Keilor Terminal Station A2, A3 & A4 Transformer Replacement

TRR Network Study Results

AusNet Services

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1 Introduction

AusNet Services is preparing business cases for several major station replacement projects in connection with the 2027-2032 Transmission Revenue Reset (TRR). Some of these projects require network studies (steady-state load flow studies) to assess the market impact of asset failures. To that end, Elite Power Solutions Pty Ltd ("EPS") were engaged by AusNet Services to conduct load flow studies for certain projects and scenarios using software, models, information and equipment provided by AusNet Services.

The avoided cost of an asset failure will be used to economically justify the investment in support of AusNet Services' TRR Capex forecast and will be used as supporting information for the TRR revenue application. The economic justification and related calculations for these projects are not included in EPS's scope but will be completed by others.

The results in this document refer to network studies carried out for the potential replacement of the A2, A3 and A4 Transformer at Keilor Terminal Station (SMTS) with Like-for-Like (750MVA) or higher capacity (1,000MVA), and are purely technical in nature.

2 Study Methodology

2.1 Network Operation Scenarios

AusNet Services obtained an updated PSSE OPDMS network model from AEMO which includes the status quo and potential reconfiguration of network at Deer Park Terminal Station (DPTS). The assessment is conducted by modelling replacing KTS A2, A3 & A4 Transformers with like-for-like (750MVA) and high capacity using lower impedance transformer (1,000MVA). The specific operating scenarios are shown in Tables 1 and 2 below.

Table 1: Status Quo Network Configuration & Operating Scenarios

Scenario	Asset Failure Contingency N-1	Asset Failure Contingency N-2	Asset Failure Contingency N-3	Secure Operating State Contingency
1	None	None	None	Trip of every element in VIC (one at a time)
1a	KTS A2 Transformer	None	None	Trip of every element in VIC (one at a time)
1b	KTS A2 Transformer	KTS A3 Transformer	None	Trip of every element in VIC (one at a time)
1c	KTS A2 Transformer	KTS A3 Transformer	KTS A4 Transformer	Trip of every element in VIC (one at a time)

Table 2: DPTS Network Re-configuration & Operating Scenarios

Scenario	Asset Failure Contingency N-1	Asset Failure Contingency N-2	Asset Failure Contingency N-3	Secure Operating State Contingency
2	None	None	None	Trip of every element in VIC (one at a time)
2a	KTS A2 Transformer	None	None	Trip of every element in VIC (one at a time)
2b	KTS A2 Transformer	KTS A3 Transformer	None	Trip of every element in VIC (one at a time)
2c	KTS A2 Transformer	KTS A3 Transformer	KTS A4 Transformer	Trip of every element in VIC (one at a time)

2.2 General Approach for Contingency Analysis

Asset Failure Contingency N-1

- PSSE Contingency Analysis (ACCC) Simulation
    - Step 1: Switch Out Element and ensure that no other Element (transformer/lines) overloads its Continuous Rating. If overload is found, System Demand is reduced.
    - Step 2: Run N-1-1 Contingency Analysis by using Short-Term Rating. System Demand is reduced and re-run ACCC until no overload is found using Short Term Rating
- Maximum Supportable Demand: System Demand – Load Shed (Step 1) – Load Shed (Step 2)

Asset Failure Contingency N-2

- PSSE Contingency Analysis (ACCC) Simulation
    - Step 1: Switch Out 2 x Elements and ensure that no other Element (transformer/lines) overloads its Continuous Rating. If overload is found, System Demand is reduced.
    - Step 2: Run N-1-1 Contingency Analysis by using Short-Term Rating. System Demand is reduced and re-run ACCC until no overload is found using Short Term Rating
- Maximum Supportable Demand: System Demand – Load Shed (Step 1) – Load Shed (Step 2)

Asset Failure Contingency N-3

- PSSE Contingency Analysis (ACCC) Simulation
    - Step 1: Switch Out 3 x Elements and ensure that no other Element (transformer/lines) overloads its Continuous Rating. If overload is found, System Demand is reduced.
    - Step 2: Run N-1-1 Contingency Analysis by using Short-Term Rating. System Demand is reduced and re-run ACCC until no overload is found using Short Term Rating
- Maximum Supportable Demand: System Demand – Load Shed (Step 1) – Load Shed (Step 2)

2.3 PSSE Base Case & Load (Bus Numbers)

PSSE Base Case (VAPR20223) was used with the demand forecast of year 2025. Below are the PSSE bus numbers used for load scaling.

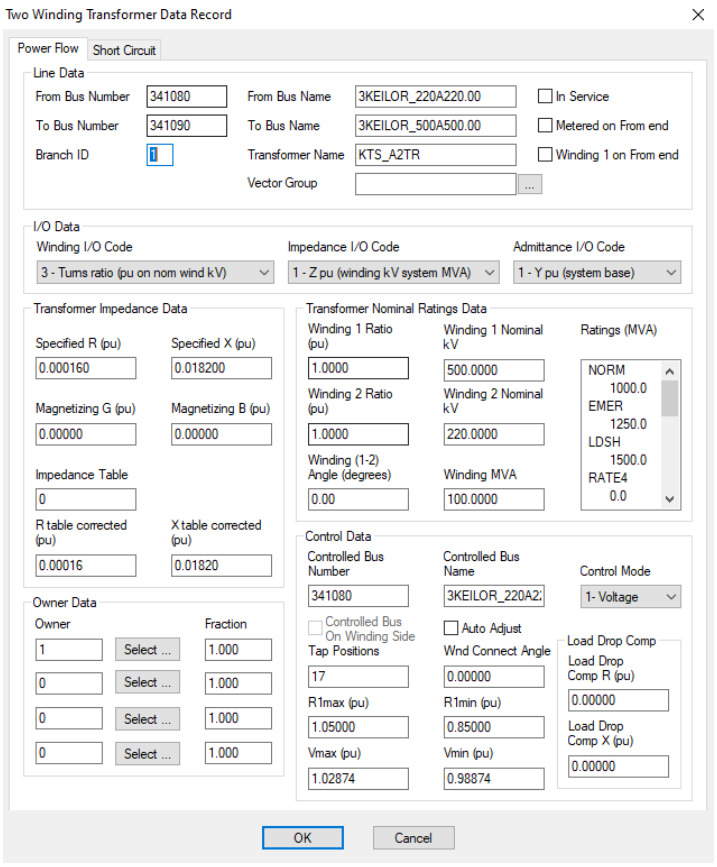
GTS
328001,328031

DPTS+KTS+ATS+BLTS+FBTS+WMTS+NPSD+TTS
323531,341001,341030,379001,379002,303001,304030,343030,302031,302030,314031,314032,314021,326001,387030,360001

SMTS+BTS+RTS+RWTS+TSTS+SVTS+HTS+MTS
373030,371031,315033,315020,365032,365022,366030,366031,366020,377031,377002,349030,349020,374001,332001

2.4 1,000 MVA Transformer Impedance

Below is the impedance used for the proposed option

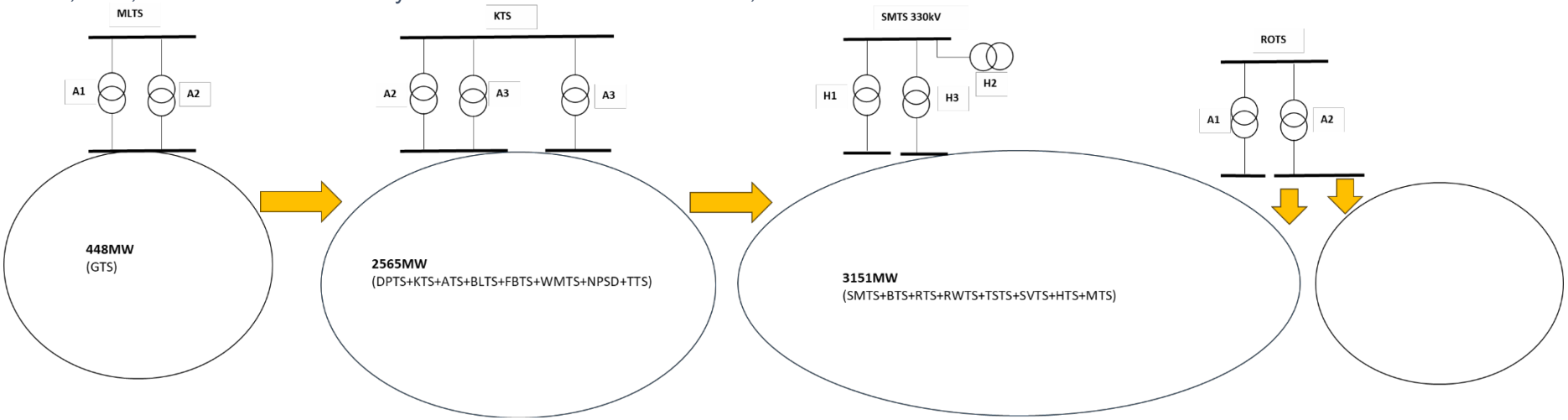


2.5 Assumptions used for the Element Ratings

- KTS A2, A3 & A4 Transformer: 750 MVA (Continuous) & 810 MVA (Short-Term)
- KTS A2, A3 & A4 Transformer: 1,000 MVA (Continuous) & 1,500 MVA (Short-Term)
- ROTS A1 & A2 Transformer: 1,000 MVA (Continuous) & 1,500 MVA (Short-Term)
- MLTS A1 & A2 Transformer: 1,000 MVA (Continuous) & 1,500 MVA (Short-Term)
- CBTS A1 Transformer: 1,000 MVA (Continuous) & 1,500 MVA (Short-Term)
- SMTS H1 Transformer: 700 MVA (Continuous & Short-Term)
- MLTS-GTS No.1 220kV line: 772 MVA (Continuous & Short-Term) / 1049 MVA (Uprate Continuous & Short-Term)
- MLTS-GTS No.2 220kV line: 775 MVA (Continuous & Short-Term) / 1049 MVA (Uprate Continuous & Short-Term)
- GTS-DPTS 220kV line: 425.5 MVA (Continuous & Short-Term)
- GTS-KTS No.1 & No.3 220kV line: 425.5 MVA (Continuous & Short-Term)
- 45degC ratings are applied on all other elements

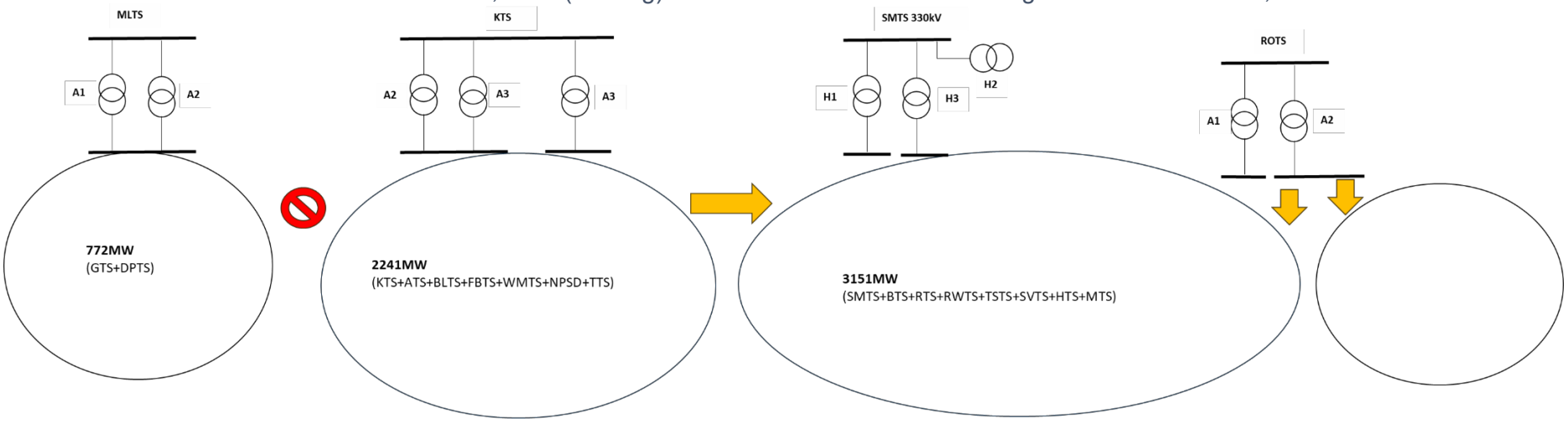
2.6 Status Quo Network Configuration

MLTS, KTS, SMTS and ROTS subsystems have a total demand of 6,164MW.



2.7 Deer Park Terminal Station Reconfiguration

MLTS, KTS, SMTS and ROTS subsystems have a total demand of 6,164MW. Deer Part Terminal Station will be transferred to MLTS Sub-system where DPTS will cut-in to the KTS-GTS No.1, No.2 (existing) & No.3 220kV lines and switching out KTS-DPTS No.1, No.2 & No.3 lines.



3 Results

Summary of results are shown in Tables 3, 4, 5 and 6. Detailed results are presented in the Appendix section.

Table 3: Results for 750MVA KTS Transformer Replacement, Network Status Quo

No	Scenario	Summer					Winter				
		MLTS (GTS) Subsystem (MW)	KTS Subsystem (MW)	SMTS+ROTS Subsystem (MW)	Maximum Supportable Demand (MW)	Load at Risk (MW)	MLTS (GTS) Subsystem (MW)	KTS Subsystem (MW)	SMTS+ROTS Subsystem (MW)	Maximum Supportable Demand (MW)	Load at Risk (MW)
1	System Intact	448	2565	3151	6164		448	2565	3151	6164	
1a	Prior Outage KTS A2	448	2565	2735	5748	416	448	2565	2735	5748	416
1b	Prior Outage KTS A2 & A3	371	2300	2735	5406	758	371	2300	2735	5406	758
1c	Prior Outage KTS A2, A3 & A4	312	1946	2298	4556	1608	312	1946	2298	4556	1608

Table 4: Results for 750MVA KTS Transformer Replacement, Deer Park Terminal Station Re-configuration

No	Scenario	Summer					Winter				
		MLTS (GTS+DPTS) Subsystem (MW)	KTS Subsystem (MW)	SMTS+ROTS Subsystem (MW)	Maximum Supportable Demand (MW)	Load at Risk (MW)	MLTS (GTS+DPTS) Subsystem (MW)	KTS Subsystem (MW)	SMTS+ROTS Subsystem (MW)	Maximum Supportable Demand (MW)	Load at Risk (MW)
2	System Intact	772	2241	3151	6164		772	2241	3151	6164	
2a	Prior Outage KTS A2	772	2241	2765	5778	386	772	2241	2880	5893	271
2b	Prior Outage KTS A2 & A3	772	1697	2765	5234	930	772	1697	2765	5234	930
2c	Prior Outage KTS A2, A3 & A4	772	1361	2239	4372	1792	772	1361	2239	4372	1792

Table 5: Results for 1,000MVA KTS Transformer Replacement, Status Quo Network

No	Scenario	Summer					Winter				
		MLTS (GTS) Subsystem (MW)	KTS Subsystem (MW)	SMTS+ROTS Subsystem (MW)	Maximum Supportable Demand (MW)	Load at Risk (MW)	MLTS (GTS) Subsystem (MW)	KTS Subsystem (MW)	SMTS+ROTS Subsystem (MW)	Maximum Supportable Demand (MW)	Load at Risk (MW)
1	System Intact	448	2565	3151	6164		448	2565	3151	6164	
1a	Prior Outage KTS A2	448	2565	3151	6164	0	448	2565	3151	6164	0
1b	Prior Outage KTS A2 & A3	448	2303	2747	5498	666	448	2303	2747	5498	666
1c	Prior Outage KTS A2, A3 & A4	448	1921	2274	4643	1521	448	1921	2274	4643	1521

Table 6: Results for 1,000MVA KTS Transformer Replacement, Deer Park Terminal Station Re-configuration

No	Scenario	Summer					Winter				
		MLTS (GTS) Subsystem (MW)	KTS Subsystem (MW)	SMTS+ROTS Subsystem (MW)	Maximum Supportable Demand (MW)	Load at Risk (MW)	MLTS (GTS) Subsystem (MW)	KTS Subsystem (MW)	SMTS+ROTS Subsystem (MW)	Maximum Supportable Demand (MW)	Load at Risk (MW)
1	System Intact	448	2565	3151	6164		448	2565	3151	6164	
1a	Prior Outage KTS A2	448	2565	3151	6164	0	448	2565	3151	6164	0
1b	Prior Outage KTS A2 & A3	448	2303	2747	5498	666	448	2303	2747	5498	666
1c	Prior Outage KTS A2, A3 & A4	448	1921	2274	4643	1521	448	1921	2274	4643	1521

4 Summary

1. **Replacement with 750MVA & Status Quo Network**

   - **System Intact**: There are existing network constraints in the base case but is not attributed to any KTS A Transformer outage. Summer and Winter Maximum Supportable Demand is approximately **6,164MW**. As such, no load at risk.

   - **Prior Outage KTS A2 Transformer**: For a contingent trip of ROTS A1 Transformer (most critical), overloads on SMTS H1 Transformer (103%), TTS-RWTS line (**122%**) and TTS-TSTS (111%) line. For a contingent trip of either one of the MLTS-GTS lines, the remaining line is overloaded by 105%. Summer and Winter Maximum Supportable Demand is approximately **5,748MW**. As such, load at risk is approximately 416MW.

   - **Prior Outage KTS A2 & A3 Transformer**: For a contingent trip of KTS A4 Transformer, overloads on SMTS H1 Transformer (103%) and EPS-TTS line (101%). For a contingent trip of ROTS A1 Transformer, overloads on SMTS H1 Transformer (107%) and EPS-TTS line (101%). For a contingent trip of ROTS A2 Transformer, overload on EPS-TTS line (101%). For a contingent trip of either one of the MLTS-GTS lines (most critical), the remaining line is overloaded by **111%**. Summer and Winter Maximum Supportable Demand is approximately **5,406MW**. As such, load at risk is approximately 758MW.

   - **Prior Outage KTS A2, A3 & A4 Transformer**: For a contingent trip of MLTS A1 or A2 Transformer, overload on SMTS H1 Transformer (102%). For a contingent trip of ROTS A1 Transformer (most critical), overloads on SMTS H1 Transformer (**121%**), EPS-TTS line (106%), SMTS-TTS 1 line (118%) and SMTS-TTS2 line (107%). For a contingent trip of ROTS A2 Transformer, overloads on SMTS H1 Transformer (106%) and EPS-TTS line (106%). For a contingent trip of NPSD, overloads on SMTS H1 Transformer (107%), EPS-TTS line (104%) and SMTS-TTS1 line (103%). For a contingent trip of either one of the MLTS-GTS lines (most critical), the remaining line is overloaded by **121%.** Summer and Winter Maximum Supportable Demand is approximately **4,556MW**, As such, load at risk is approximately 1,608MW.

2. **Replacement with 750MVA & DPTS Reconfiguration & Uprating of MLTS-GTS lines**

   - **System Intact**: There are existing network constraints in the base case but is not attributed to any KTS A Transformer outage. Summer and Winter Maximum Supportable Demand is approximately **6,164MW**. As such, no load at risk.

   - **Prior Outage KTS A2 Transformer**: For a contingent trip of ROTS A1 Transformer (most critical), overloads on EPS-TTS line (101%), SMTS H1 Transformer (106%), TTS-RWTS line (**119%**) and TTS-TSTS (110%). Summer and Winter Maximum Supportable Demand is approximately **5,778MW** and **5,893MW**, respectively. As such load at risk for Summer and Winter are approximately 386MW and 271MW, respectively.

   - **Prior Outage KTS A2 & A3 Transformer**: For a contingent trip of KTS A4 Transformer (most critical), overloads on SMTS H1 Transformer (**116%**), EPTS-TTS line (107%) and SMTS-TTS1 (113%). For a contingent trip of ROTS A1 Transformer, overloads on KTS A4 Transformer (110%), SMTS H1 Transformer (115%), EPS-TTS line (104%), SMTS-TTS1 line (110%) and SMTS-TTS2 line (102%). For a contingent trip of ROTS A2 Transformer, overloads on KTS A4 Transformer (101%) and EPS-TTS line (104%). For a contingent trip of NPSD, overloads on KTS A4 Transformer (105%), SMTS H1 Transformer (102%) and EPS-TTS line (102%).

Summer and Winter Maximum Supportable Demand is approximately **5,234MW**. As such load at risk is approximately 930MW.

- **Prior Outage KTS A2, A3 & A4 Transformer**: For a contingent trip of ROTS A1 Transformer (most critical), overloads on SMTS H1 Transformer (**130%**), EPS-TTS line (108%), SMTS-TTS1 line (128%), SMTS-TTS2 line (111%) and TTS-TSTS line (102%). For a contingent trip of ROTS A2 Transformer, overloads on SMTS H1 Transformer (112%), EPS-TTS line (107%) and SMTS-TTS1 line (106%). For a contingent trip of NPSD, overloads on SMTS H1 Transformer (116%), EPTS-TTS line (104%) and SMTS-TTS1 line (111%). Summer and Winter Maximum Supportable Demand is approximately **4,327MW**. As such, load at risk is approximately 1,792MW.

3. Replacement with 1000MVA & Status Quo Network

- **System Intact**: There are existing network constraints in the base case but is not attributed to any KTS A Transformer outage. Summer and Winter Maximum Supportable Demand is approximately **6,164MW**. As such, no load at risk.

- **Prior Outage KTS A2 Transformer**: There are existing network constraints in the base case but is not attributed to any KTS A Transformer outage. Summer and Winter Maximum Supportable Demand is approximately **6,164MW**. As such, no load at risk.

- **Prior Outage KTS A2 & A3 Transformer**: For a contingent trip of KTS A4 Transformer, overloads on SMTS H1 Transformer (109%), EPTS-TTS line (104%) and SMTS-TTS1 line (101%). For a contingent trip of ROTS A1 Transformer (most critical), overloads on SMTS H1 Transformer (105%), TTS-RWTS line (**114%**) and TTS-TSTS line (108%). For a contingent trip of ROTS A2 Transformer, overload on EPS-TTS1 line (101%). Summer and Winter Maximum Supportable Demand is approximately **5,498MW**. As such, load at risk is approximately 666MW.

- **Prior Outage KTS A2, A3 & A4 Transformer**: For a contingent trip of MLTS A1 or A2 Transformer, overload on SMTS H1 Transformer (103%). For a contingent trip of ROTS A1 Transformer (most critical), overloads on SMTS H1 Transformer (**123%**), EPS-TTS line (106%), SMTS-TTS1 line (119%) and SMTS-TTS2 line (107%). For a contingent trip of ROTS A2 Transformer, overloads on SMTS H1 Transformer (107%) and EPS-TTS line (106%). For a contingent trip of NPSD, overloads on SMTS H1 Transformer (109%), EPS-TTS line (104%) and SMTS-TTS1 line (104%). Summer and Winter Maximum Supportable Demand is approximately **4,643MW**. As such, load at risk is approximately 1,521MW.

4. **Replacement with 1000MVA & DPTS Reconfiguration & Uprating of MLTS-GTS lines**

- **System Intact**: There are existing network constraints in the base case but is not attributed to any KTS A Transformer outage. Summer and Winter Maximum Supportable Demand is approximately **6,164MW**. As such, no load at risk.

- **Prior Outage KTS A2 Transformer**: There are existing network constraints in the base case but is not attributed to any KTS A Transformer outage. Summer and Winter Maximum Supportable Demand is approximately **6,164MW**. As such, no load at risk.

- **Prior Outage KTS A2 & A3 Transformer**: For a contingent trip of KTS A4 Transformer (most critical), overloads on SMTS H12 Transformer (**121%**), EPS-TTS line (109%) and SMTS-TTS1 line (117%). For a contingent trip of ROTS A1 Transformer, overloads on SMTS H1 Transformer (110%), EPS-TTS line (102%), SMTS-TTS1 line (101%), SMTS-TTS2 line (101%), TTS-RWTS line (110%) and TTS-TSTS (107%). For a contingent trip of ROTS A2 Transformer, overload on EPS-TTS line (102%). Summer and Winter Maximum Supportable Demand is approximately **5,207MW**. As such, load at risk is approximately 957MW.

- **Prior Outage KTS A2, A3 & A4 Transformer**:
  For a contingent trip of ROTS A1 Transformer (most critical), overloads on SMTS H1 Transformer (**127%**), EPS-TTS line (106%), SMT-TTS1 (127%) and SMTS-TTS2 line (110%). For a contingent trip of ROTS A2 Transformer, overloads on SMTS H1 Transformer (110%), EPS-TTS line (105%) and SMTS-TTS1 line (106%). For a contingent trip of NPSD, overloads on SMTS H1 Transformer (113%), SMTS-TTS1 line (111%) and EPS-TTS line (104%). Summer and Winter Maximum Supportable Demand is approximately **4,352MW**. As such, load at risk is approximately 1,812MW.

5 Appendix

Detailed results are shown in the respective spreadsheets:

- Summary_KTS_ATR_750MVA_v5.xlsx
- Summary_KTS_ATR_1000MVA_v3.xlsx