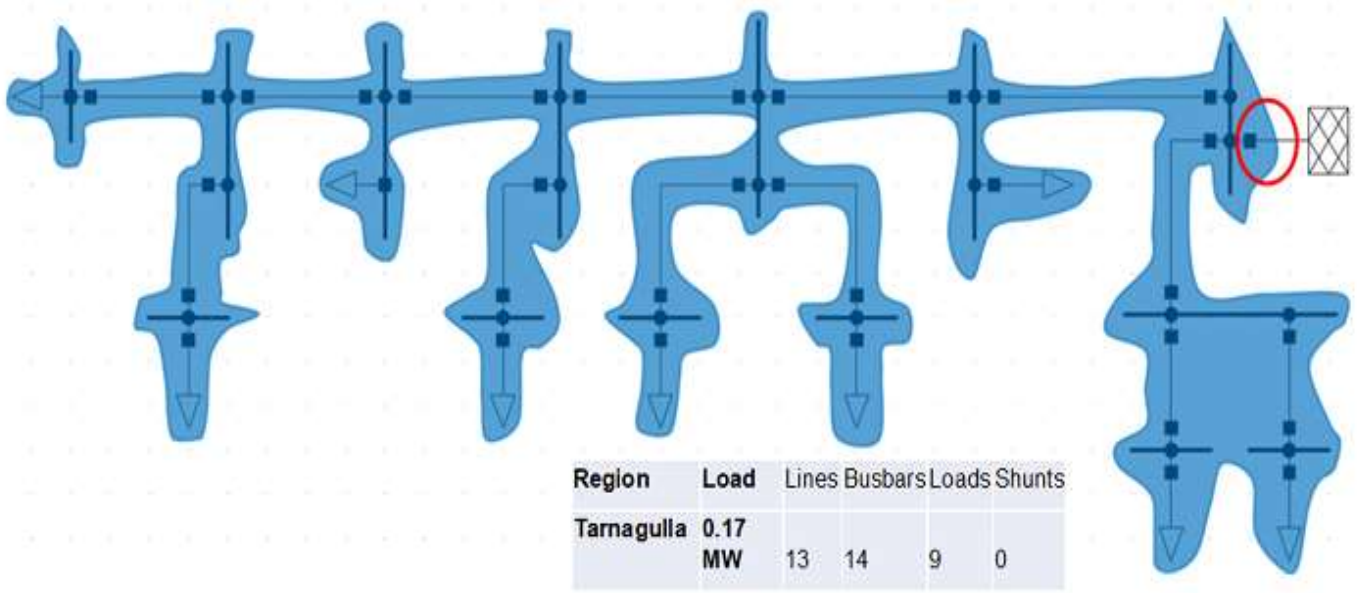
Partially Grid-connected Scenarios

Scenario	Grid	Feeder	Feeder	Donald	Donald	Litchfield
S17	1	1	0	0	0	0
S18	1	1	0	2	2	0
S19	1	1	0	2	0	2
S20	1	1	0	2	2	2
S21	1	1	2	2	0	0
S22	1	1	2	2	2	0
S23	1	1	2	2	0	2
S24	1	1	2	2	2	2
S25	1	1	1	0	0	0
S26	1	1	1	2		2
S27	1	1	1	2	2	0
S28	1	1	1	2	2	2
S29	1	1	1	1	0	0
S30	1	1	1	1	0	1
S31	1	1	1	1	1	0
S32	1	1	1	1	1	1

Number & Colour	Description
0	Individual feeder islanded
1	Area islanded scenarios
2	Different area islanded scenarios

- Total 32 scenarios represent single islands and/or clusters of islands.
- 32 islanded scenarios have been considered for cost estimation and reliability analysis.
- All of these islands are designed to (electrically) operate independently.

Possible Islanding Option: Tarnagulla Network



Region	Load	Lines	Busbars	Loads	Shunts
Tarnagulla	0.17 MW	13	14	9	0

- **Being a smaller network, Tarnagulla network is either would be grid-connected or islanded. No cluster of islands is possible.**

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2

Economic Analysis for Islanding Options

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Optimization in Homer Software

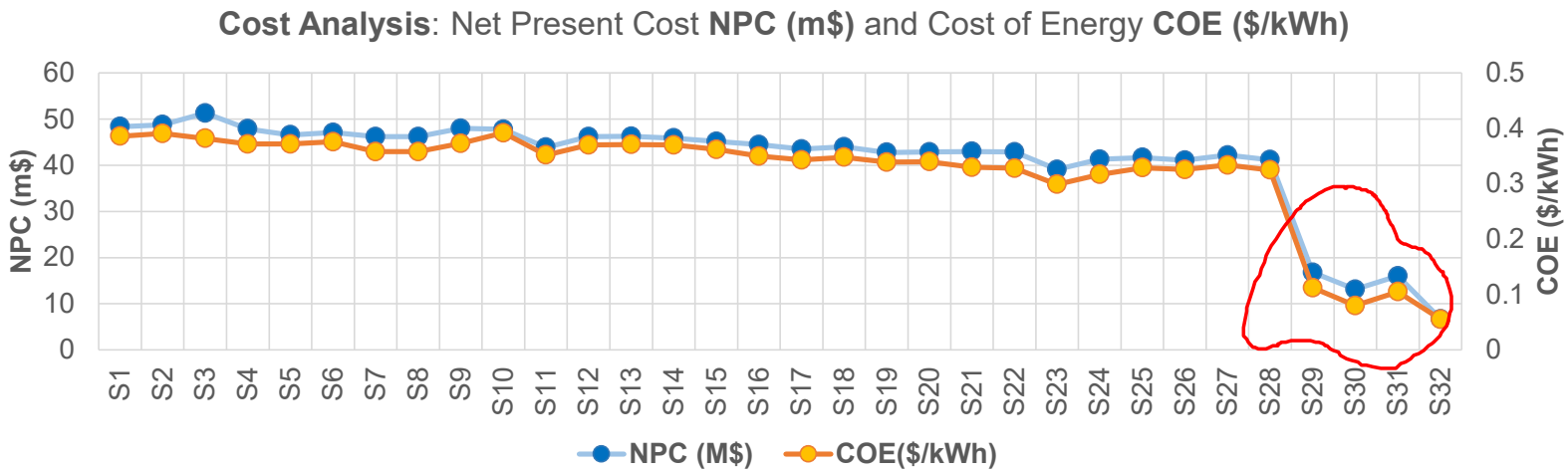
- Local **generation and load** data has been modelled for Homer input.
- All **cost information** have been provided based on the available (literature) information.
- The **load following dispatch** has been considered in Homer optimization.
- Australian NEM price has been considered for the grid-electricity scenarios.

Techno-Economic Analysis: Donald Network

Scenario S1					
Network Name	Feeder B	Feeder A	Donald	Donald South	Litchfield
Network Topology	0	0	0	0	0
Load (MW)	0.42	0.1	2.36	0.06	0.29
Required Generation					
Solar PV (kW)	229	67.8	1190	40.7	172
DG (kW)	475	110	1900	70	335
Battery Storage (kWh)	13	7	43	5	13
Converter (kW)	29.4	15.8	98.2	10.7	30.4
Network Costs					
NPC (m$)	6.56	1.80	34.35	1.08	4.62
COE ($/kWh)	0.404	0.456	0.375	0.463	0.412
Operating Cost (M$)	362,807	98,306	1.90	58.347	252,610
Total Costs					
NPC (m$)			48.41		
COE ($/kWh)			0.386		
Operating Cost (M$/yr)			4.081		

- **Economic analysis for each scenario** has been performed separately.
- **All 32 scenarios** will be compared with their Net Present Cost, **NPC (m$)** and Cost of Energy, **COE ($/kWh)**.

Cost Analysis: Donald Network



- Cost of energy (**COE**) in the islanded option(s) could be 2 to 7 times expensive then the grid connected option(s).
- Better to have **large areas connected together** in a microgrid, rather than having individual smaller ones.
- **Economically, S32 is the best option** (e.g., grid-connected option).
- System reliability analysis will be presented in the next Section.

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Cost Analysis: Tarnagulla

Tarnagulla Islanded	
Load (MW)	0.17
Required Generation	
Solar PV (kW)	134
DG (kW)	170
Battery (kWh)	12
Converter (kW)	9.7
Total Costs	
NPC (m$)	**3.50**
COE ($/kWh)	**0.420**
Operating Cost (m$/yr)	**0.194**

Tarnagulla Grid-Connected	
Load (MW)	0.17
Required Generation	
Solar PV (kW)	201
DG (kW)	70
Battery (kWh)	0
Converter (kW)	0
Total Costs	
NPC (m$)	**0.856**
COE ($/kWh)	**0.077**
Operating Cost (m$/yr)	**0.260**

- Based on the economic consideration, it is better to keep the Tarnagulla network grid-connected.
- Energy cost would be 4 times more in the islanded scenario.
- Reliability considerations will be presented in the next Section.

3

Reliability Assessment for Islanding Options

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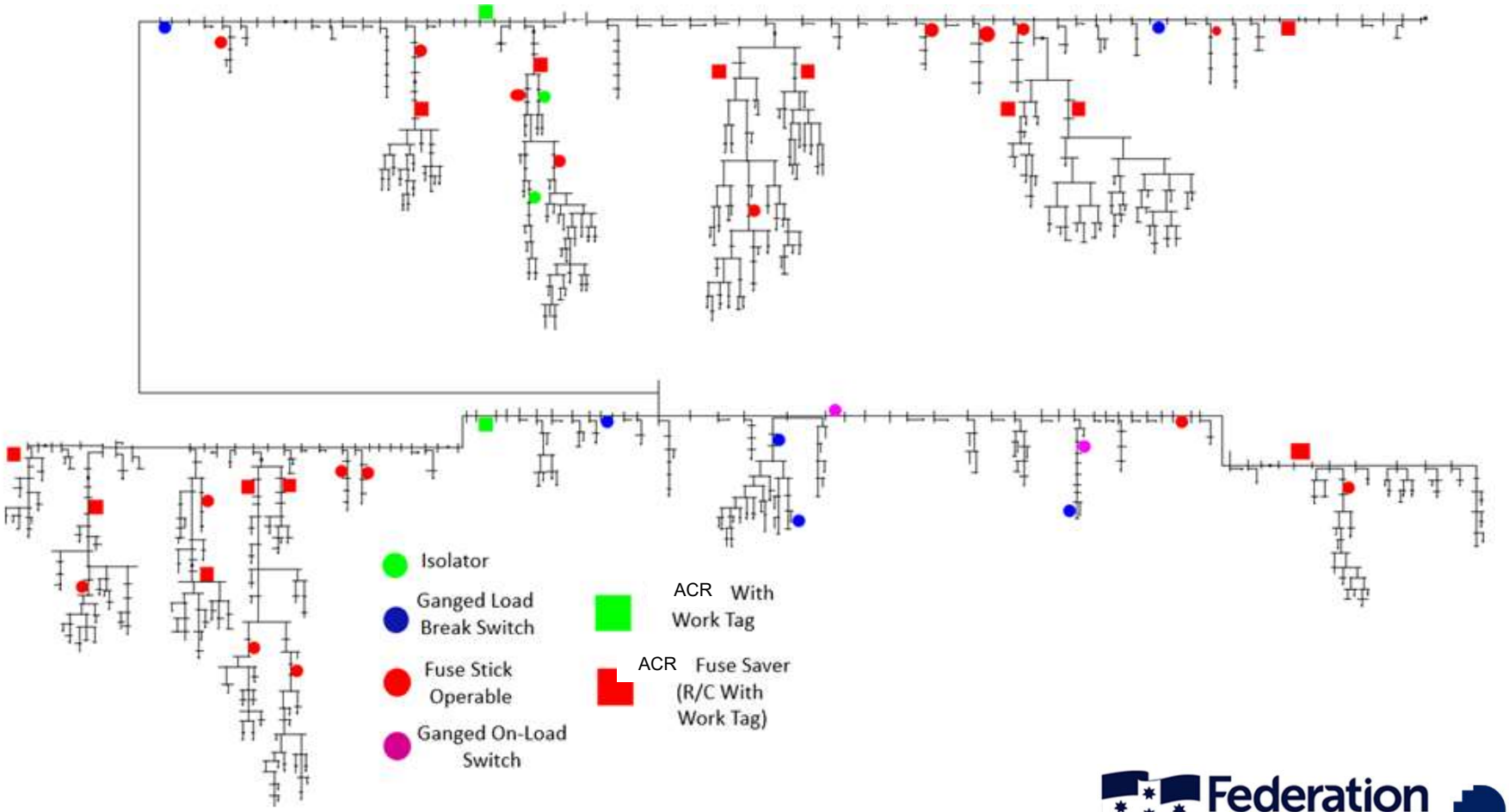
Reliability Model with Protection Equipment: Donald Network



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Reliability Analysis Approach: Donald Network

Input Reliability data		
CB at 22 kV feeder	Time to actuate switch	30 min
	CB fails to open	5%
CB at secondary side of transformer	Time to actuate switch	1 min
Terminal 22 kV	Forced Outage rate	0.0104 1/a
	Forced Outage Expectancy	0.208 h/a
	Forced Outage Duration	20 h
	Failure frequency	1.99094
Terminal 0.4 kV	Repair duration	1.914055
22 kV overhead lines	Failure frequency	0.177 1/(_a*km)
	Repair duration	10 h
	Transient fault frequency	12.5053
Solar-PV	Failure rate	0.2487
	Repair duration	40 h
Battery	Failure rate	0.2487
	Repair duration	40 h

Major reliability input data

- Outage Duration: Number of hours
- Outage Rate: Outage per year

Limitations of the reliability data

- Network specific data is proprietary
- Data has been obtained from the literature
- Literature data has been multiplied with the real network characteristics

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Reliability Indices Considered in this Study

Energy Not Served (ENS)

This index is measured in MWh/a and informs about the total amount of energy not supplied to system loads due to outages.

System Average Interruption Duration Index (SAIDI)

This index indicates the total duration of interruption for the average customer during a predefined period of time. It is commonly measured in customer minutes or customer hours of interruption. Mathematically, this is given below.

$$SAIDI = \frac{\sum Customer\ Interruption\ Durations}{Total\ Number\ of\ Customers\ Served}$$

Customer Average Interruption Duration Index (CAIDI)

CAIDI represents the average time required to restore service. Mathematically, this is given below.

$$CAIDI = \frac{\sum Customer\ Interruption\ Durations}{Total\ Number\ of\ Customers\ Interrupted} = \frac{SAIDI}{SAIFI}$$

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Reliability Indices Considered in this Study

System Average Interruption Frequency Index (SAIFI)

This index indicates the total duration of interruption for the average customer during a predefined period of time. It is commonly measured in customer minutes or customer hours of interruption. Mathematically, this equation is given below.

$$SAIFI = \frac{\sum Number\ of\ Customers\ Interrupted}{Total\ Number\ of\ Customers\ Served}$$

Customer Average Interruption Frequency Index (CAIFI)

This index gives the average frequency of sustained interruptions for those customers experiencing sustained interruptions. The customer is counted once regardless of the number of times interrupted for this calculation. Mathematically, this is given below.

$$CAIFI = \frac{\sum Total\ Number\ of\ Interruptions\ Occured}{Total\ Number\ of\ Customers\ Affected}$$

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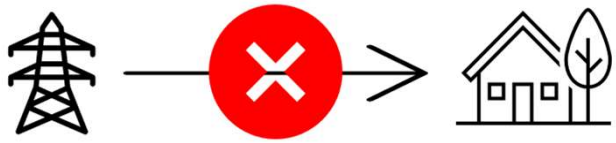
Reliability Indices: Donald Network

Islanded Scenarios

Lower values show higher reliability

Islanded Scenarios (1X)

Scenarios	Islanded Reliability Indices			
	SAIFI	CAIFI	SAIDI	ENS
S1	29.874	30.845	115.919	358.226
S2	30.951	31.079	120.145	367.129
S3	33.357	34.441	116.211	357.193
S4	34.436	34.579	120.436	366.092
S5	31.459	32.482	116.712	359.607
S6	32.536	32.671	120.937	368.51
S7	34.941	36.077	117.003	358.574
S8	36.021	36.17	121.229	367.474
S9	31.231	32.246	116.598	359.409
S10	32.309	32.443	120.824	368.312
S11	34.713	35.842	116.889	358.376
S12	35.793	35.942	121.115	367.276
S13	68.754	70.989	135.359	424.486
S14	71.385	71.682	140.362	435.006
S15	78.923	81.489	138.994	431.433
S16	81.556	81.896	143.996	441.95



ENS 358 MWh per year means **5 days of load shading** per year.

ENS (Energy Not Served) is a good measure of reliability. ENS is **358 MWh** per year means that 358 MWh energy will not be served to the system (customers) in a year.

For example, if Donald area has 1000 customer, each of them will have 358 kWh energy deficit (in a year).

358 kWh is equivalent to 5 days of energy for a 3-kW residential customer load serving for 24 hours each day.

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Reliability Indices: Donald Network

Islanded Scenarios

Islanded Scenarios (1X)

Scenarios	Islanded Reliability Indices			
	SAIFI	CAIFI	SAIDI	ENS
S1	29.874	30.845	115.919	358.226
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S11	34.713	35.842	116.889	358.376
S12	35.793	35.942	121.115	367.276
S13	68.754	70.989	135.359	424.486
S14	71.385	71.682	140.362	435.006
S15	78.923	81.489	138.994	431.433
S16	81.556	81.896	143.996	441.95

Lower values show higher reliability

Legend:

- Low Reliability
- Medium Reliability
- High Reliability

Grid Connected Scenarios

Grid Connected Scenarios (1X)

Scenarios	Islanded Reliability Indices			
	SAIFI	CAIFI	SAIDI	ENS
S17	30.298	31.283	117.614	362.75
S18	31.374	31.505	121.84	371.653
S19	33.78	34.878	117.906	361.717
S20	34.859	35.004	122.331	370.617
S21	31.655	32.684	118.293	363.933
S22	32.733	32.868	122.589	372.836
S23	35.137	36.279	118.584	362.9
S24	36.217	36.368	122.81	371.8
S25	32.024	33.065	118.486	364.271
S26	35.506	36.661	118.778	363.238
S27	33.101	33.239	122.712	373.174
S28	36.586	36.738	123.003	372.138
S29	71.248	73.564	138.098	432.494
S30	81.763	84.421	141.906	439.86
S31	73.959	74.267	143.141	443.096
S32	84.476	84.848	146.948	450.461

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Sensitivity Analysis with 1X, 2X, 5X, and 10X of Reliability Parameters

- Remote feeder failure rate is higher due to the vegetation, animal/bird interruption etc.
- Repair time if higher to identify the location of the fault and to restore the system.
- Reliability input parameters can model these (failure rate and repair time) parameters.

Grid Connected Scenarios (1X)

Case	Islanded Reliability Indices			
	SAIFI	CAIFI	SAIDI	ENS
S17	30.298	31.283	117.614	362.x
S18	31.374	31.505	121.84	371.653
S19	33.78	34.878	117.906	361.717
S20	34.859	35.004	122.331	370.617
S21	31.655	32.684	118.293	363.933
S22	32.733	32.868	122.589	372.836
S23	35.137	36.279	118.584	362.9
S24	36.217	36.368	122.81	371.8
S25	32.024	33.065	118.486	364.271
S26	35.506	36.661	118.778	363.238
S27	33.101	33.239	122.712	373.174
S28	36.586	36.738	123.003	372.138
S29	71.248	73.564	138.098	432.494
S30	81.763	84.421	141.906	439.86
S31	73.959	74.267	143.141	443.096
S32	84.476	84.848	146.948	450.461

Grid Connected Scenarios (2X)

Case	Islanded Reliability Indices			
	SAIFI	CAIFI	SAIDI	ENS
S17	31.656	32.684	133.368	404.x
S18	32.733	32.869	137.594	413.691
S19	35.138	36.28	133.66	403.755
S20	36.217	36.367	137.885	412.654
S21	33.012	34.085	134.046	405.971
S22	34.09	34.232	138.272	414.874
S23	36.495	37.681	134.338	404.938
S24	37.574	37.731	138.564	413.838
S25	34.022	35.128	136.734	410.658
S26	37.504	38.723	137.025	409.625
S27	35.099	35.244	140.959	419.56
S28	38.584	38.744	141.25	418.524
S29	81.989	84.654	160.717	494.089
S30	94.071	97.129	165.309	503.324
S31	85.064	85.418	165.942	505.07
S32	97.149	97.553	170.533	514.305

Grid Connected Scenarios (5X)

Case	Islanded Reliability Indices			
	SAIFI	CAIFI	SAIDI	ENS
S17	35.728	36.889	243.455	698.x
S18	36.805	36.958	247.681	707.454
S19	39.21	40.485	243.747	697.519
S20	40.289	40.457	247.972	706.418
S21	37.085	38.291	244.133	699.734
S22	38.163	38.322	248.36	708.638
S23	40.567	41.886	244.425	698.701
S24	41.647	41.821	248.651	707.602
S25	40.013	41.314	263.189	732.862
S26	43.4951	44.909	263.481	731.829
S27	41.089	41.261	267.415	741.765
S28	44.574	44.759	267.706	740.729
S29	14.209	117.922	300.41	862.236
S30	130.994	135.252	307.353	877.073
S31	118.378	118.871	306.182	874.354
S32	135.165	135.727	313.124	889.191

Grid Connected Scenarios (10X)

Case	Islanded Reliability Indices			
	SAIFI	CAIFI	SAIDI	ENS
S17	42.516	43.898	636.355	1746.x
S18	43.593	43.774	640.581	1755.895
S19	43.593	43.774	640.581	1755.895
S20	47.077	47.274	640.872	1754.858
S21	43.873	45.299	637.034	1748.175
S22	44.951	45.138	641.26	1757.078
S23	47.355	48.895	637.325	1747.141
S24	48.435	48.637	641.551	1756.042
S25	50.004	51.629	713.734	1881.911
S26	53.487	55.225	714.025	1880.878
S27	167.911	173.369	772.687	2087.025
S28	173.901	174.625	779.369	2101.038
S29	167.911	173.369	772.687	2087.021
S30	192.534	198.792	783.549	2111.17
S31	173.901	174.625	779.369	2101.034
S32	198.526	199.352	790.23	2125.184

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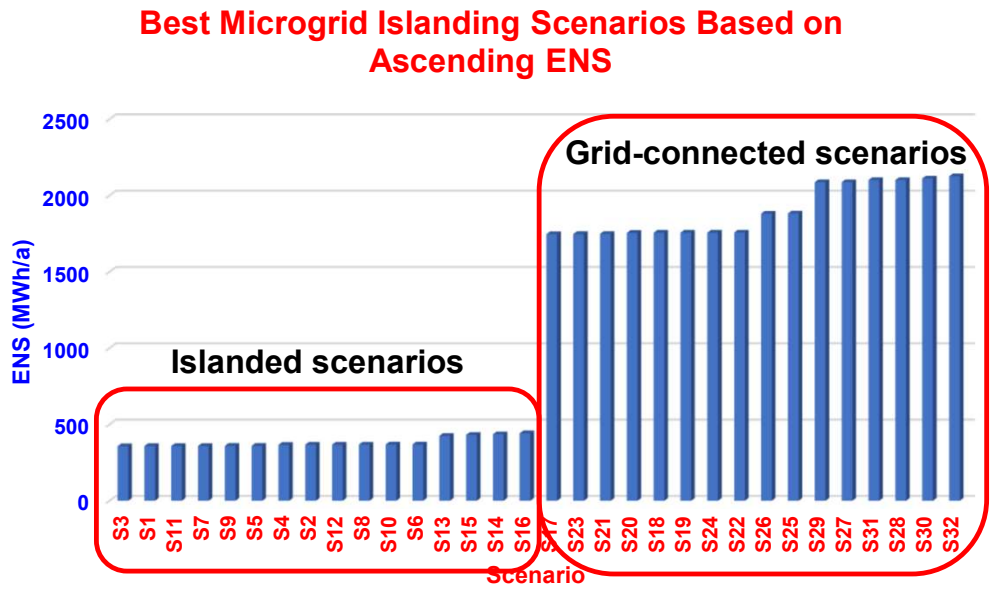
Priority Ranking as per Reliability (ENS)

Scenarios	ENS
S3	357.193
S1	358.226
S11	358.376
S7	358.574
S9	359.409
S5	359.607
S4	366.092
S2	367.129
S12	367.276
S8	367.474
S10	368.312
S6	368.51
S13	424.486
S15	431.433
S14	435.006
S16	441.95
S17	1746.992
S23	1747.141
S21	1748.175
S20	1754.858
S18	1755.895
S19	1755.895
S24	1756.042
S22	1757.078
S26	1880.878
S25	1881.911
S29	2087.021
S27	2087.025
S31	2101.034
S28	2101.038
S30	2111.17
S32	2125.184



Scenario	Grid	Feeder B	Feeder A	Donald	Donald South	Litchfield
S1	0	0	0	0	0	0
S2	0	0	0	1	1	0
S3	0	0	0	1	0	1
S4	0	0	0	1	1	1
S5	0	1	1	0	0	0
S6	0	2	2	1	1	0
S7	0	2	2	1	0	1
S8	0	2	2	1	1	1
S9	0	0	1	1	0	0
S10	0	0	1	1	1	0
S11	0	0	1	1	0	1
S12	0	0	1	1	1	1
S13	0	1	1	1	0	0
S14	0	1	1	1	1	0
S15	0	1	1	1	0	1
S16	0	1	1	1	1	1

Scenario	Grid	Feeder	Feeder	Donald	Donald	Litchfield
S17	1	1	0	0	0	0
S18	1	1	0	2	2	0
S19	1	1	0	2	0	2
S20	1	1	0	2	2	2
S21	1	1	2	2	0	0
S22	1	1	2	2	2	0
S23	1	1	2	2	0	2
S24	1	1	2	2	2	2
S25	1	1	1	0	0	0
S26	1	1	1	2		2
S27	1	1	1	2	2	0
S28	1	1	1	2	2	2
S29	1	1	1	1	0	0
S30	1	1	1	1	0	1
S31	1	1	1	1	1	0
S32	1	1	1	1	1	1

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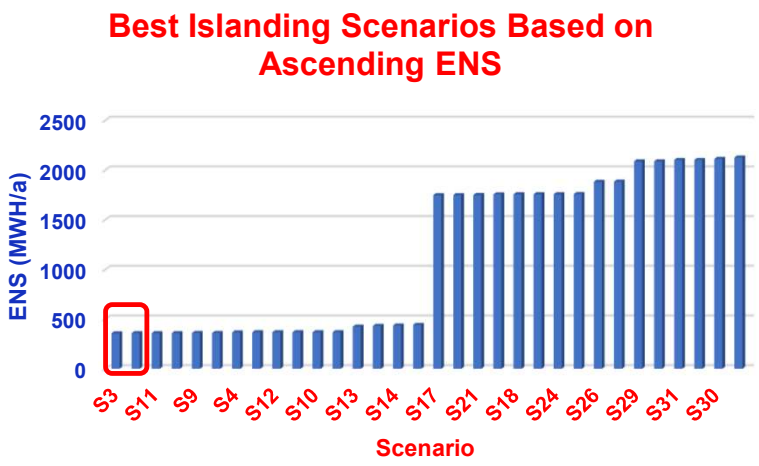
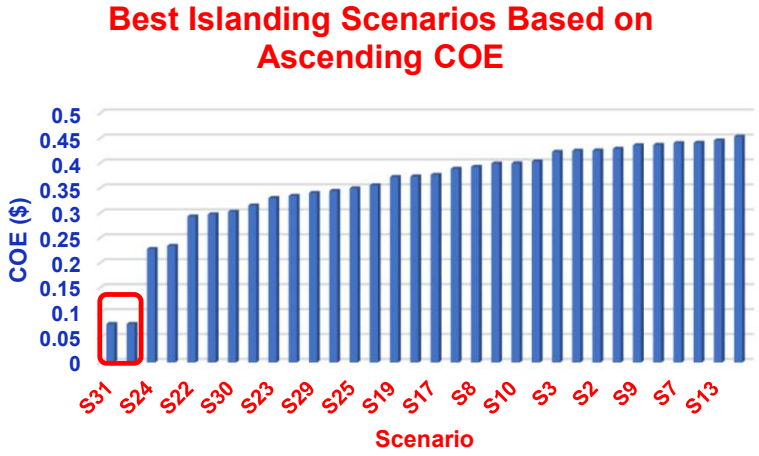
Priority Ranking as per Reliability (ENS) and Cost (COE)

Scenarios	ENS
S3	357.193
S1	358.226
S11	358.376
S7	358.574
S9	359.409
S5	359.607
S4	366.092
S2	367.129
S12	367.276
S8	367.474
S10	368.312
S6	368.51
S13	424.486
S15	431.433
S14	435.006
S16	441.95
S17	1746.992
S23	1747.141
S21	1748.175
S20	1754.858
S18	1755.895
S19	1755.895
S24	1756.042
S22	1757.078
S26	1880.878
S25	1881.911
S29	2087.021
S27	2087.025
S31	2101.034
S28	2101.038
S30	2111.17
S32	2125.184

Scenarios	COE
S31	0.0774
S32	0.0774
S24	0.2278
S28	0.234
S22	0.293
S27	0.297
S30	0.3023
S20	0.3149
S23	0.33
S26	0.334
S29	0.34
S18	0.344
S25	0.349
S21	0.3554
S19	0.372
S16	0.373
S17	0.3763
S12	0.3885
S8	0.3925
S14	0.399
S10	0.3993
S6	0.403
S3	0.4225
S4	0.4246
S2	0.425
S5	0.4285
S9	0.4355
S11	0.4363
S7	0.44
S1	0.4404
S13	0.4453
S15	0.453

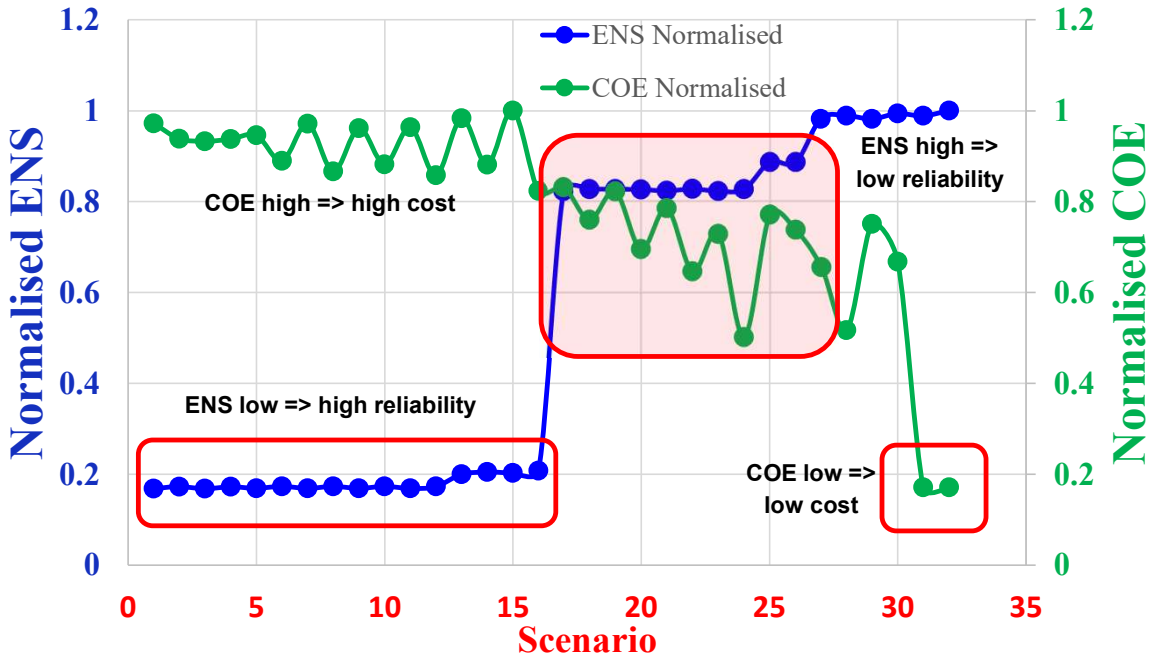




Scenario	Grid	Feeder B	Feeder A	Donald	Donald South	Litchfield
S1	0	0	0	0	0	0
S2	0	0	0	1	1	0
S3	0	0	0	1	0	1
S4	0	0	0	1	1	1
S5	0	1	1	0	0	0
S6	0	2	2	1	1	0
S7	0	2	2	1	0	1
S8	0	2	2	1	1	1
S9	0	0	1	1	0	0
S10	0	0	1	1	1	0
S11	0	0	1	1	0	1
S12	0	0	1	1	1	1
S13	0	1	1	1	0	0
S14	0	1	1	1	1	0
S15	0	1	1	1	0	1
S16	0	1	1	1	1	1

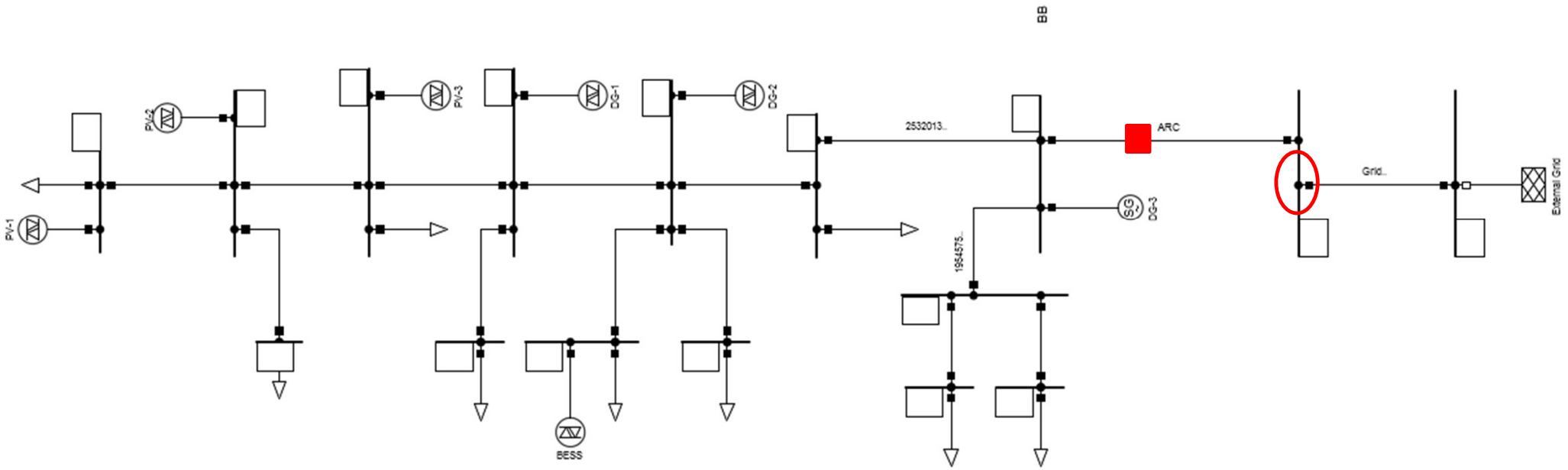
Scenario	Grid	Feeder	Feeder	Donald	Donald	Litchfield
S17	1	1	0	0	0	0
S18	1	1	0	2	2	0
S19	1	1	0	2	0	2
S20	1	1	0	2	2	2
S21	1	1	2	2	0	0
S22	1	1	2	2	2	0
S23	1	1	2	2	0	2
S24	1	1	2	2	2	2
S25	1	1	1	0	0	0
S26	1	1	1	2		2
S27	1	1	1	2	2	0
S28	1	1	1	2	2	2
S29	1	1	1	1	0	0
S30	1	1	1	1	0	1
S31	1	1	1	1	1	0
S32	1	1	1	1	1	1

Priority Ranking as per Reliability (ENS) and Cost (COE)



- Cost analysis identified the ½ to 1/7th cheaper electricity for S32, in the grid connected mode.
- Based on reliability, S3 scenario is the best islanding candidate in the Donald area.
- Reliability analysis identified 5.6 days of energy outage (for each customer) in the grid connected mode.
- A combined cost and reliability ranking would offer the options to prioritize.

Reliability Model with Protection Equipment: Tarnagulla Network



ACR with Work Tag

Location of Islanding

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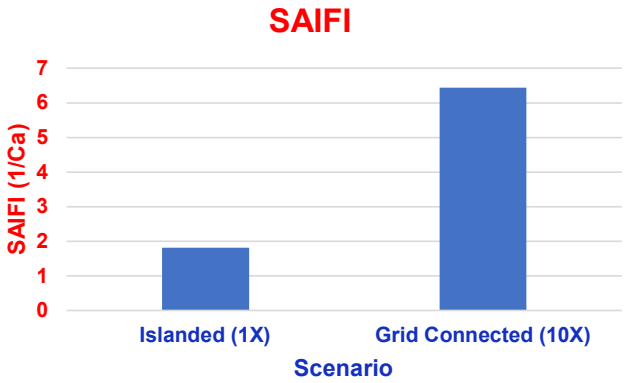
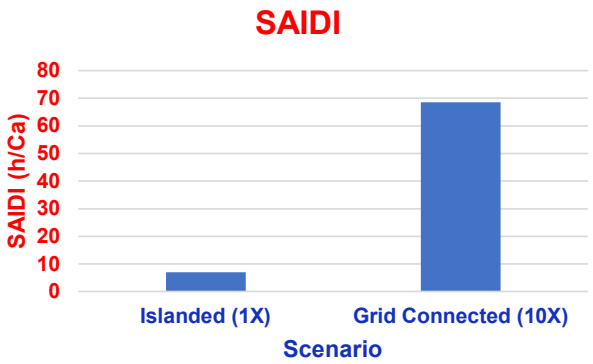
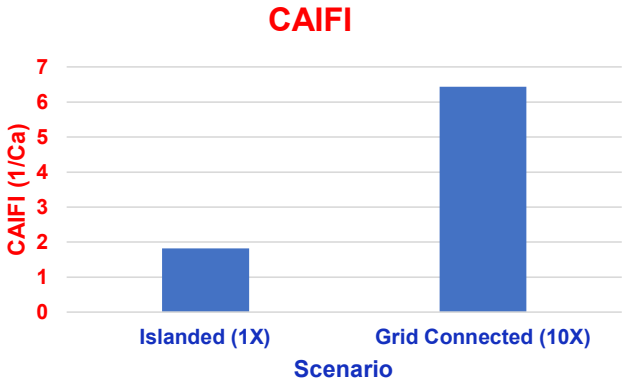
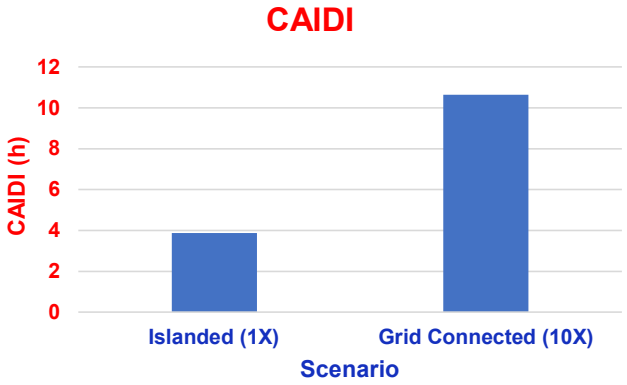
Reliability Indices: Tarnagulla Network









- SAIFI: **system interruptions per year** is 3.5 times worse in grid connected scenario.
- SAIDI: **system interruption duration per year** is 9.7 times worse in grid connected scenario.
- CAIFI: customer interruptions per year is 3.5 times worse in grid connected scenario.
- CAIDI: customer interruption duration per year is 3 times worse in grid connected scenario.

Reliability Indices: Tarnagulla Network

Supply feeder		SAIFI	CAIFI	SAIDI	CAIDI	ENS	ENS Explained
	1X	3.875	3.874	10.995	2.838	1.911	0.66 days of power outage
Low reliability	**2X**	4.16	4.16	12.739	3.063	2.212	0.76 days of power outage
Very low reliability	**5X**	5.015	5.015	24.949	4.975	4.314	1.49 days of power outage
Worst reliability	**10X**	6.439	6.439	68.554	10.645	11.821	4.10 days of power outage

- Cost analysis identified the 1/4th cheaper electricity the grid connected mode.
- Reliability analysis identified 4.1 days of power outage (for each customer) in the grid connected mode.
- A combined cost and reliability ranking would offer the options to prioritize.

4

Combined Cost and Reliability Analysis for Islanding Options

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Combined Cost and Reliability Analysis

Converting reliability into $

VCR (Value of Customer Reliability) has been considered as **16.96 $/kWh** for regional Victorian (TAS, NSW) residential customers as prescribed by Australian Energy Regulator (AER).

2019 VCR values

Residential customer VCRs by climate zone and remoteness - in $/kWh

Residential customer segment	Applicable State or Territory	Residential VCR ($/kwh) $2019
Climate Zone 1 Regional	Queensland	23.95
Climate Zone 2 CBD & Suburban	Queensland, New South Wales	22.95
Climate Zone 2 Regional	Queensland, New South Wales	25.56
Climate Zone 7 CBD & Suburban	Australian Capital Territory, Victoria	21.39
Climate Zone 7 Regional	Tasmania, Victoria, New South Wales	16.96
Northern Territory	Northern Territory	18.31

Combined Reliability and Cost Index (CRCI),

$$CRCI = \gamma NPC_{VCR} + (1-\gamma) NPC_{COE}$$

NPC_{COE} is the net present worth of the cost of energy served

NPC_{VCR} is the net present worth of the cost of customer reliability

γ = 0 means the ranking is done based on the economic/cost analysis

γ = 1 means the ranking is done based on the reliability analysis

γ is varied from 0 to 1 with a step of 0.1

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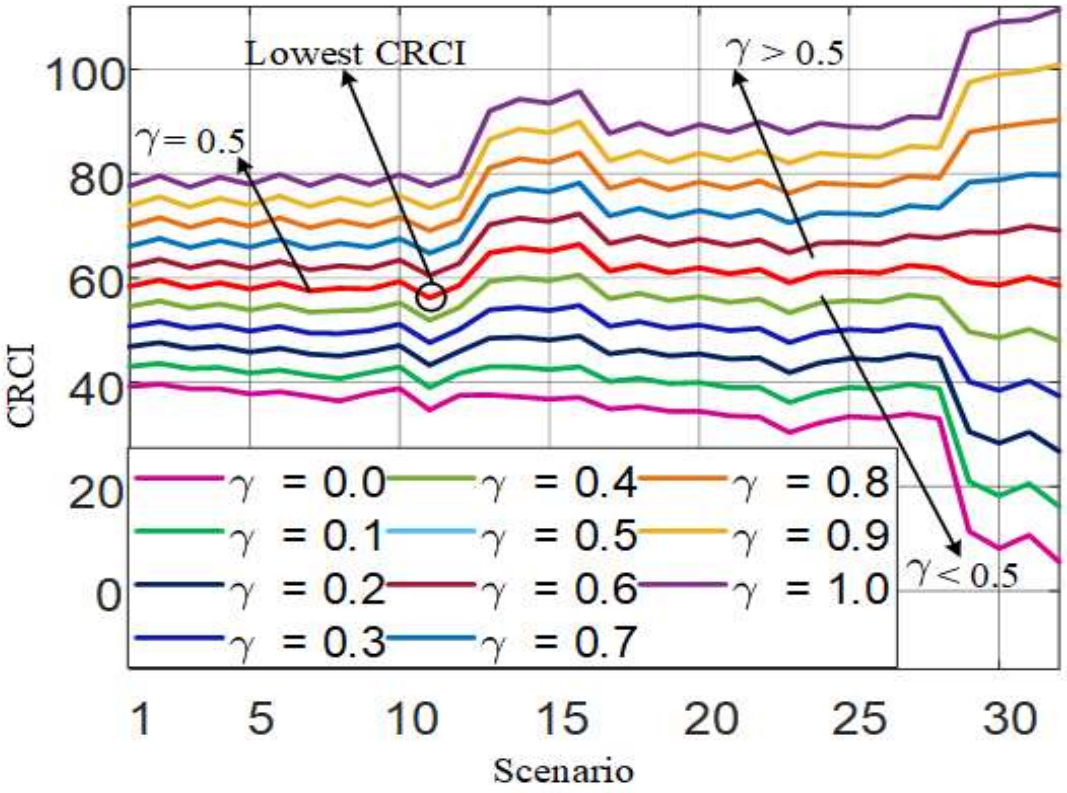
Ranking of Islanding Options



γ = 1 means the ranking is done based on the reliability analysis

Reliability is given higher priority

γ = 0.5 means the ranking is done based on reliability and cost analysis

Cost is given higher priority

γ = 0 means the ranking is done based on the cost analysis

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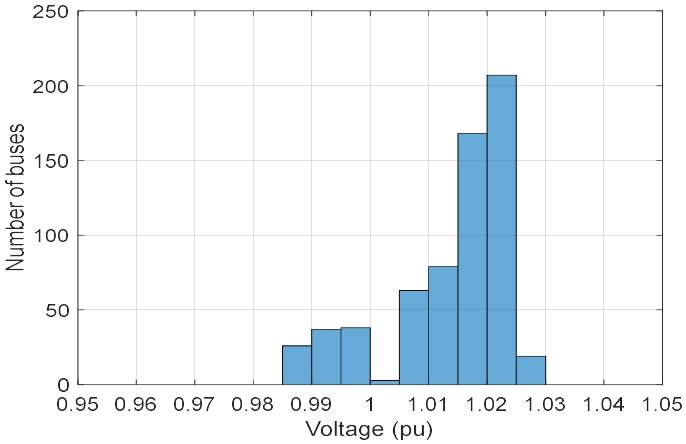
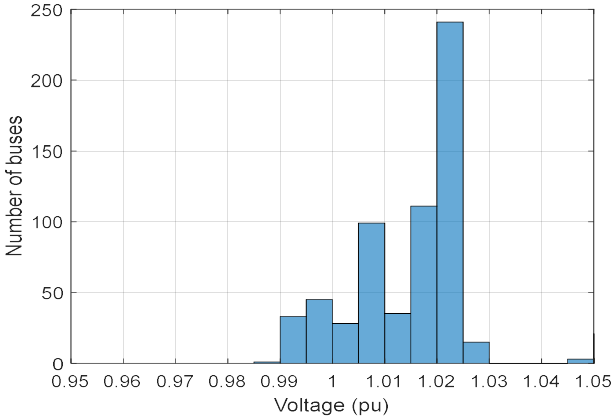
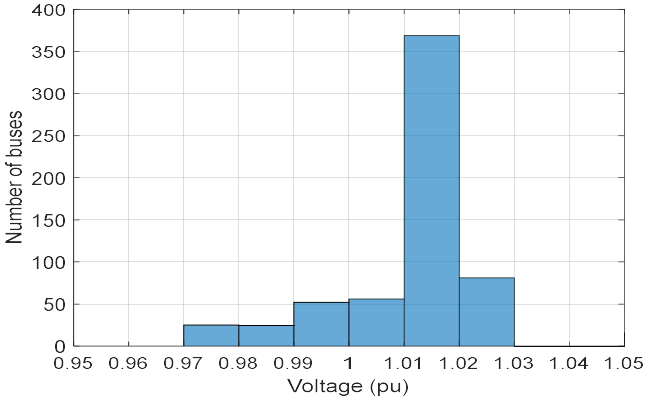
Voltage Profile Analysis of Scenario 11



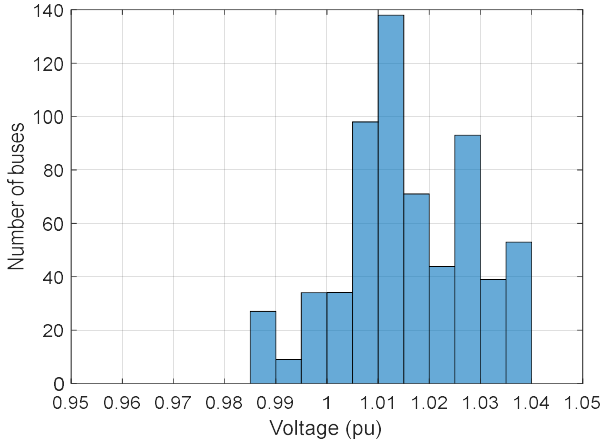
Scenario S11 voltage profiles (base-case 30% DERs).



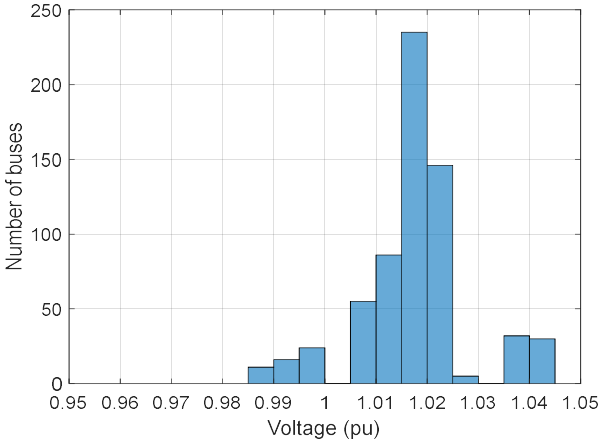
Scenario S11 voltage profiles (90% load from base case – 30% DERs).



Scenario S11 voltage profiles (115% load from base case – 30% DERs).



Scenario S11 voltage profiles (50% DERs).



Scenario S11 voltage profiles (60% DERs).

Voltage stays within the limit [0.94 to 1.06] in all cases

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A Review of Network Reliability Index: SAIDI

Table 5: Jurisdictional SAIDI Standards[36]

Region	Utility Company	CBD	Urban	Rural Short	Rural Long
ACT	ActewAGL	-	40	40	40
New South Wales	Ausgrid (Energy Australia)	45	80	300	700
	Endeavour (Integral) Energy	-	80	300	none
	Essential (Country) Energy	-	125	300	700
Queensland	Ergon Energy	-	149	424	964
	Energex	15	106	218	-
SA	ETSA Utilities	25	115	240 - 450	240 - 450
Tasmania	Aurora Energy	60	120	480	600
Victoria	CitiPower	11	22	-	-
	JEN	-	68	153	153
	Powercor	-	82	115	234
	SP AusNet	-	102	209	257
	United Energy	-	55	99	99
NT	Power and Water Corporation	-	-	-	-
WA	Western Power	30	160	290	290

Feeder (length/location) reliability significantly affect the overall power supply reliability

S. Hesmondhalgh, W. Zarakas and T. Brown, "Approaches to setting electric distribution reliability standards and outcomes," The Brattle Group, London, 2012

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Summary

- **Grid-connected operation** is the **most cost-effective** design of microgrid.
- **System reliability is increased in islanded mode**.
- Based on the **Combined Reliability and Cost Index**, the islanded scenarios is **slightly better**.
- Islanded microgrid can meet the electric load demand reliably and continuously under different operation scenarios.
- **~ 5 days of outage per year** as opposed to **~ 40 m$ investment**, which will lead to 5 times expensive electricity.

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Further Considerations

- Options for the **cost recovery mechanism** for islanded operation.
- Identifying the **value stream for stranded assets** in the microgrid.
- Analysis of the **scenarios considering future** battery/solar/grid price.
- Impact of the **sensitivity of the VCR** (**V**alue of **C**ustomer **R**eliability).
- Estimation of the **primary and secondary community benefits** from islanding.

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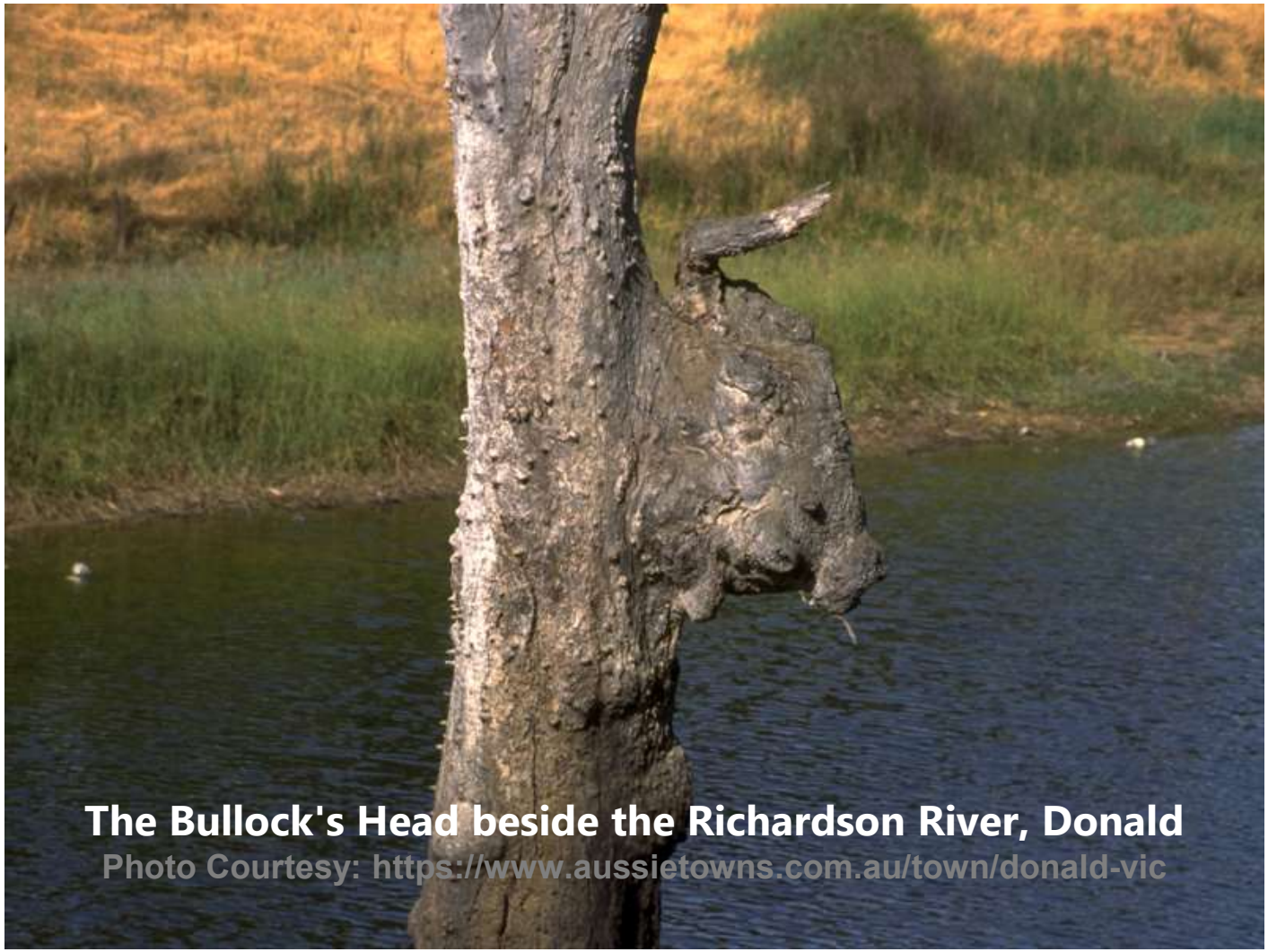
Thank You
Q & A



The Bullock's Head beside the Richardson River, Donald

Photo Courtesy: https://www.aussietowns.com.au/town/donald-vic

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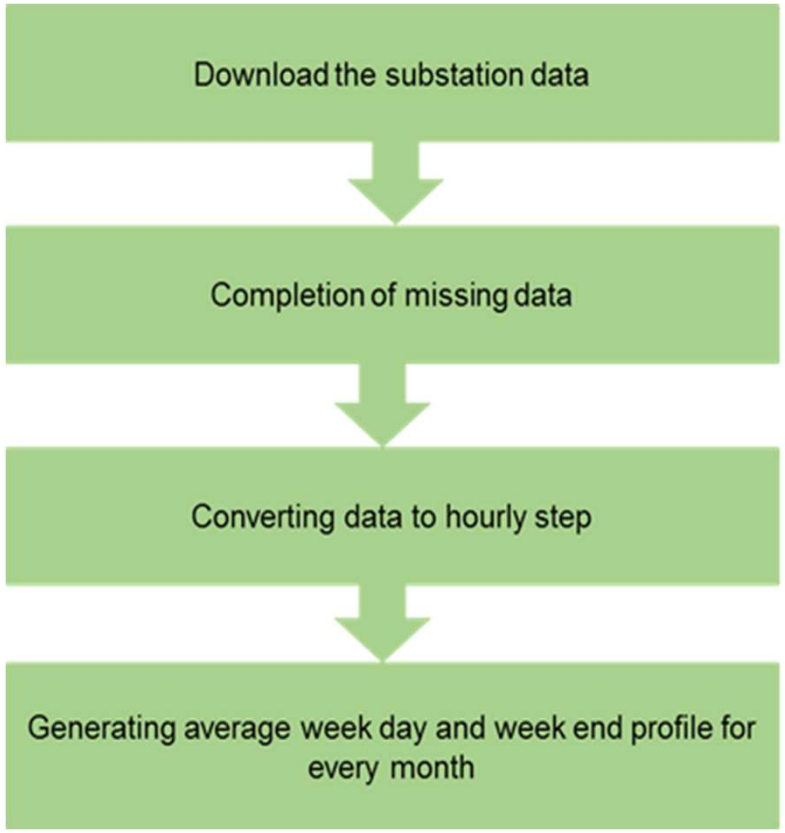
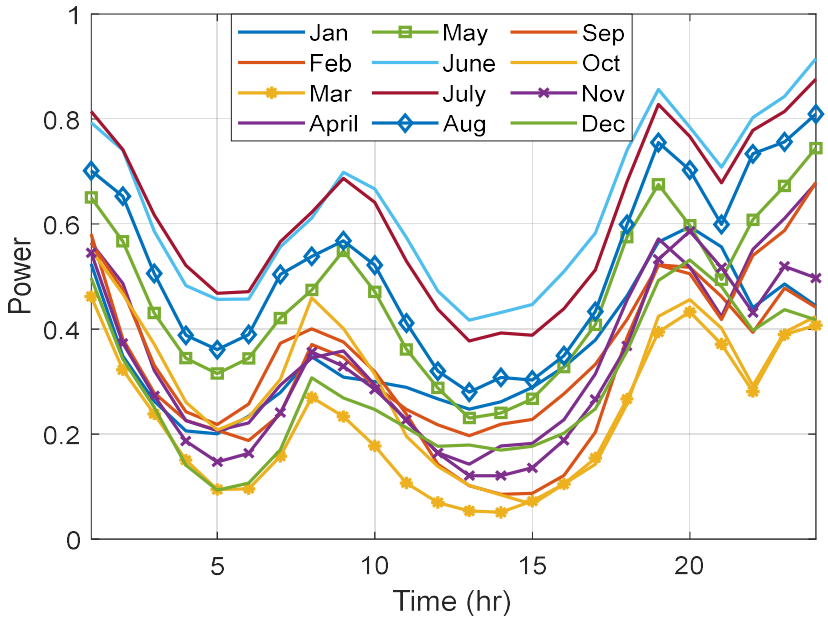
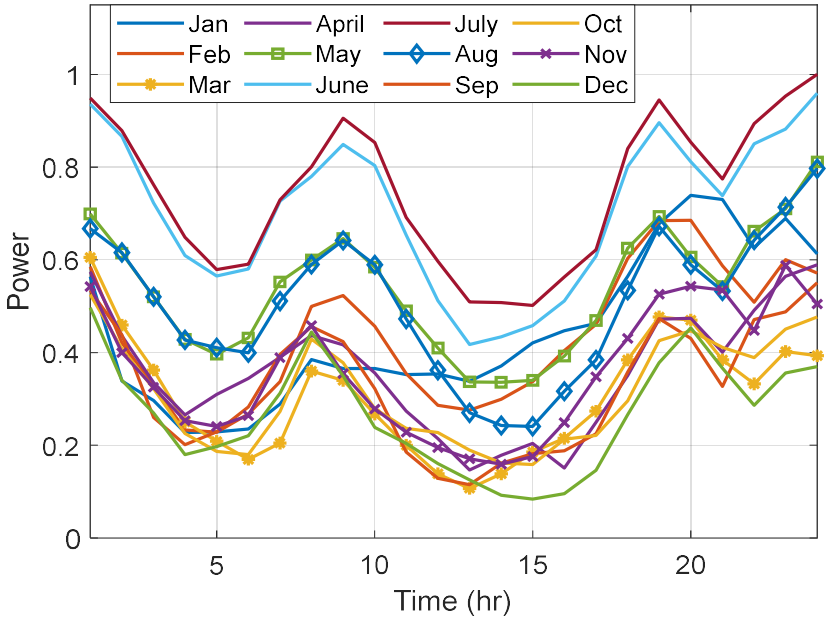
Data Analysis Framework



Data Analytics: Donald



Daily load profile for weekdays



Daily load profile for weekends

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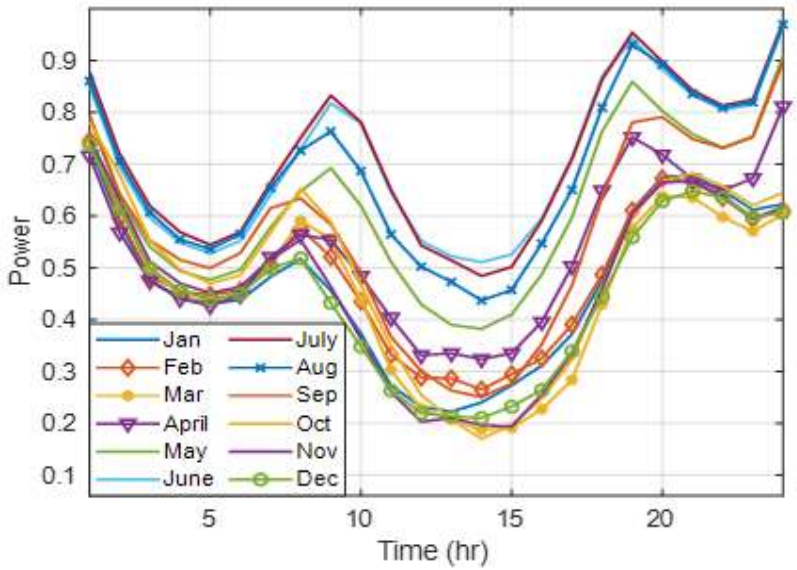
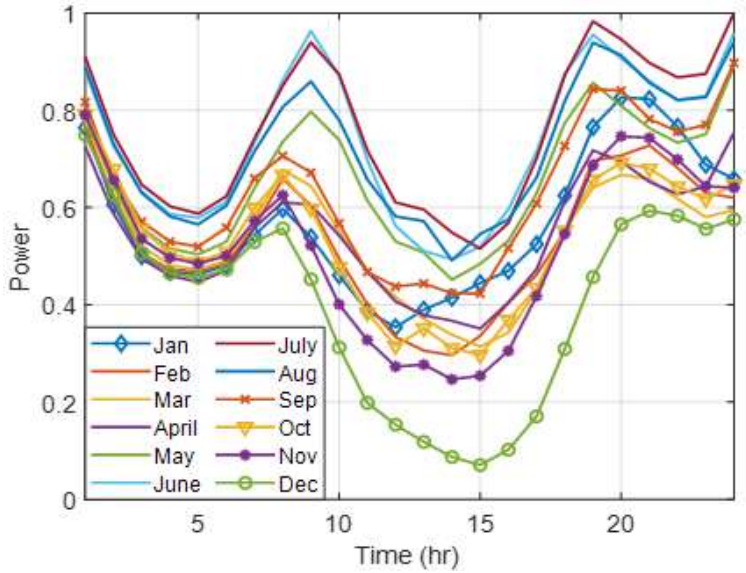
Data Analytics: Tarnagulla



Daily load profile for weekdays



Daily load profile for weekends

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Sensitivity Analysis: S11

Base case

Parameters	Values
Investment cost (m$)	1.60
NPC (m$)	43
COE ($/kWh)	0.369
Operation cost (m$/yr)	2.67

50% cost reduction for Battery, PV, and converter

Parameters	Values
Investment cost (m$)	5.88
NPC (m$)	34
COE ($/kWh)	0.3192
Operation cost (m$/yr)	1.78

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