Horsham Solar Farm

Steady State Grid Impact Assessment

29th January 2023

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Defined Terms

Term	Definition
AC	Alternating Current
AVR	Automatic Voltage Regulator
DC	Direct Current
HV	High Voltage
kV	Kilovolt, equivalent to 10^3 volts
LV	Low voltage
MVA	Megavolt-ampere, equivalent to 10^6 volt ampere
MVAr	Megavolt-ampere reactive, equivalent to 10^6 volt-amperes reactive
MW	Megawatt, equivalent to 10^6 watts
OH	Overhead Conductor
OLTC	Onload Tap Changing/Changers
ONAN	Oil Natural Air Natural cooling method
OOS	Out of Service
PCS	Power Conversion System
PF	Power Factor
POC	Point of Connection
PSS®E	Power System Simulator for Engineering from SIEMENS
pu	Per Unit
SLD	Single Line Diagram
Tx	Transformer
UG	Underground Cable
UGOH	Underground to Overhead Connection
VC	Voltage Control
VDC	Voltage Drop Control
V_k	Impedance Voltage
V_1	Positive Sequence Voltage
V_nLL	Nominal Line to Line Voltage
ZS	Zone Substation

Generators Nomenclature

Generator Name	Nomenclature in the report
HORSF	Horsham Solar Farm
GLWWSF	Glenrowan West Solar Farm
GLWSF	Glenrown Solar Farm
STCKHWF	Stockyard Hill Wind Farm
VBB	Victorian Big Battery
MUR1WF	Murra Warra 1 Wind Farm
MUR2WF	Murra Warra 2 Wind Farm
YTPSF	Yatpool Solar Farm
YNDWF	Yendon Wind Farm
WTNSF	Winton Solar Farm

Executive Summary

ESCO Pacific Holdings Pty Ltd is proposing to connect Horsham Solar Farm (HORSF) into the AEMO network in Horsham Victoria. The proposed plant will have a maximum export capacity (active power) of 118.8 MWac at PoC. The Horsham Solar Farm will be directly connected to the existing 220kV busbar in the Horsham 220/66 kV Zone Substation.

This report forms a part of the HORSF connection application to the AEMO. This report aims to assess the steady state requirements for the proposed power plant. The studies were conducted in PSS®E v34.5.1 version using the data provided in the AEMO data pack [1] . This includes thermal loadings, voltage levels, generation change and loss of line voltage fluctuations, and short circuit calculations. The studies were set up so that the HORSF was operating in a voltage droop control with a droop of 4.0% on 90.72 MVAr base and a voltage setpoint of 1.02 pu at the PoC.

The aim of the report is to:

- Provide network modelling and study execution details.
- Demonstrate the compliance of HORSF to reactive power capability requirements
- Analyze the impacts of the proposed plant on the current network

The study results shows that the Horsham Solar Farm is able to meet the automatic access standard NER clause S5.2.5.1 for reactive power capability at 35°C; thus, providing and absorbing 46.926 MVAr at the PoC which is 0.395x118.8 MWac. At 50°C, due to 10% derating in the plant MVA there is small decrease in reactive power when generating full active power at 0.9pu POC voltage. So, a negotiated access standard is requested as per section 6.1.

Furthermore, there are no thermal constraints identified under system normal and the considered contingency conditions on the network with the addition of HORSF. Overall voltage fluctuations on the network due to change in generation (i.e., cloud cover and trip of generating units) and due to loss of line contingency are within 3% (for generation change) and 5% (for generator trip and loss of line contingency). The only exception occurs at the Kiamal 220kV bus (3KIAMAL_220A) when losing the Kiamal to Redcliff 220 kV line. For this case4, the existing voltage fluctuation is above 5% i.e., 5.047% and the addition of HORSF this voltage fluctuation increases to 5.595 %. Due to the small magnitude of this exacerbation i.e., 0.55% and the long distance between HORSF and 3KIAMAL_220A bus this is deemed acceptable. This exacerbation is not expected to impact system security and the limit is slightly exceeded with and without HORSF present. In fact, Horsham is not causing the fluctuation and under slightly different network conditions the plant would likely mitigate the fluctuation rather than exacerbate it, given it stabilizes the voltage at HOTS 220 kV. No further issues have been identified in the Horsham Solar Farm steady state analysis.

Overall, the inclusion of HORSF 118.8 MWac will enhance flexibility to system operators by providing reactive power capability of +46.926 MVAr/-46.926 MVAr. Also, the plants fast acting droop capability will allow to reduce voltage steps on the network.

Table of Contents

1 Introduction

1.1 Project Details

ESCO Pacific is proposing to develop Horsham Solar Farm with maximum active power output of 118.8 MWac in Horsham Victoria connecting to Ausnet's network. This report presents the steady state analysis consisting of the following assessments:

1. Reactive power capability
2. Thermal loading assessment
3. Load flow and voltage analysis under system normal and N-1 conditions
4. Fault level calculation for three-phase faults and single phase to ground faults.

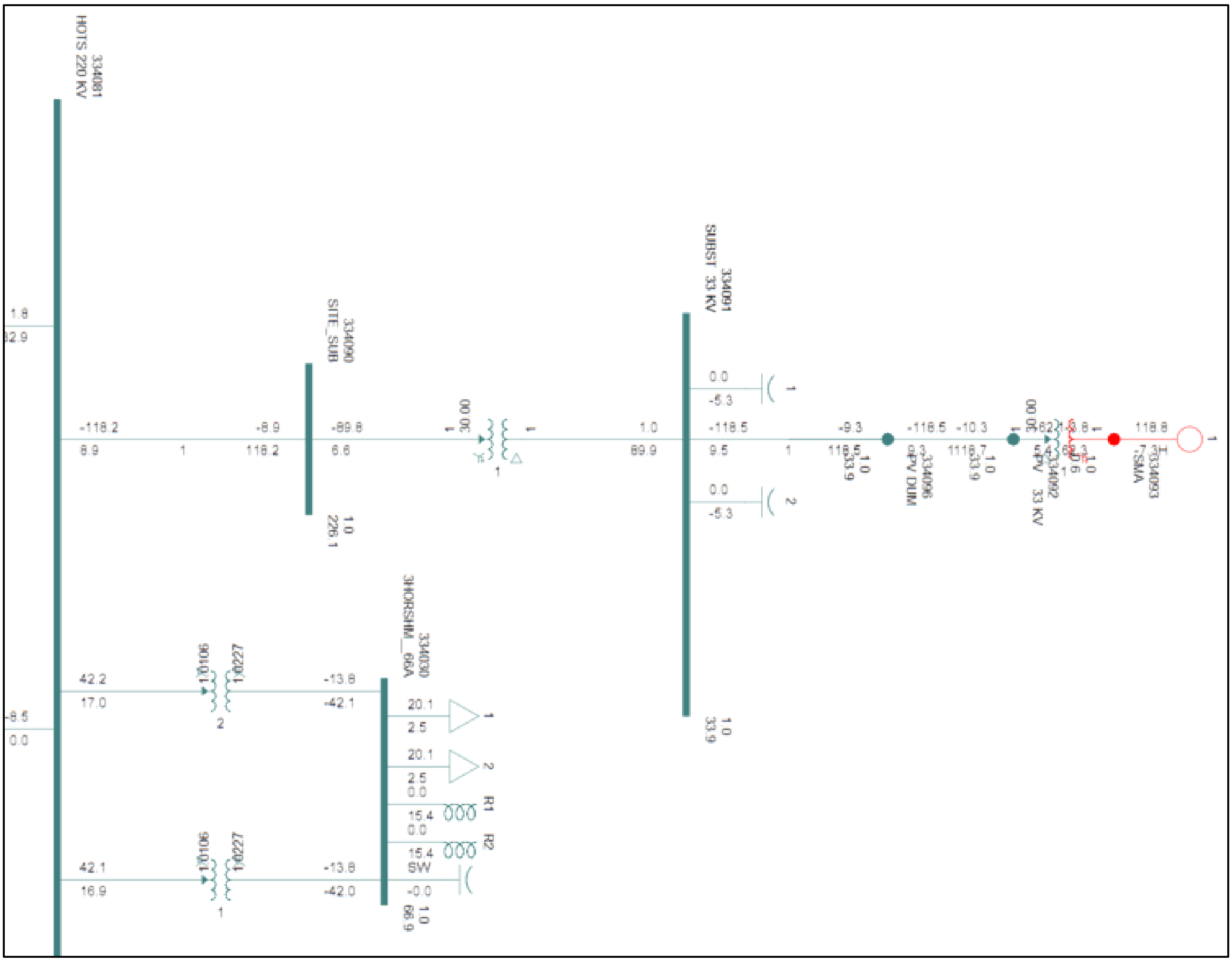


Figure 1 Proposed location of the Horsham Solar Farm connecting to existing 220 kV bus at the 220/66 kV Horsham ZS.

1.2 Site Information

Table 1 Site Information

Variable	Value
Lot/DP	Multiple Lots
Address	Horsham-Lubeck Road Riverside VIC 3401
LGA	Horsham Rural City Council

1.3 Connection Details

Table 2 Connection Details

Variable	Value
NSP	Ausnet
Supply Area	Horsham
Point of Connection Voltage	220 kV
Feeder Name	N/A
Relevant Zone Substation	Horsham 220/66 kV Terminal Station

2 Model Construction

This chapter's emphasis is on the input data required and the methodology used to construct the network model integrated with Horsham Solar Farm. Software used for the network modelling and the analysis is PSS®E v34.5.1.

2.1 Input Data

The network models and the steady state studies are based upon the AEMO summer high and spring low cases together with data outlined in the table below.

Table 3 Input data references

Variable	Value	Source
Enquiry Response	Horsham Data Pack VIC runback schemes, fault levels, breaker clearing times.	AEMO
PSS®E Models	High: 20210124-180000-SystemNormal.sav Low: 20210328-110152-SystemNormal.sav	AEMO
RUGS	VIC RUGS as specified in section 3	AEMO
Inverter Plant Model	SMA SC 4200 UP	SMA

2.2 Horsham Solar Farm Plant Model

To conduct the steady state studies the HORSF was modelled as one aggregated generator. The graphical representation of the solar plant is shown in Figure 1. The one aggregated generator has the combined capacity of inverter plant as follows:

- 1 x aggregated generator consisting of combined 151.2 MVA
- 1 x aggregated inverter transformer accommodating 151.2 MVA
- 33kV cable reticulation system modeled as an aggregated equivalent
- 1 x 170 MVA 220/33 kV power transformer
- 2 x 5 MVAr capacitor banks located on the 33kV buses

The aggregated load flow model is shown in figure below:

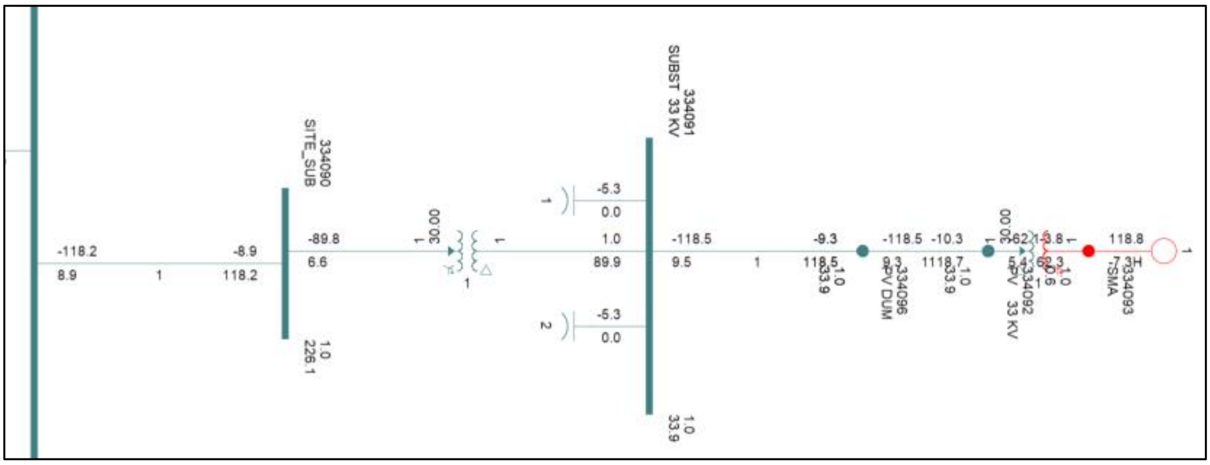


Figure 1 HORSF graphical representation in PSS®E

Table 4 Aggregated HORSF generator parameters

Description	Value
Mbase	151.2 MVA
Pmax	118.8 MW
Pmin	0 MW
Pgen[1]	119
Qmax[2]	46.926
Qmin	-46.926
Base kV	0.63 kV
R Source	0
X Source	10000.0
Control Mode[3]	N/A

[1] 118.8 MW at the PoC, this needs to be adjusted where generation change is required.
[2] Max Qmax and Qmin at the PoC is ±46.926 MVAr and this is taken into consideration when simulating the load flow as per the HORSF voltage droop characteristics.
[3] Voltage droop control mode is implemented using PSS®E python API.

Table 5 Inverter short circuit impedances

Description	Value	Description	Value
Positive R	0.12 pu	**Zero R**	99999 pu
Sub transient X	0.74 pu	**Zero X**	99999 pu
Transient X	0.74 pu	**Reference Angle**	0
Synchronous X	0.88 pu	**Grounding R**	0
Negative R	0.12 pu	**Grounding X**	0
Negative X	0.88 pu		

Table 6 Equivalent 33/0.63 kV transformer data

Description	Value	unit
Transformer rating	151.2	MVA
Winding 1 nominal	33	kV
Winding 2 nominal	0.63	kV
Specified R	0.0065	pu
Specified X	0.065	pu
R-Zero	0.004878	pu
X-Zero	0.034756	pu
Vector group	Dyn1	Text
HV – LV winding angle	30	°
Tap change type	Off load	Text
Number of taps	5	Qty
Tap changer step size	2.5	%
R1 max	1.1	pu
R1 min	0.9	pu
Tap setting (HV:LV)	1:1	Text

Table 7 Equivalent 33kV cable parameters

Description	Value	unit
	BUS 334092 to 334096	
Specified R	0.001732	pu on 100 MVA base
Specified X	0.002928	pu on 100 MVA base
Specified B	0.012514	pu on 100 MVA base
R-Zero	0.007515	pu on 100 MVA base
X-Zero	0.001222	pu on 100 MVA base
B-Zero	0.012514	pu on 100 MVA base

Table 8 Capacitor bank parameters

Description	Value	unit
Capacitor – 1	5	MVAr
Capacitor - 2	5	MVAr

Table 9 220/33 kV Grid interface main transformer data

Description	Value	unit
Transformer rating	170	MVA
Winding 1 nominal	220	kV
Winding 2 nominal	33	kV
Specified R	0.003529	pu
Specified X	0.168	pu
Vector group	Ynd1	Text
HV – LV winding angle	30	°
Tap change type	On load	Text
Number of taps	17	Qty
Tap changer step size	1.25	%
R1 max	1.1	pu
R1 min	0.9	pu
Tap setting (HV:LV)	1:1	Text

2.3 Integration of the HORSF into the Network

The Horsham Solar Farm is connected directly to the existing 220 kV busbar at Horsham 220/ 66 kV Zone Substation. In the PSS®E model this happens on the bus number 334081 (3HORSHM_220B). The figure below shows the integration of HORSF at bus number 334081 i.e., Horsham ZS 220 kV terminal.

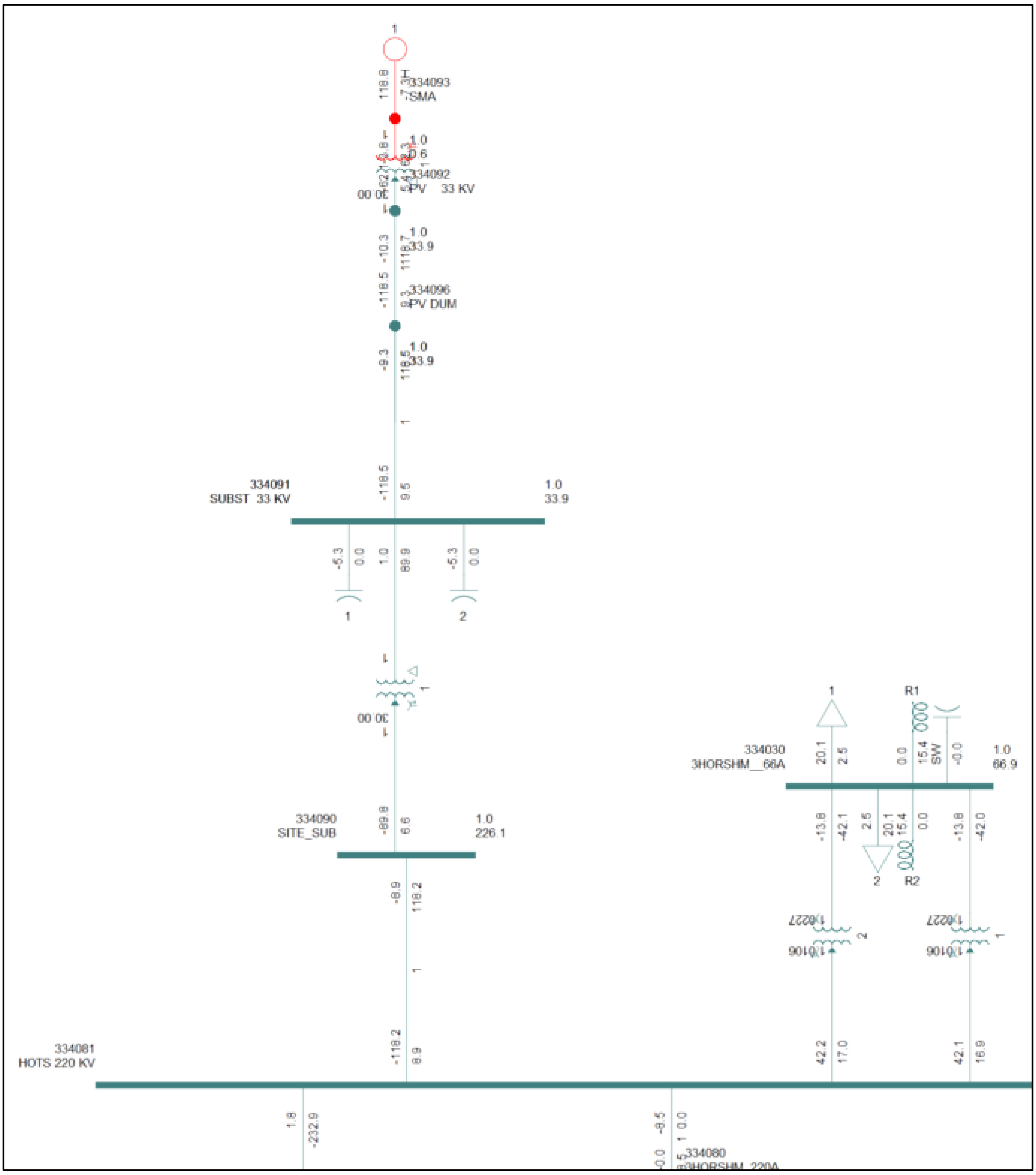


Figure 2 Integration of HORSF into the network model at Horsham 220 kV bus at Horsham 220/66 kV ZS

3 Generators within proximity

The following committed generators are identified within HORSF proximity.

Table 10 Generators within Horsham Solar Farm proximity

Name	Shor Name
Glenrowan West Solar Farm	GLWWSF
Glenrown Solar Farm	GLWSF
Stockyard Hill Wind Farm	STCKHWF
Victorian Big BESS	VBB
Murra Warra 1 Wind Farm	MUR1WF
Murra Warra 2 Wind Farm	MUR2WF
Yatpool Solar Farm	YTPSF
Yendon Wind Farm	YNDWF
Winton Solar Farm	WTNSF

Each of them is added to the high and low load snapshots as per their RUG and the steady state analysis have been with the inclusion of these generators.

4 Study Execution

This chapter outlines the steady state assessment criteria and the methodology employed by the proposed generator to fulfill the criteria.

4.1 Monitored Elements

Following network elements were monitored during the steady state analysis

Table 11 Monitored Buses

Bus Name	PSS®E Bus Number	Comments
3ARAR_T_220A	306580	ARART 220 kV
3ARAR_T_220F	306585	ARART 220 kV
3BULGTS_220A	316580	BULGANA 220 kV
HOTS 220 KV_POC	334081	HORSHAM 220 kV
3KIAMAL_220A	342280	KIAMAL 220 kV
3ARAR_T_220B	306581	ARART 220 kV
3CROWLA_220A	321580	CROWNLANDS 220 KV
3MURRAW_220A	355880	MURRA WARRA 220 kV
3REDCLF_220A	364080	RED CLIFF 220 kV
3BALRAT_220A	309080	BALARAT 220 kV
3WAUBRA_220A	384080	WAUBRA 220 kV

Table 12 Monitored Branches

Branch Name	Branch from	Branch to	Branch id	Branch Code
3BALRAT_220A - 3WAUBRA_220A	309080	384080	1	3BALRAT_220A - 3WAUBRA_220A
3ARAR_T_220B - 3WAUBRA_220A	306581	384080	1	3ARAR_T_220B - 3WAUBRA_220A
3ARAR_T_220F - 3CROWLA_220A	306585	321580	1	3ARAR_T_220F - 3CROWLA_220A
3BULGTS_220A - 3CROWLA_220A	316580	321580	1	3BULGTS_220A - 3CROWLA_220A
3BULGTS_220A - HOTS 220 KV	316580	334081	1	3BULGTS_220A - HOTS 220 KV
3HORSHM__66A - HOTS 220 KV	334030	334081	1	3HORSHM__66A - HOTS 220 KV
3HORSHM__66A - HOTS 220 KV	334030	334081	2	3HORSHM__66A - HOTS 220 KV
HOTS 220 KV - 3MURRAW_220A	334081	355880	1	HOTS 220 KV - 3MURRAW_220A
3KIAMAL_220A -3MURRAW_220A	342280	355880	1	3KIAMAL_220A - 3MURRAW_220A
3KIAMAL_220A - 3REDCLF_220A	342280	364080	1	3KIAMAL_220A - 3REDCLF_220A

4.2 Study requirements

The steady state consists of four key components, each of which illustrate the findings of the respective part of the study:

1) Plant reactive power capability
   a) This criterion is based on the reactive power requirement from the automatic access standard S5.2.5.1(a) i.e. that the proposed plant should be capable of supplying or absorbing the reactive power which is at least 0.395 of its intended active power value.
2) Impact on thermal network capability for standard configuration and contingency events
   a) This part of the steady state analysis investigates line loading and transformer loading under network normal and N-1 conditions, with and without the proposed generator. This reveals the pre-existing issues as well as issues caused by the inclusion of the proposed generator.
3) Impact on network voltage capability for standard configuration and contingency events. This part further divided into three parts
   a) The first part looks at Bus voltages under system normal conditions (i.e. no line outages or other contingencies. Adding generation to a bus or a line may shift the voltage levels at that bus or surrounding buses due to the impact it has on the power flows in the area. The normal operating band of the NEM is between 0.9 p.u. voltage and 1.1 p.u. voltage. The results presented in results section will highlight the changes in relevant bus voltages due to the addition of the newly proposed generator.
   b) The second part of this assessment explores voltage fluctuations for a change in the generation output. This includes voltage fluctuations due to generation output variation considering a change from 100% output to 75%, 50% and 25% with all network transformer taps locked. This also includes voltage fluctuations due to trip of the proposed plant, considering a change from 100%, 75%, 50% and 25% output to no output (plant trip) with all the network transformer taps locked. This is quantified and compared against the Table6 IEC 61000.3.7:2012 (p.33) applicable thresholds.
   c) The third part of this assessment focusses on voltage stability under credible contingencies. The voltage changes due to loss of line with fixed tap load flows on the network should not be worse than the system without the proposed plant.
4) The last part of the Steady State analysis investigates fault current at buses of interest. These fault levels are required to not exceed planning levels. This item is unlikely to be problematic in most instances as the contribution from inverter-based resources behind transformer and cable impedances is generally normally small compared against existing headroom.

Following table provides the summary of different test scenarios performed on Horsham Solar Farm as per the above test types in accessing the steady state analysis. The Case Reference column in the table below corresponds to the cases/contingencies being studied, For instance

- Network Normal case reference refers to the network normal conditions case. The corresponding Voltage levels test type will consider voltage levels deviation with and without HORSF as well as voltage levels to be remain within 0.9 to 1.1pu.
- ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS refers to the contingency where ARARAT to CROWNLANDS 2200kV line is out of service. The Contingency test type will consider line loadings with and without HORSF while that contingency is in place. The voltage fluctuation will also be measured when the network is going from network normal to that contingency. This voltage fluctuations will be assessed against with and without HORSF in service. Furthermore, during these line contingencies inter trip schemes have been placed thus tripping the required committed generators as per the contingency. These inter trip schemes have been implemented as per the provided document 2g_Western Vic Generation Fast trip Schemes and Murraylink VFRB.docx [2]
- HORSF_GenChng 100% to 75% refers to the case where generation of HORSF is changed from 100% to 75%.
- HORSF_GenTrip 75% to 0% refers to the case where HORSF is tripped while generating at 75%. The Gen Change and Gen Trip will observe voltage fluctuations before and after the event and the plant itself is required for this test to be performed.

Table 13 Case Reference and the corresponding Test Types used in HORSF SS Analysis

Case Reference	TestType
Network Normal	Voltage levels
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	Contingency
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	Contingency
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	Contingency
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	Contingency
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	Contingency
HOTS220 - HOTS66 kV Tx OOS	Contingency
HORSF_GenChng 118.8MW to 89.1MW (100% to 75%)	GenChange
HORSF_GenChng 118.8MW to 59.4MW (100% to 50%)	GenChange
HORSF_GenChng 118.8MW to 29.7MW (100% to 25%)	GenChange
HORSF_GenTrip 118.8MW to 0MW (100% to 0%)	GenTrip
HORSF_GenTrip 89.1MW to 0MW (75% to 0%)	GenTrip
HORSF_GenTrip 59.4MW to 0MW (50% to 0%)	GenTrip
Network Normal High Load	Fault Levels

4.3 HORSF Steady State Grid Impact Assessment Summary

The table below shows the summary of steady state analysis conducted on the HORSF. The HORSF has met the steady state criteria.

Table 14 HORSF steady state grid impact assessment summary

Assessment	Assessment criteria	Notes	Assessment results
Generator reactive power capability	Automatic access standard	Tap changers enabled	**Criterion met**
Impact on thermal network capability for standard configuration and contingency events	≤ 100% Thermal limit; or not exacerbated by given exacerbation value from NSP where already>100%	Tap changers enabled	**Criterion met**
Impact on network voltage capability for standard configuration and contingency events	a) Voltage levels between 0.9 to 1.1pu b) ≤ 3% voltage fluctuations GenChange c) ≤ 5% voltage fluctuations GenTrip d) ≤ 5% Voltage fluctuations due to loss of line contingencies Note: Existing out of bound voltage fluctuations are not be exacerbated by a given limit provided by the NSP.	Tap changers disabled	a) **Criterion met** b) **Criterion met** c) **Criterion met** d) **Criterion met**
Short circuit calculation studies	≤ Provided fault level limits		**Criterion met**

5 HORSF Plant Control Strategy and Optimistaion

To assess the steady state studies of Horsham solar farm, the following PSS®E sav cases have been used. The raw snapshots were integrated with committed generators and the HORSF SMIB model. This results in creation of HORSF_high_genon.sav and HORSF_low_genon.sav. After that HORSF is deactivated, resulting in the creation of HORSF_high_genoff.sav and HORSF_low_genoff.sav.

Table 15 PSS®E sav cases used for steady state analysis

Sav cases
HORSF_high_genon.sav
HORSF_high_genoff.sav
HORSF_Low_genon.sav
HORSF_Low_genoff.sav

Initial assessment of HORSF operating at voltage setpoint of 1.02pu in a voltage droop control mode with a droop of 4.0% on 90.72 MVAr base shows compliance in steady state analysis. No further assessment was required, therefore Horsham solar farm is operated in the above settings.

6 Simulation Results

6.1 Reactive Power Capability Curve

Based on the reactive power requirement from the automatic access standard S5.2.5.1(a), HORSF is required to supply and absorb at least 46.926 MVAr at the connection point (CP) for a rated active power output of 118.8 MW.

The calculation for the required reactive power is given below:

$Qpoc = \pm 0.395 \times Prated,POC = \pm 0.395 \times 118.8.0 = \pm 46.926\ MVAr$

To assess the reactive power capability of HORSF, active power output at inverter terminal has been incrementally increased from its minimum to 118.8 MW; and at each level of the active power generation, reactive power has been changed till it reaches the maximum and minimum capacity of the plant. This process is repeated at different voltage level 0.9pu, 1.0pu and 1.1pu. The active power and reactive power were measured at the POC, which was used as an estimate of the reactive power capability of the aggregated plant.

It is important to note that the method used here has not taken the plant controller operation into consideration which has been addressed in dynamic analysis in the connection study i.e., PPC is disabled for this study.

Figures below shows that HORSF has sufficient leading and lagging reactive power capability at all levels of active power and it is able to comply with the automatic access standard S5.2.5.1(a) for 118.8 MW active power output at the CP at an ambient temperature of 35°C.

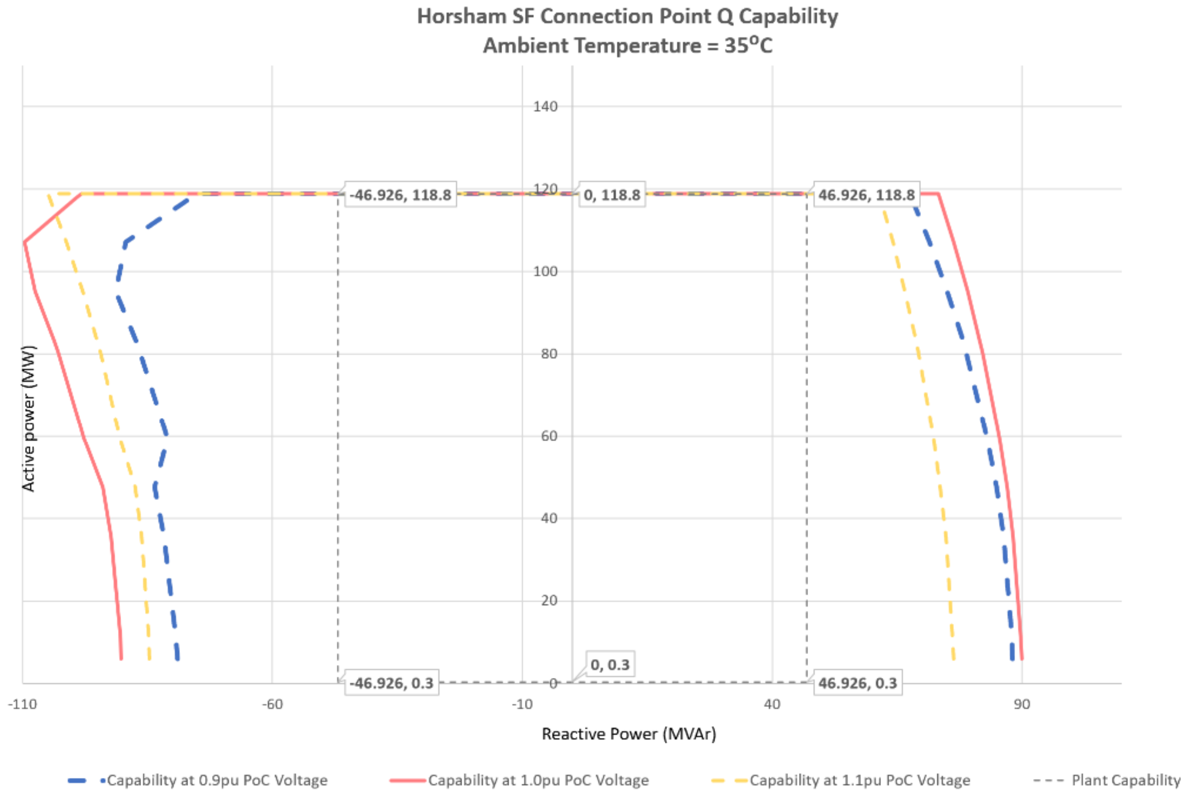


Figure 3 HORSF reactive power capability at 35°C (AAS)

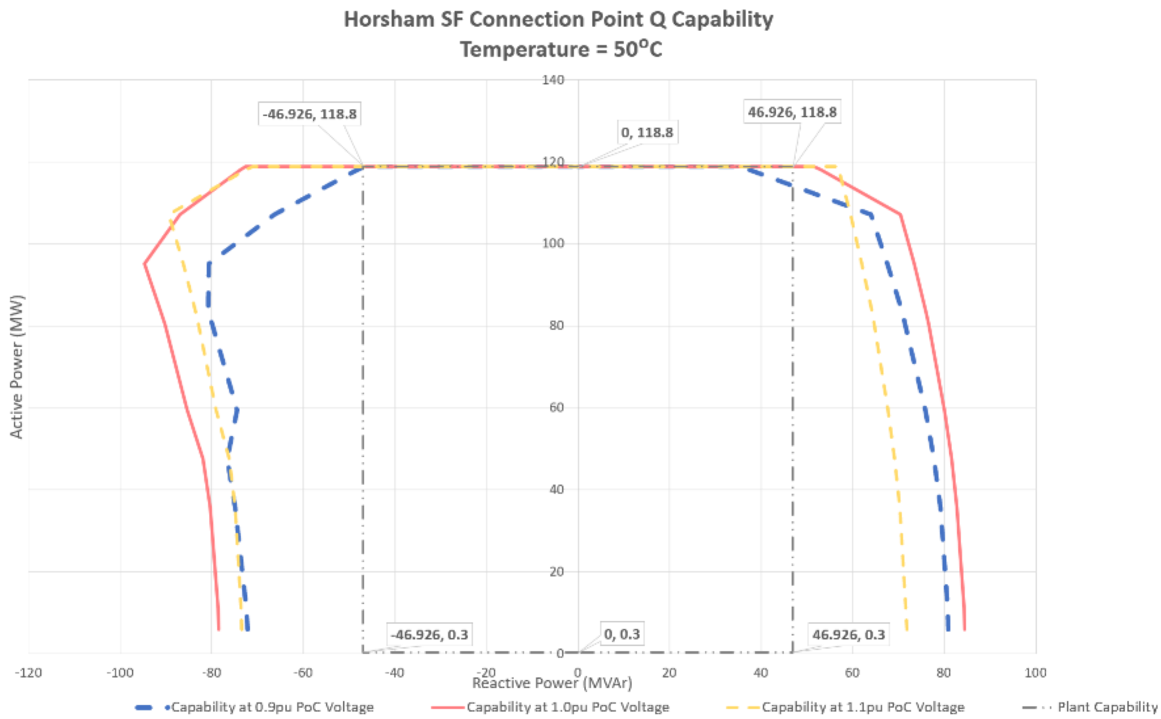


Figure 4 HORSF reactive power capability at 50°C (NAS)

There will be a 10% derating in the HORSF plant MVA at 50°C. The plant capability at 50°C is shown in figure above and it does not comply with automatic access standard at 50°C with a full active power of 118.8 MW when POC voltage is 0.9pu. There are no issues at POC voltage of 1 and 1.1pu. Therefore, a negotiated access standard is required for HORSF S5251 at 50°C. Taking the above figure into consideration, above results at 50°C will not impact the studies much.

6.2 Voltage Levels

The voltage levels at buses of interest have been analysed for system normal conditions (no contingencies) with Horsham Solar Farm in service and compared to the voltage levels prior to adding the HORSF. The normal operating voltage band of each considered bus is defined as 0.9 p.u. to 1.1 p.u.

6.2.1 Summary of Findings

The results for each bus before and after the inclusion of Horsham Solar Farm are listed in the tables below. There are no issues observed in the voltage levels with the addition of HORSF into the network.

6.2.1.1 HighLoad

Bus Name	Voltage Level(pu) GenOFF	Voltage Level(pu) GenON
3ARAR_T_220A	1.026	1.018
3ARAR_T_220F	1.026	1.018
3BULGTS_220A	1.026	1.02
HOTS 220 KV_POC	1.028	1.028
3KIAMAL_220A	1.024	1.022
3ARAR_T_220B	1.026	1.018
3CROWLA_220A	1.025	1.018
3MURRAW_220A	1.04	1.04
3REDCLF_220A	1.004	1.004
3BALRAT_220A	1.038	1.033
3WAUBRA_220A	1.031	1.024

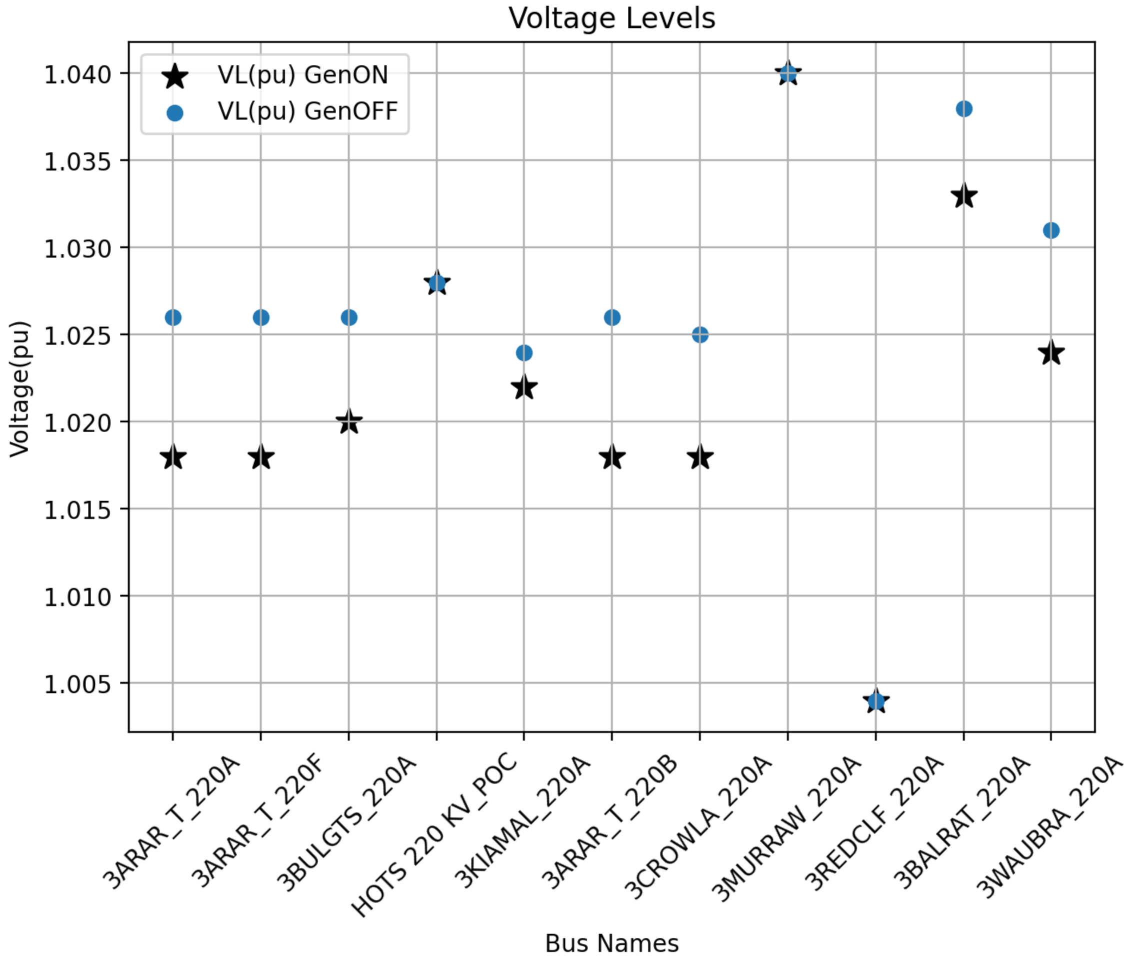
6.2.1.2 LowLoad

Bus Name	Voltage Level(pu) GenOFF	Voltage Level(pu) GenON
3ARAR_T_220A	1.033	1.02
3ARAR_T_220F	1.033	1.02
3BULGTS_220A	1.027	1.015
HOTS 220 KV_POC	1.022	1.021
3KIAMAL_220A	1.009	1.008
3ARAR_T_220B	1.033	1.02
3CROWLA_220A	1.03	1.017
3MURRAW_220A	1.04	1.04
3REDCLF_220A	0.998	0.998
3BALRAT_220A	1.054	1.047
3WAUBRA_220A	1.043	1.031

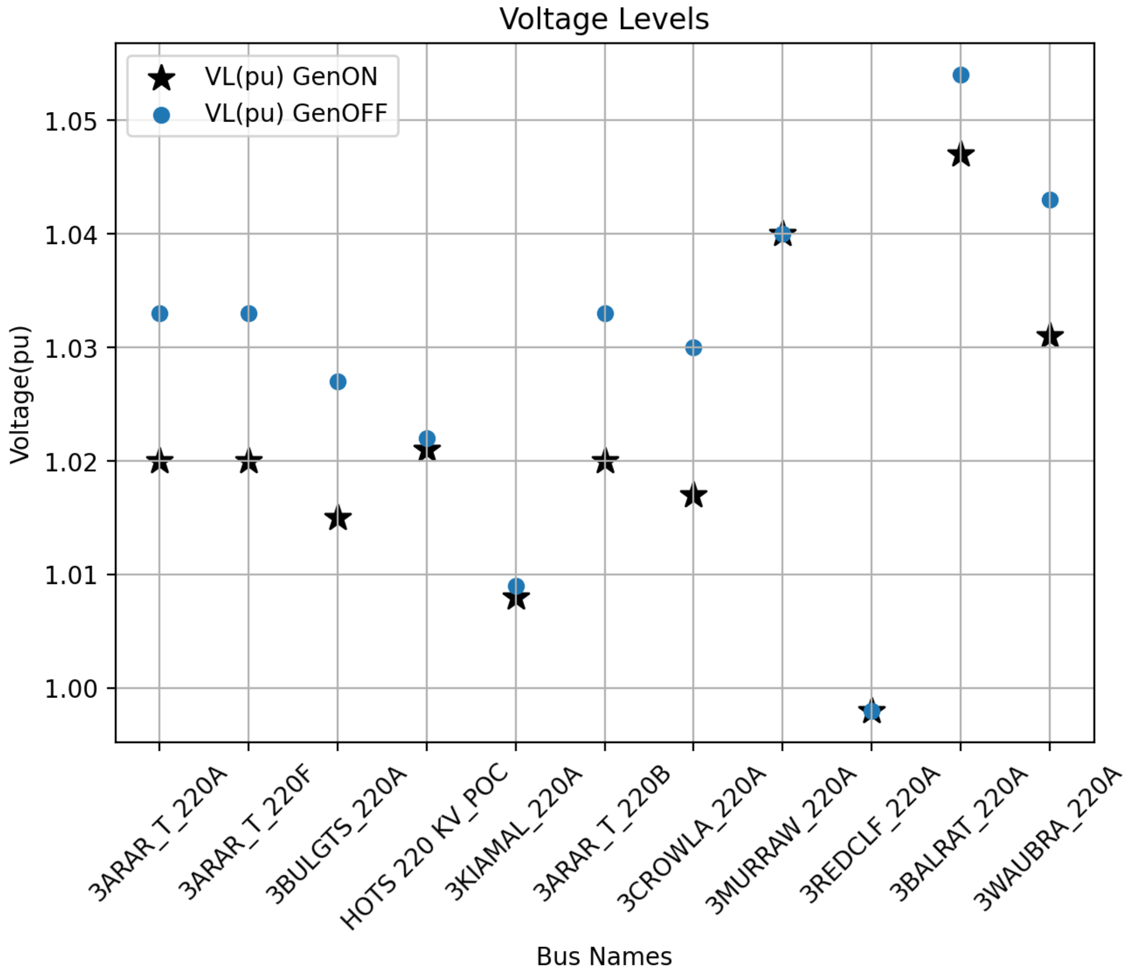
6.2.2 Plots

The scatter plots show the absolute voltage level in the reference case(s) analysed in this study.

6.2.2.1 HighLoad



6.2.2.2 LowLoad



6.3 Line and Transformer Loadings

Line and transformer loadings in the area around Horsham have been analysed under various conditions, including relevant N-1 scenarios. For each scenario, the analysis is conducted in two cases which are with and without the inclusion of HORSF by using the GenOn and GenOff cases created earlier.

6.3.1 Summary of Findings

The maximum and minimum loading levels for each contingency or case reference including network normal before and after addition of Horsham Solar Farm are listed in the tables below. The Case Reference column in the table below represents contingency or network normal and the corresponding row represents the maximum and minimum loading branch. Full results are provided in Appendix 2.

6.3.1.1 HighLoad

Case Reference	Branch Name	Max Loading(%) GenOFF	Max Loading(%) GenON	Branch Name	Min Loading(%) GenOFF	Min Loading(%) GenON
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	3KIAMAL_220A - 3REDCLF_220A	35.4	59.53	3BULGTS_220A - 3CROWLA_220A	0.66	0.66
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	3KIAMAL_220A - 3REDCLF_220A	35.21	59.33	3ARAR_T_220F - 3CROWLA_220A	0.0	0.0
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	3KIAMAL_220A - 3REDCLF_220A	35.49	59.63	3ARAR_T_220F - 3CROWLA_220A	6.32	6.28
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	3BALRAT_220A - 3WAUBRA_220A	12.49	33.85	3KIAMAL_220A - 3REDCLF_220A	7.13	7.13
HOTS220 - HOTS66 kV Tx OOS	3BALRAT_220A - 3WAUBRA_220A	60.54	74.47	3KIAMAL_220A - 3MURRAW_220A	32.45	39.81
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3BALRAT_220A - 3WAUBRA_220A	51.79	71.58	3KIAMAL_220A - 3MURRAW_220A	5.18	5.69
Network Normal	3BALRAT_220A - 3WAUBRA_220A	60.04	73.88	3HORSHM__66A - HOTS 220 KV	33.78	35.44

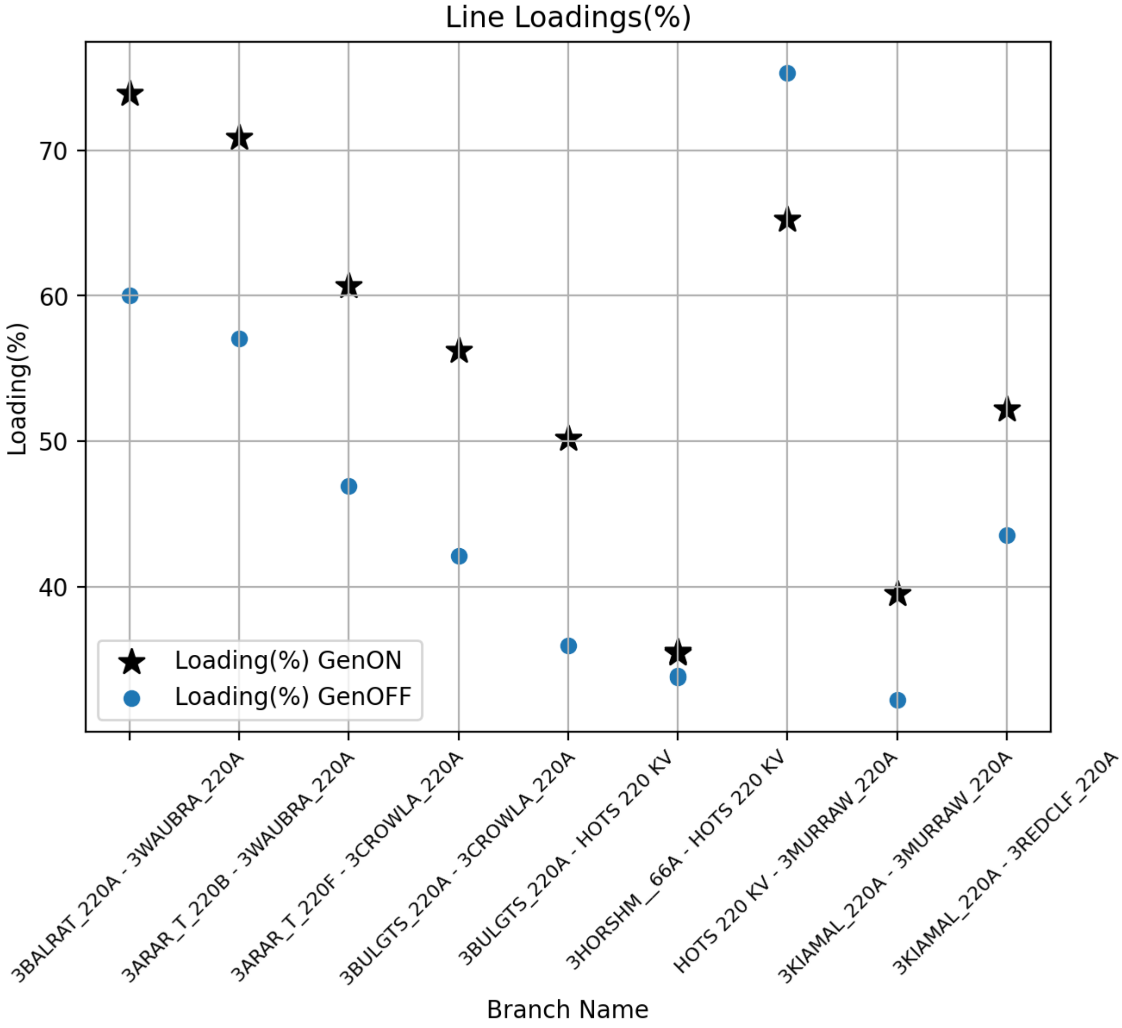
6.3.1.2 LowLoad

Case Reference	Branch Name	Max Loading(%) GenOFF	Max Loading(%) GenON	Branch Name	Min Loading(%) GenOFF	Min Loading(%) GenON
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	3KIAMAL_220A - 3REDCLF_220A	43.04	62.44	3BULGTS_220A - 3CROWLA_220A	0.52	0.52
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	3KIAMAL_220A - 3REDCLF_220A	42.96	62.37	3ARAR_T_220F - 3CROWLA_220A	0.0	0.0
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	3KIAMAL_220A - 3REDCLF_220A	43.09	62.48	3ARAR_T_220F - 3CROWLA_220A	1.11	1.12
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	3BALRAT_220A - 3WAUBRA_220A	9.38	26.27	3HORSHM__66A - HOTS 220 KV	11.5	12.49
HOTS220 - HOTS66 kV Tx OOS	3BALRAT_220A - 3WAUBRA_220A	70.63	84.28	3KIAMAL_220A - 3MURRAW_220A	9.45	13.63
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3BALRAT_220A - 3WAUBRA_220A	52.09	70.22	3HORSHM__66A - HOTS 220 KV	13.89	15.99
Network Normal	3BALRAT_220A - 3WAUBRA_220A	70.35	83.97	3KIAMAL_220A - 3MURRAW_220A	9.41	13.54

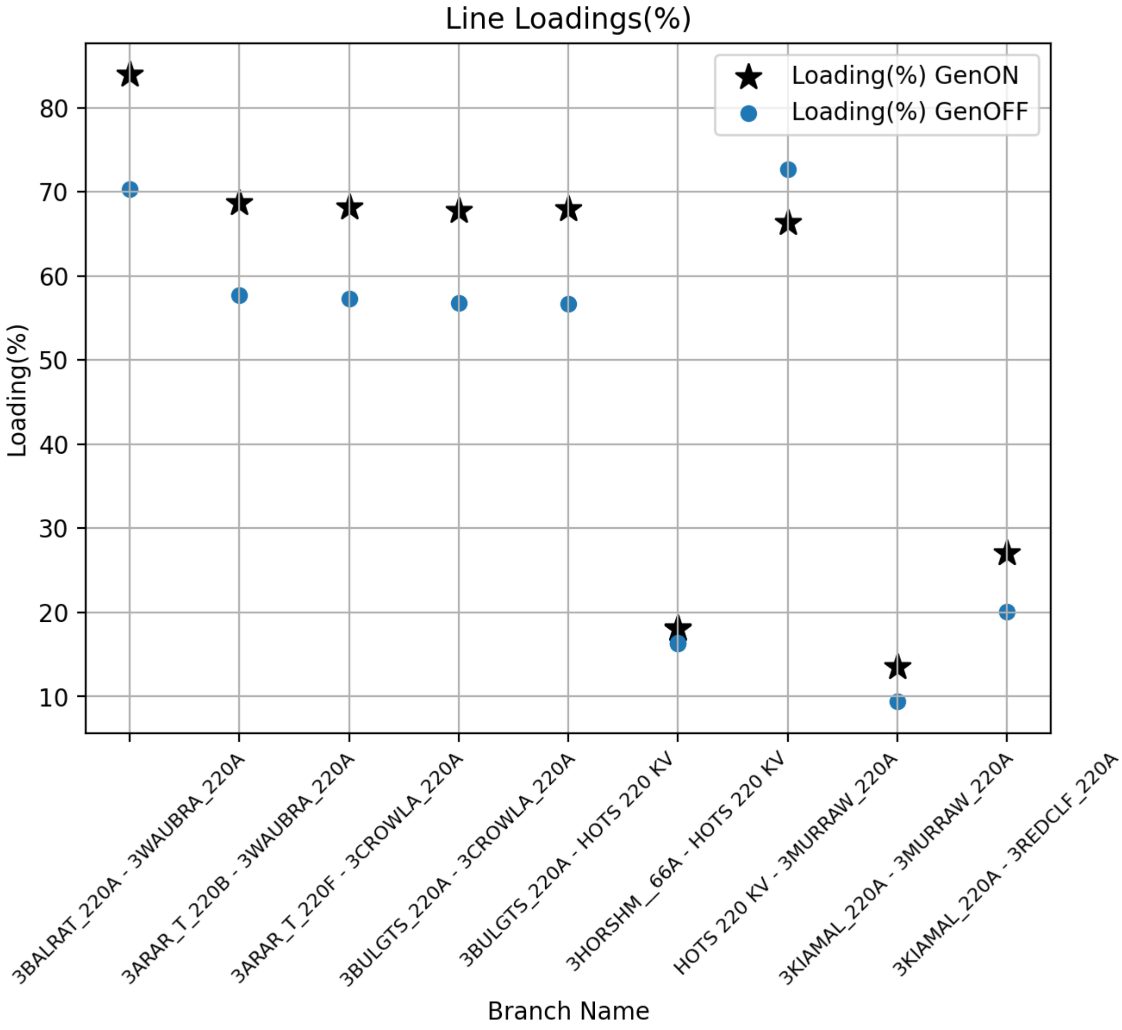
6.3.2 Plots

The scatter plots show the results for the line loadings with and without HORSF in service in network normal conditions.

6.3.2.1 HighLoad



6.3.2.2 LowLoad



6.4 Voltage Fluctuations for Change of Generation

This section explores the impact of a sudden loss of generation on the bus voltages at the buses of interest. The output of Horsham Solar Farm can suddenly change due to unexpected tripping of the plant or weather-related circumstances such as a change in cloud cover. A sudden change in the output of the plant must not cause a voltage disturbance larger than 3% due to loss of generation and larger than 5% due to trip of the plant.

6.4.1 Summary of Findings

The maximum and minimum voltage fluctuation for each generation change case are listed in the tables below. The Case Reference column in the table below represents generation change and the corresponding row represents the maximum and minimum voltage fluctuation busbar. Full results are provided in Appendix 3. The results show that voltage fluctuations for change of generation are within the acceptable range.

6.4.1.1 HighLoad

Case Reference	Bus Name	Max Volt Fluc(%)	Bus Name	Min Volt Fluc(%)
HORSF_GenChng - 118.8MW to 29.7MW (100% to 25%)	3ARAR_T_220A	0.695	HOTS 220 KV_POC	-0.011
HORSF_GenChng - 118.8MW to 59.4MW (100% to 50%)	3WAUBRA_220A	0.516	3MURRAW_220A	0.0
HORSF_GenChng - 118.8MW to 89.1MW (100% to 75%)	3WAUBRA_220A	0.267	3MURRAW_220A	0.0
HORSF_GenTrip - 118.8MW to 0MW (100% to 0%)	3ARAR_T_220A	0.787	3MURRAW_220A	0.0
HORSF_GenTrip - 29.7MW to 0MW (25% to 0%)	3BULGTS_220A	0.124	3MURRAW_220A	0.0
HORSF_GenTrip - 59.4MW to 0MW (50% to 0%)	3ARAR_T_220A	0.316	3MURRAW_220A	0.0
HORSF_GenTrip - 89.1MW to 0MW (75% to 0%)	3ARAR_T_220A	0.543	3MURRAW_220A	0.0

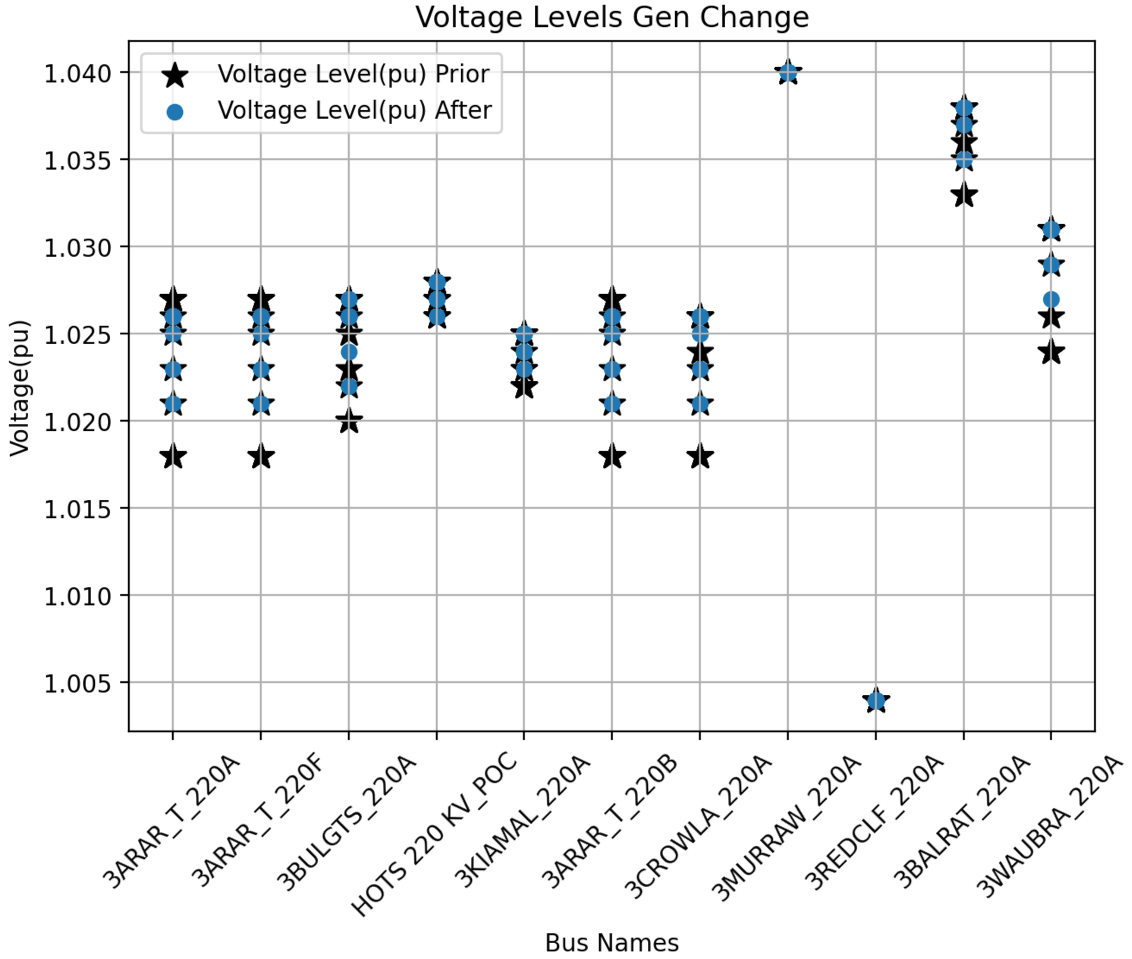
6.4.1.2 LowLoad

Case Reference	Bus Name	Max Volt Fluc(%)	Bus Name	Min Volt Fluc(%)
HORSF_GenChng - 118.8MW to 29.7MW (100% to 25%)	3ARAR_T_220A	1.274	3MURRAW_220A	0.0
HORSF_GenChng - 118.8MW to 59.4MW (100% to 50%)	3ARAR_T_220A	0.868	3MURRAW_220A	0.0
HORSF_GenChng - 118.8MW to 89.1MW (100% to 75%)	3ARAR_T_220A	0.441	3MURRAW_220A	0.0
HORSF_GenTrip - 118.8MW to 0MW (100% to 0%)	3ARAR_T_220A	1.698	3MURRAW_220A	0.0
HORSF_GenTrip - 29.7MW to 0MW (25% to 0%)	3ARAR_T_220A	0.392	3MURRAW_220A	0.0
HORSF_GenTrip - 59.4MW to 0MW (50% to 0%)	3ARAR_T_220A	0.798	3MURRAW_220A	0.0
HORSF_GenTrip - 89.1MW to 0MW (75% to 0%)	3ARAR_T_220A	1.227	3MURRAW_220A	0.0

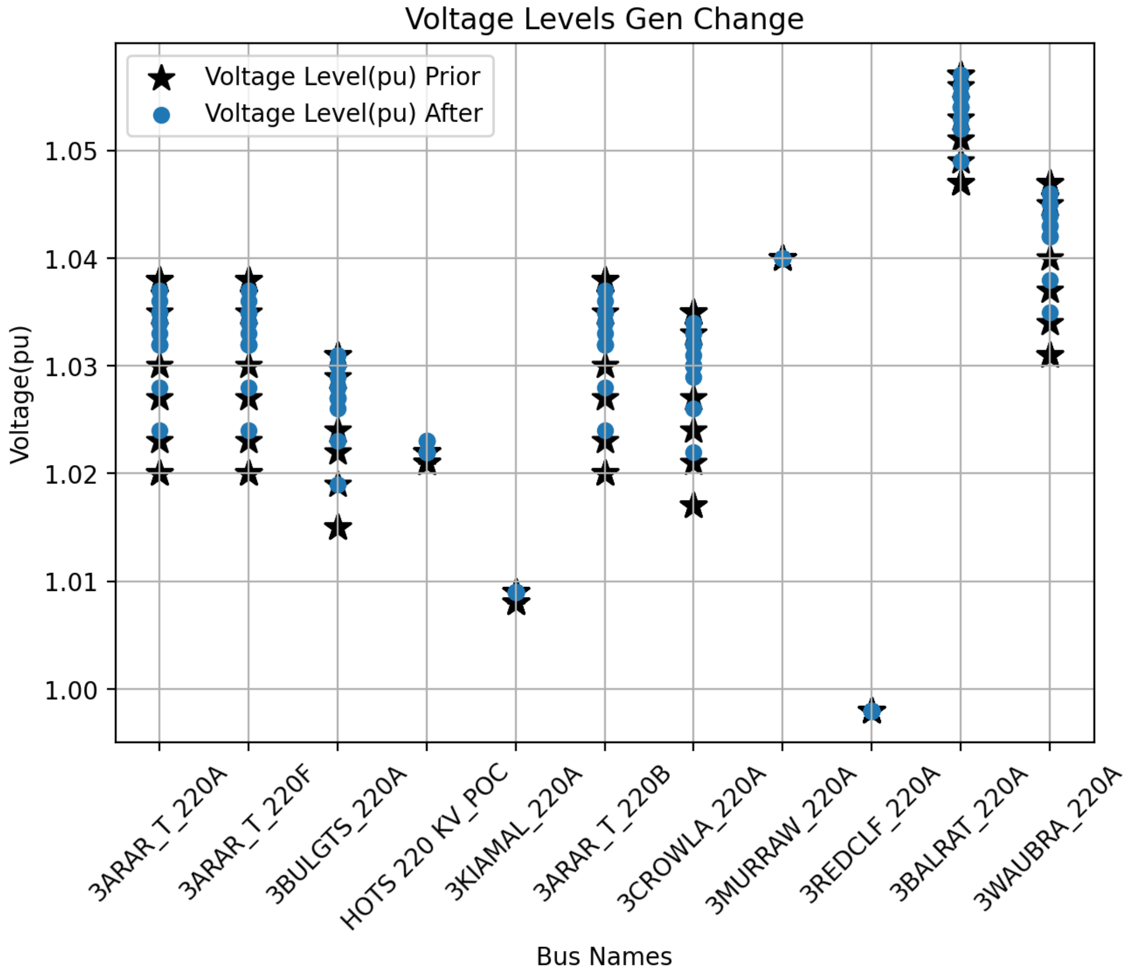
6.4.2 Plots

The scatter plots shows the voltage profile of the network during loss of generation events prior and after connecting the proposed plant.

6.4.2.1 HighLoad



6.4.2.2 LowLoad



6.5 Voltage fluctuations due to loss of line contingencies

This section explores voltage fluctuations at the buses of interest due to loss of line contingencies. These voltage fluctuations are than compared with the existing voltage fluctuations i.e. prior connecting the proposed plant. The voltage fluctuations should not be above 5% or should not exacerbate by a value provided by the NSP.

6.5.1 Summary of Findings

The maximum and minimum voltage fluctuation for each bus under the given scenarios are listed in the tables below. Full results are provided in Appendix4.

The results show that with the inclusion of HORSF, the voltage fluctuations are within the acceptable range in most of the credible contingency scenarios except at the Kiamal 220kV bus (3KIAMAL_220A) due to loss of Kiamal to Redcliff 220 kV line. The existing voltage fluctuation is 5.047 % and with the addition of HORSF the voltage fluctuation exceeds to 5.595 %. Due to the small magnitude of this exacerbation i.e., 0.55% and the long distance between HORSF and 3KIAMAL_220A bus this is deemed acceptable. This exacerbation is not expected to impact system security and the limit is slightly exceeded with and without HORSF present. In fact, Horsham is not causing the fluctuation and under slightly different network conditions the plant would likely mitigate the fluctuation rather than exacerbate it, given it stabilizes the voltage at HOTS 220 kV.

There are no other voltage fluctuation issues.

Table 16 Voltage fluctuation above 5% in high load scenario

Case Reference	Bus Name	Voltage Level(pu) GenON	Volt Fluc(%) GenON	Voltage Level(pu) GenOFF	Volt Fluc(%) GenOFF
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3KIAMAL_220A	1.078	5.595	1.075	5.047

6.5.1.1 HighLoad

Case Reference	Bus Name	Max Volt Fluc(%) GenON	Max Volt Fluc(%) GenOFF	Bus Name	Min Volt Fluc(%) GenON	Min Volt Fluc(%) GenOFF
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	3ARAR_T_220A	3.238	2.548	3KIAMAL_220A	-0.063	0.257
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	3ARAR_T_220A	2.082	1.217	3KIAMAL_220A	-0.053	0.263
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	3ARAR_T_220A	1.949	1.238	3KIAMAL_220A	-0.068	0.255
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	3ARAR_T_220A	1.661	0.968	HOTS 220 KV_POC	-0.066	-0.5
HOTS220 - HOTS66 kV Tx OOS	3MURRAW_220A	0.0	0.0	3BULGTS_220A	-0.057	-0.028
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3KIAMAL_220A	5.595	5.047	3MURRAW_220A	0.0	0.0
Network Normal	3KIAMAL_220A	0.0	0.0	3ARAR_T_220A	-0.001	0.0

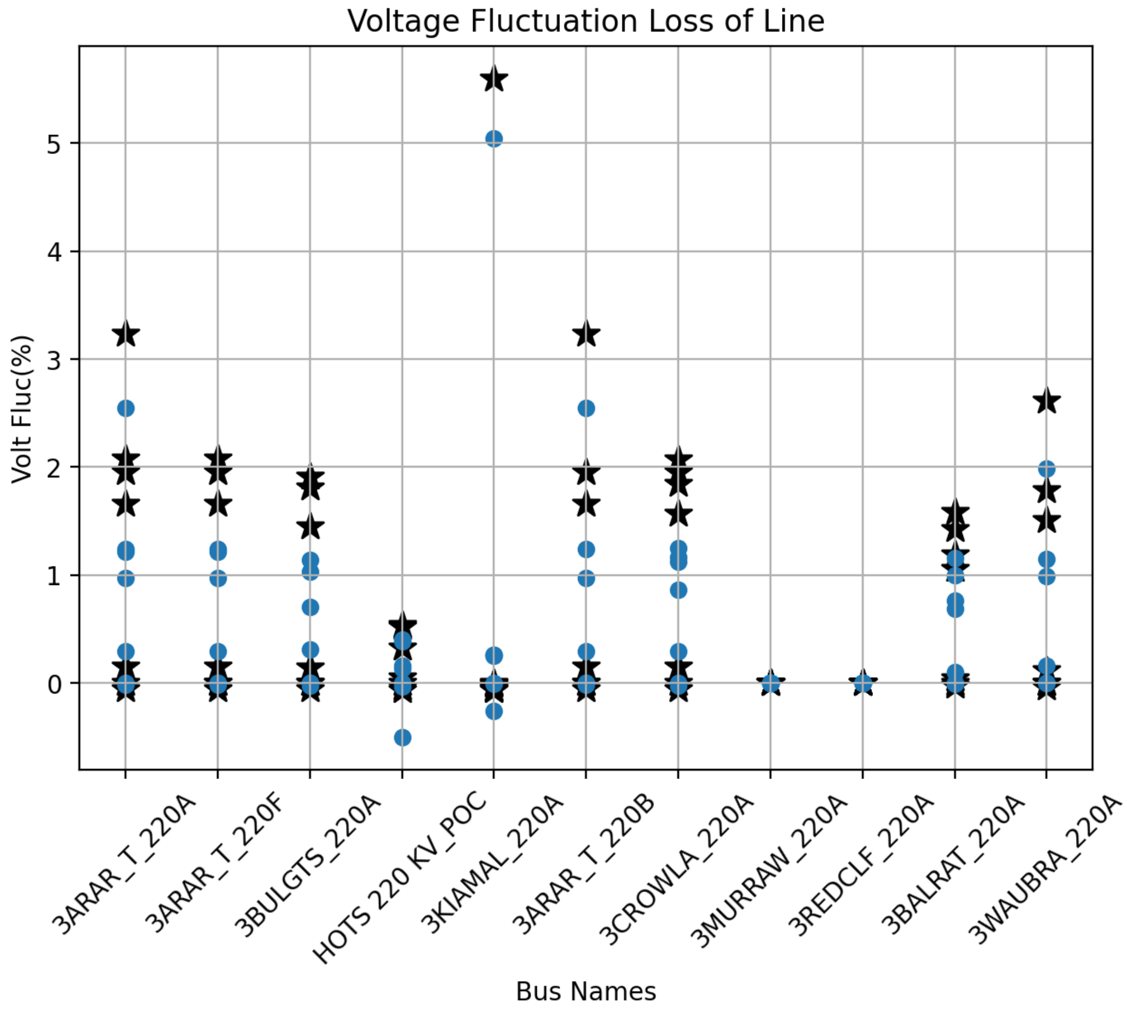
6.5.1.2 LowLoad

Case Reference	Bus Name	Max Volt Fluc(%) GenON	Max Volt Fluc(%) GenOFF	Bus Name	Min Volt Fluc(%) GenON	Min Volt Fluc(%) GenOFF
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	3ARAR_T_220A	3.417	2.422	3MURRAW_220A	-3.0	-3.0
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	3BALRAT_220A	1.789	1.377	3MURRAW_220A	-3.0	-3.0
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	3CROWLA_220A	3.099	2.148	3MURRAW_220A	-3.0	-3.0
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	3BULGTS_220A	3.654	1.631	3KIAMAL_220A	-2.186	-2.346
HOTS220 - HOTS66 kV Tx OOS	3MURRAW_220A	0.0	0.0	3BULGTS_220A	-0.055	-0.024
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3WAUBRA_220A	1.382	0.696	3MURRAW_220A	-3.0	-3.0
Network Normal	3KIAMAL_220A	-0.0	0.0	HOTS 220 KV_POC	-0.028	0.0

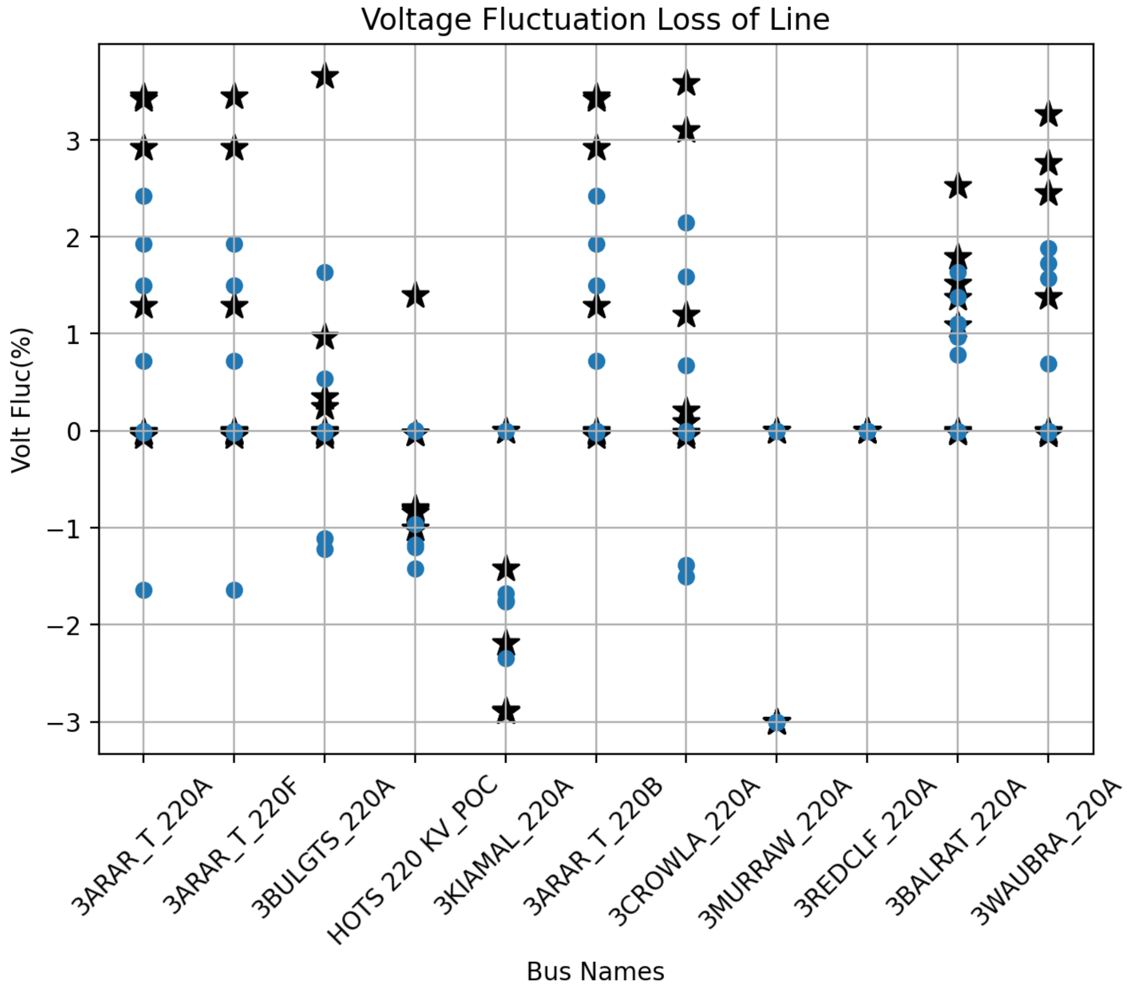
6.5.2 Plots

The scatter plots shows the summary of voltage fluctuations due to loss of line contingencies.

6.5.2.1 HighLoad



6.5.2.2 LowLoad



6.6 Fault Level Analysis

The fault levels were calculated using the IEC 60909 fault calculation function in PSS®E for both 3 phase and phase to ground faults. The short circuit current studies have been performed on the maximum load case. Following table shows the fault levels on the monitored buses.

6.6.1 HighLoad

Bus Name	Bus No	1ph Fault (MVA) GenOff	1ph Fault (MVA) GenON	3ph Fault (MVA) GenOFF	3ph Fault (MVA) GenON
3ARAR_T_220A	306580	1842.52	1905.96	2026.92	2165.86
3ARAR_T_220F	306585	1842.52	1905.96	2026.92	2165.86
3BULGTS_220A	316580	1478.27	1544.49	1811.74	1989.03
HOTS 220 KV_POC	334081	1508.79	1694.21	1714.31	2147.11
3KIAMAL_220A	342280	1921	1946.56	2068.36	2119.36
3ARAR_T_220B	306581	1842.52	1905.96	2026.92	2165.86
3CROWLA_220A	321580	1678.18	1740.95	1936.51	2087.26
3MURRAW_220A	355880	1287.3	1365.62	1861.07	2146.64
3REDCLF_220A	364080	2633.95	2649.29	2013.96	2032.9
3BALRAT_220A	309080	4761.56	4805.6	4750.17	4830.4
3WAUBRA_220A	384080	2607.65	2656.54	2799.76	2901.11

7 Conclusion

Steady state study has been caried out with consideration of various test scenarios for different assessments including voltage levels and thermal loading assessments, and the results show that no issues have been identified in these assessments. In addition, the inclusion of HORSF provides a reactive power support of +-46.926 MVA to enhance the stability and controllability of the existing network.

In summary, Horsham solar farm will improve the network with respect to voltage stability and the plant operation will be in voltage droop control mode with 3.9% droop on 46.926 MVAr and a voltage setpoint of 1.02pu.

8 References

[1] AEMO, "Horsham Data Pack and VIC runback schemes, fault levels, breaker clearing times".

[2] AEMO, *2g_Western Vic Generation Fast trip Schemes and Murraylink VFRB,* VIC: AEMO, 2020.

9 Appendices

This section provides the detailed results where applicable for the assessments performed in this steady state analysis.

9.1.1 Appendix 1

The voltage levels for all the monitored buses as per section 6.2

9.1.1.1 HighLoad

Bus Name	Voltage Level(pu) GenOFF	Voltage Level(pu) GenON
3ARAR_T_220A	1.026	1.018
3ARAR_T_220F	1.026	1.018
3BULGTS_220A	1.026	1.02
HOTS 220 KV_POC	1.028	1.028
3KIAMAL_220A	1.024	1.022
3ARAR_T_220B	1.026	1.018
3CROWLA_220A	1.025	1.018
3MURRAW_220A	1.04	1.04
3REDCLF_220A	1.004	1.004
3BALRAT_220A	1.038	1.033
3WAUBRA_220A	1.031	1.024

9.1.1.2 LowLoad

Bus Name	Voltage Level(pu) GenOFF	Voltage Level(pu) GenON
3ARAR_T_220A	1.033	1.02
3ARAR_T_220F	1.033	1.02
3BULGTS_220A	1.027	1.015
HOTS 220 KV_POC	1.022	1.021
3KIAMAL_220A	1.009	1.008
3ARAR_T_220B	1.033	1.02
3CROWLA_220A	1.03	1.017
3MURRAW_220A	1.04	1.04
3REDCLF_220A	0.998	0.998
3BALRAT_220A	1.054	1.047
3WAUBRA_220A	1.043	1.031

9.1.2 Appendix 2

The thermal loadings for all the monitored branches in network normal and N-1 contingencies as per section 6.3.

9.1.2.1 HighLoad

Case Reference	Branch Name	max Loading(%) GenOFF	Loading(%) GenON
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	3ARAR_T_220B - 3WAUBRA_220A	9.98	9.98
	3BALRAT_220A - 3WAUBRA_220A	12.72	12.72
	3BULGTS_220A - 3CROWLA_220A	0.66	0.66
	3BULGTS_220A - HOTS 220 KV	0.66	0.66
	3HORSHM__66A - HOTS 220 KV	34.1	40.11
	3KIAMAL_220A - 3MURRAW_220A	25.34	45.86
	3KIAMAL_220A - 3REDCLF_220A	35.4	59.53
	HOTS 220 KV - 3MURRAW_220A	23.27	12.95
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	3ARAR_T_220F - 3CROWLA_220A	0.0	0.0
	3BULGTS_220A - 3CROWLA_220A	1.01	1.01
	3BULGTS_220A - HOTS 220 KV	1.02	1.02
	3HORSHM__66A - HOTS 220 KV	34.39	40.46
	3KIAMAL_220A - 3MURRAW_220A	25.18	45.69
	3KIAMAL_220A - 3REDCLF_220A	35.21	59.33
	HOTS 220 KV - 3MURRAW_220A	23.42	12.62
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	3ARAR_T_220B - 3WAUBRA_220A	15.85	15.83
	3ARAR_T_220F - 3CROWLA_220A	6.32	6.28
	3BALRAT_220A - 3WAUBRA_220A	18.28	18.27
	3HORSHM__66A - HOTS 220 KV	33.97	39.95
	3KIAMAL_220A - 3MURRAW_220A	25.42	45.94

	3KIAMAL_220A - 3REDCLF_220A	35.49	59.63
	HOTS 220 KV - 3MURRAW_220A	24.07	15.24
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	3ARAR_T_220B - 3WAUBRA_220A	10.5	31.02
	3ARAR_T_220F - 3CROWLA_220A	4.08	21.0
	3BALRAT_220A - 3WAUBRA_220A	12.49	33.85
	3BULGTS_220A - 3CROWLA_220A	6.02	15.67
	3BULGTS_220A - HOTS 220 KV	12.48	9.61
	3HORSHM__66A - HOTS 220 KV	29.55	31.25
	3KIAMAL_220A - 3REDCLF_220A	7.13	7.13
HOTS220 - HOTS66 kV Tx OOS	3ARAR_T_220B - 3WAUBRA_220A	57.64	71.43
	3ARAR_T_220F - 3CROWLA_220A	47.49	61.24
	3BALRAT_220A - 3WAUBRA_220A	60.54	74.47
	3BULGTS_220A - 3CROWLA_220A	42.72	56.83
	3BULGTS_220A - HOTS 220 KV	36.54	50.79
	3HORSHM__66A - HOTS 220 KV	65.94	69.03
	3KIAMAL_220A - 3MURRAW_220A	32.45	39.81
	3KIAMAL_220A - 3REDCLF_220A	43.81	52.52
	HOTS 220 KV - 3MURRAW_220A	75.0	64.91
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3ARAR_T_220B - 3WAUBRA_220A	48.57	68.68
	3ARAR_T_220F - 3CROWLA_220A	38.45	58.5
	3BALRAT_220A - 3WAUBRA_220A	51.79	71.58
	3BULGTS_220A - 3CROWLA_220A	33.55	54.01
	3BULGTS_220A - HOTS 220 KV	27.32	47.96
	3HORSHM__66A - HOTS 220 KV	33.03	35.29

	3KIAMAL_220A - 3MURRAW_220A	5.18	5.69
	HOTS 220 KV - 3MURRAW_220A	61.58	61.56
Network Normal	3ARAR_T_220B - 3WAUBRA_220A	57.07	70.87
	3ARAR_T_220F - 3CROWLA_220A	46.93	60.68
	3BALRAT_220A - 3WAUBRA_220A	60.04	73.88
	3BULGTS_220A - 3CROWLA_220A	42.15	56.25
	3BULGTS_220A - HOTS 220 KV	35.97	50.21
	3HORSHM__66A - HOTS 220 KV	33.89	35.55
	3KIAMAL_220A - 3MURRAW_220A	32.24	39.56
	3KIAMAL_220A - 3REDCLF_220A	43.56	52.23
	HOTS 220 KV - 3MURRAW_220A	75.31	65.24

9.1.2.2 LowLoad

Case Reference	Branch Name	Loading(%) GenOFF	Loading(%) GenON
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	3ARAR_T_220B - 3WAUBRA_220A	4.37	4.37
	3BALRAT_220A - 3WAUBRA_220A	6.51	6.52
	3BULGTS_220A - 3CROWLA_220A	0.52	0.52
	3BULGTS_220A - HOTS 220 KV	0.52	0.52
	3HORSHM__66A - HOTS 220 KV	26.14	33.03
	3KIAMAL_220A - 3MURRAW_220A	26.82	45.92
	3KIAMAL_220A - 3REDCLF_220A	43.04	62.44
	HOTS 220 KV - 3MURRAW_220A	11.86	7.2
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	3ARAR_T_220F - 3CROWLA_220A	0.0	0.0
	3BULGTS_220A - 3CROWLA_220A	0.8	0.8
	3BULGTS_220A - HOTS 220 KV	0.8	0.81

	3HORSHM__66A - HOTS 220 KV	26.29	33.19
	3KIAMAL_220A - 3MURRAW_220A	26.74	45.85
	3KIAMAL_220A - 3REDCLF_220A	42.96	62.37
	HOTS 220 KV - 3MURRAW_220A	11.96	7.14
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	3ARAR_T_220B - 3WAUBRA_220A	5.37	5.38
	3ARAR_T_220F - 3CROWLA_220A	1.11	1.12
	3BALRAT_220A - 3WAUBRA_220A	7.33	7.35
	3HORSHM__66A - HOTS 220 KV	26.08	32.96
	3KIAMAL_220A - 3MURRAW_220A	26.86	45.96
	3KIAMAL_220A - 3REDCLF_220A	43.09	62.48
	HOTS 220 KV - 3MURRAW_220A	11.62	7.35
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	3ARAR_T_220B - 3WAUBRA_220A	8.1	20.19
	3ARAR_T_220F - 3CROWLA_220A	4.54	16.73
	3BALRAT_220A - 3WAUBRA_220A	9.38	26.27
	3BULGTS_220A - 3CROWLA_220A	3.99	16.53
	3BULGTS_220A - HOTS 220 KV	6.14	17.08
	3HORSHM__66A - HOTS 220 KV	11.54	12.53
	3KIAMAL_220A - 3REDCLF_220A	17.26	17.08
HOTS220 - HOTS66 kV Tx OOS	3ARAR_T_220B - 3WAUBRA_220A	57.96	68.95
	3ARAR_T_220F - 3CROWLA_220A	57.5	68.43
	3BALRAT_220A - 3WAUBRA_220A	70.63	84.28
	3BULGTS_220A - 3CROWLA_220A	57.04	68.04
	3BULGTS_220A - HOTS 220 KV	56.95	68.22

	3HORSHM__66A - HOTS 220 KV	31.29	34.55
	3KIAMAL_220A - 3MURRAW_220A	9.45	13.63
	3KIAMAL_220A - 3REDCLF_220A	20.23	27.21
	HOTS 220 KV - 3MURRAW_220A	72.55	66.16
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3ARAR_T_220B - 3WAUBRA_220A	41.43	57.51
	3ARAR_T_220F - 3CROWLA_220A	40.92	57.15
	3BALRAT_220A - 3WAUBRA_220A	52.09	70.22
	3BULGTS_220A - 3CROWLA_220A	40.43	56.6
	3BULGTS_220A - HOTS 220 KV	40.47	56.98
	3HORSHM__66A - HOTS 220 KV	13.93	16.04
	3KIAMAL_220A - 3MURRAW_220A	17.21	17.04
	HOTS 220 KV - 3MURRAW_220A	52.22	52.3
Network Normal	3ARAR_T_220B - 3WAUBRA_220A	57.73	68.71
	3ARAR_T_220F - 3CROWLA_220A	57.28	68.19
	3BALRAT_220A - 3WAUBRA_220A	70.35	83.97
	3BULGTS_220A - 3CROWLA_220A	56.82	67.8
	3BULGTS_220A - HOTS 220 KV	56.73	67.98
	3HORSHM__66A - HOTS 220 KV	16.39	18.11
	3KIAMAL_220A - 3MURRAW_220A	9.41	13.54
	3KIAMAL_220A - 3REDCLF_220A	20.12	27.08
	HOTS 220 KV - 3MURRAW_220A	72.65	66.28

9.1.3 Appendix 3

The voltage fluctuations due to change in generation output on all the monitored buses as per section 6.4.

9.1.3.1 HighLoad

		max		
Case Reference	Bus Name	Volt Fluc(%)	Voltage Level(pu) After	Voltage Level(pu) Prior
HORSF_GenChng - 118.8MW to 29.7MW (100% to 25%)	3ARAR_T_220A	0.695	1.025	1.018
	3ARAR_T_220B	0.695	1.025	1.018
	3ARAR_T_220F	0.695	1.025	1.018
	3BALRAT_220A	0.481	1.038	1.033
	3BULGTS_220A	0.603	1.026	1.02
	3CROWLA_220A	0.654	1.025	1.018
	3KIAMAL_220A	0.263	1.025	1.022
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	1.004	1.004
	3WAUBRA_220A	0.686	1.031	1.024
	HOTS 220 KV_POC	-0.011	1.027	1.028
HORSF_GenChng - 118.8MW to 59.4MW (100% to 50%)	3ARAR_T_220A	0.509	1.023	1.018
	3ARAR_T_220B	0.509	1.023	1.018
	3ARAR_T_220F	0.509	1.023	1.018
	3BALRAT_220A	0.358	1.037	1.033
	3BULGTS_220A	0.44	1.024	1.02
	3CROWLA_220A	0.478	1.023	1.018
	3KIAMAL_220A	0.18	1.024	1.022
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	1.004	1.004
	3WAUBRA_220A	0.516	1.029	1.024
	HOTS 220 KV_POC	0.003	1.028	1.028
HORSF_GenChng - 118.8MW to 89.1MW (100% to 75%)	3ARAR_T_220A	0.264	1.021	1.018
	3ARAR_T_220B	0.264	1.021	1.018
	3ARAR_T_220F	0.264	1.021	1.018
	3BALRAT_220A	0.185	1.035	1.033
	3BULGTS_220A	0.229	1.022	1.02
	3CROWLA_220A	0.248	1.021	1.018
	3KIAMAL_220A	0.093	1.023	1.022
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	1.004	1.004
	3WAUBRA_220A	0.267	1.027	1.024

	HOTS 220 KV_POC	0.004	1.028	1.028
HORSF_GenTrip - 118.8MW to 0MW (100% to 0%)	3ARAR_T_220A	0.787	1.026	1.018
	3ARAR_T_220B	0.787	1.026	1.018
	3ARAR_T_220F	0.787	1.026	1.018
	3BALRAT_220A	0.516	1.038	1.033
	3BULGTS_220A	0.718	1.027	1.02
	3CROWLA_220A	0.755	1.026	1.018
	3KIAMAL_220A	0.341	1.025	1.022
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	1.004	1.004
	3WAUBRA_220A	0.686	1.031	1.024
	HOTS 220 KV_POC	0.05	1.028	1.028
HORSF_GenTrip - 29.7MW to 0MW (25% to 0%)	3ARAR_T_220A	0.104	1.026	1.025
	3ARAR_T_220B	0.104	1.026	1.025
	3ARAR_T_220F	0.104	1.026	1.025
	3BALRAT_220A	0.045	1.038	1.037
	3BULGTS_220A	0.124	1.026	1.025
	3CROWLA_220A	0.111	1.026	1.024
	3KIAMAL_220A	0.078	1.025	1.024
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	1.004	1.004
	3WAUBRA_220A	0.016	1.031	1.031
	HOTS 220 KV_POC	0.065	1.028	1.027
HORSF_GenTrip - 59.4MW to 0MW (50% to 0%)	3ARAR_T_220A	0.316	1.026	1.023
	3ARAR_T_220B	0.316	1.026	1.023
	3ARAR_T_220F	0.316	1.026	1.023
	3BALRAT_220A	0.192	1.038	1.036
	3BULGTS_220A	0.306	1.026	1.023
	3CROWLA_220A	0.31	1.026	1.023
	3KIAMAL_220A	0.161	1.025	1.023
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	1.004	1.004
	3WAUBRA_220A	0.225	1.031	1.029
	HOTS 220 KV_POC	0.055	1.028	1.027
HORSF_GenTrip - 89.1MW to 0MW (75% to 0%)	3ARAR_T_220A	0.543	1.026	1.021
	3ARAR_T_220B	0.543	1.026	1.021
	3ARAR_T_220F	0.543	1.026	1.021
	3BALRAT_220A	0.349	1.038	1.035
	3BULGTS_220A	0.504	1.027	1.022
	3CROWLA_220A	0.524	1.026	1.021

	3KIAMAL_220A	0.248	1.025	1.023
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	1.004	1.004
	3WAUBRA_220A	0.448	1.031	1.026
	HOTS 220 KV_POC	0.05	1.028	1.027

9.1.3.2 LowLoad

		max		
Case Reference	Bus Name	Volt Fluc(%)	Voltage Level(pu) After	Voltage Level(pu) Prior
HORSF_GenChng - 118.8MW to 29.7MW (100% to 25%)	3ARAR_T_220A	1.274	1.032	1.02
	3ARAR_T_220B	1.274	1.032	1.02
	3ARAR_T_220F	1.274	1.032	1.02
	3BALRAT_220A	0.735	1.054	1.047
	3BULGTS_220A	1.162	1.027	1.015
	3CROWLA_220A	1.252	1.03	1.017
	3KIAMAL_220A	0.102	1.009	1.008
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.998	0.998
	3WAUBRA_220A	1.142	1.042	1.031
	HOTS 220 KV_POC	0.109	1.022	1.021
HORSF_GenChng - 118.8MW to 59.4MW (100% to 50%)	3ARAR_T_220A	0.868	1.028	1.02
	3ARAR_T_220B	0.868	1.028	1.02
	3ARAR_T_220F	0.868	1.028	1.02
	3BALRAT_220A	0.501	1.052	1.047
	3BULGTS_220A	0.792	1.023	1.015
	3CROWLA_220A	0.854	1.026	1.017
	3KIAMAL_220A	0.072	1.009	1.008
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.998	0.998
	3WAUBRA_220A	0.779	1.038	1.031
	HOTS 220 KV_POC	0.071	1.022	1.021
HORSF_GenChng - 118.8MW to 89.1MW (100% to 75%)	3ARAR_T_220A	0.441	1.024	1.02
	3ARAR_T_220B	0.441	1.024	1.02
	3ARAR_T_220F	0.441	1.024	1.02
	3BALRAT_220A	0.257	1.049	1.047
	3BULGTS_220A	0.4	1.019	1.015
	3CROWLA_220A	0.432	1.022	1.017
	3KIAMAL_220A	0.038	1.009	1.008

	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.998	0.998
	3WAUBRA_220A	0.397	1.035	1.031
	HOTS 220 KV_POC	0.026	1.022	1.021
HORSF_GenTrip - 118.8MW to 0MW (100% to 0%)	3ARAR_T_220A	1.698	1.037	1.02
	3ARAR_T_220B	1.698	1.037	1.02
	3ARAR_T_220F	1.698	1.037	1.02
	3BALRAT_220A	0.985	1.057	1.047
	3BULGTS_220A	1.558	1.031	1.015
	3CROWLA_220A	1.672	1.034	1.017
	3KIAMAL_220A	0.127	1.009	1.008
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.998	0.998
	3WAUBRA_220A	1.52	1.046	1.031
	HOTS 220 KV_POC	0.195	1.023	1.021
HORSF_GenTrip - 29.7MW to 0MW (25% to 0%)	3ARAR_T_220A	0.392	1.034	1.03
	3ARAR_T_220B	0.392	1.034	1.03
	3ARAR_T_220F	0.392	1.034	1.03
	3BALRAT_220A	0.227	1.055	1.053
	3BULGTS_220A	0.359	1.028	1.024
	3CROWLA_220A	0.386	1.031	1.027
	3KIAMAL_220A	0.025	1.009	1.009
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.998	0.998
	3WAUBRA_220A	0.351	1.043	1.04
	HOTS 220 KV_POC	0.044	1.022	1.022
HORSF_GenTrip - 59.4MW to 0MW (50% to 0%)	3ARAR_T_220A	0.798	1.035	1.027
	3ARAR_T_220B	0.798	1.035	1.027
	3ARAR_T_220F	0.798	1.035	1.027
	3BALRAT_220A	0.46	1.055	1.051
	3BULGTS_220A	0.731	1.029	1.022
	3CROWLA_220A	0.785	1.032	1.024
	3KIAMAL_220A	0.055	1.009	1.008
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.998	0.998
	3WAUBRA_220A	0.714	1.044	1.037
	HOTS 220 KV_POC	0.084	1.023	1.022
HORSF_GenTrip - 89.1MW to 0MW (75% to 0%)	3ARAR_T_220A	1.227	1.035	1.023
	3ARAR_T_220B	1.227	1.035	1.023
	3ARAR_T_220F	1.227	1.035	1.023

	3BALRAT_220A	0.71	1.056	1.049
	3BULGTS_220A	1.124	1.03	1.019
	3CROWLA_220A	1.207	1.033	1.021
	3KIAMAL_220A	0.089	1.009	1.008
	3MURRAW_220A	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.998	0.998
	3WAUBRA_220A	1.099	1.045	1.034
	HOTS 220 KV_POC	0.127	1.023	1.022

9.1.4 Appendix4

The voltage fluctuations due to loss of line contingencies on all the monitored buses as per section 6.5.

9.1.4.1 HighLoad

		max			
Case Reference	Bus Name	Volt Fluc(%) GenOFF	Volt Fluc(%) GenON	Voltage Level(pu) GenOFF	Voltage Level(pu) GenON
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	3ARAR_T_220A	2.548	3.238	1.051	1.051
	3ARAR_T_220B	2.548	3.238	1.051	1.051
	3ARAR_T_220F	0.0	0.0	1.026	1.018
	3BALRAT_220A	1.16	1.582	1.049	1.049
	3BULGTS_220A	1.034	1.81	1.036	1.038
	3CROWLA_220A	1.119	1.949	1.037	1.038
	3KIAMAL_220A	0.257	-0.063	1.027	1.021
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	1.004	1.004
	3WAUBRA_220A	1.988	2.612	1.051	1.05
	HOTS 220 KV_POC	0.383	0.522	1.032	1.033
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	3ARAR_T_220A	1.217	2.082	1.038	1.039
	3ARAR_T_220B	0.0	0.0	1.026	1.018
	3ARAR_T_220F	1.217	2.082	1.038	1.039
	3BALRAT_220A	0.999	1.425	1.048	1.047
	3BULGTS_220A	1.141	1.912	1.038	1.039
	3CROWLA_220A	1.246	2.071	1.038	1.039
	3KIAMAL_220A	0.263	-0.053	1.027	1.021
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	1.004	1.004
	3WAUBRA_220A	0.0	0.0	1.031	1.024

	HOTS 220 KV_POC	0.404	0.538	1.032	1.033
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	3ARAR_T_220A	1.238	1.949	1.038	1.038
	3ARAR_T_220B	1.238	1.949	1.038	1.038
	3ARAR_T_220F	1.238	1.949	1.038	1.038
	3BALRAT_220A	0.761	1.188	1.045	1.045
	3BULGTS_220A	0.0	0.0	1.026	1.02
	3CROWLA_220A	1.167	1.84	1.037	1.037
	3KIAMAL_220A	0.255	-0.068	1.027	1.021
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	1.004	1.004
	3WAUBRA_220A	1.147	1.783	1.042	1.042
	HOTS 220 KV_POC	0.156	0.324	1.029	1.031
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	3ARAR_T_220A	0.968	1.661	1.036	1.035
	3ARAR_T_220B	0.968	1.661	1.036	1.035
	3ARAR_T_220F	0.968	1.661	1.036	1.035
	3BALRAT_220A	0.684	1.052	1.045	1.044
	3BULGTS_220A	0.7	1.451	1.033	1.034
	3CROWLA_220A	0.866	1.571	1.034	1.034
	3KIAMAL_220A	-0.257	-0.019	1.022	1.022
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	1.004	1.004
	3WAUBRA_220A	0.992	1.512	1.041	1.039
	HOTS 220 KV_POC	-0.5	-0.066	1.023	1.027
HOTS220 - HOTS66 kV Tx OOS	3ARAR_T_220A	-0.02	-0.056	1.026	1.018
	3ARAR_T_220B	-0.02	-0.056	1.026	1.018
	3ARAR_T_220F	-0.02	-0.056	1.026	1.018
	3BALRAT_220A	-0.005	-0.022	1.038	1.033
	3BULGTS_220A	-0.028	-0.057	1.026	1.019
	3CROWLA_220A	-0.022	-0.055	1.025	1.018
	3KIAMAL_220A	-0.009	-0.012	1.024	1.022
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	1.004	1.004
	3WAUBRA_220A	0.0	-0.046	1.031	1.023
	HOTS 220 KV_POC	-0.032	-0.039	1.027	1.027

KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3ARAR_T_220A	0.293	0.15	1.029	1.02
	3ARAR_T_220B	0.293	0.15	1.029	1.02
	3ARAR_T_220F	0.293	0.15	1.029	1.02
	3BALRAT_220A	0.098	0.041	1.039	1.033
	3BULGTS_220A	0.308	0.146	1.029	1.021
	3CROWLA_220A	0.296	0.147	1.028	1.02
	3KIAMAL_220A	5.047	5.595	1.075	1.078
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	1.004	1.004
	3WAUBRA_220A	0.161	0.121	1.032	1.025
	HOTS 220 KV_POC	0.131	0.048	1.029	1.028
Network Normal	3ARAR_T_220A	0.0	-0.001	1.026	1.018
	3ARAR_T_220B	0.0	-0.001	1.026	1.018
	3ARAR_T_220F	0.0	-0.001	1.026	1.018
	3BALRAT_220A	0.0	-0.0	1.038	1.033
	3BULGTS_220A	0.0	-0.001	1.026	1.02
	3CROWLA_220A	0.0	-0.001	1.025	1.018
	3KIAMAL_220A	0.0	0.0	1.024	1.022
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	1.004	1.004
	3WAUBRA_220A	0.0	-0.0	1.031	1.024
	HOTS 220 KV_POC	0.0	-0.001	1.028	1.028

9.1.4.2 LowLoad

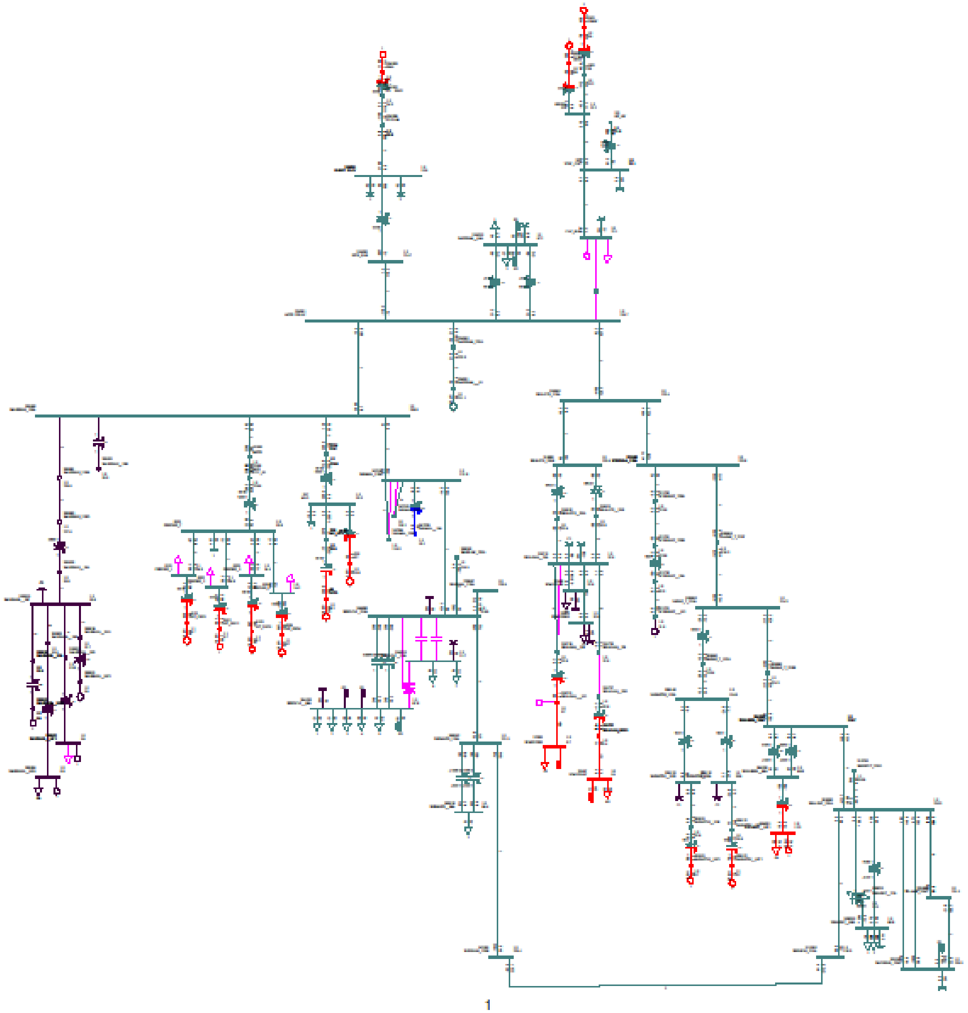
		max			
Case Reference	Bus Name	Volt Fluc(%) GenOFF	Volt Fluc(%) GenON	Voltage Level(pu) GenOFF	Voltage Level(pu) GenON
ARTS-CWTS (ARARAT to CROWNLANDS) 220kV line OOS	3ARAR_T_220A	2.422	3.417	1.057	1.054
	3ARAR_T_220B	2.422	3.417	1.057	1.054
	3ARAR_T_220F	0.0	0.0	1.033	1.02
	3BALRAT_220A	1.106	1.512	1.065	1.062
	3BULGTS_220A	-1.218	0.242	1.015	1.018
	3CROWLA_220A	-1.505	0.088	1.015	1.018
	3KIAMAL_220A	-1.755	-2.889	0.991	0.979
	3MURRAW_220A	-3.0	-3.0	1.01	1.01
	3REDCLF_220A	0.0	0.0	0.998	0.998
	3WAUBRA_220A	1.883	2.761	1.061	1.058

	HOTS 220 KV_POC	-1.198	-0.816	1.01	1.013
ARTS-WBTS-BATS (ARARAT to WAUBRA to BALLARAT) 220kV line OOS	3ARAR_T_220A	-1.644	-0.016	1.016	1.019
	3ARAR_T_220B	0.0	0.0	1.033	1.02
	3ARAR_T_220F	-1.644	-0.016	1.016	1.019
	3BALRAT_220A	1.377	1.789	1.068	1.065
	3BULGTS_220A	-1.113	0.343	1.016	1.019
	3CROWLA_220A	-1.38	0.21	1.016	1.019
	3KIAMAL_220A	-1.751	-2.884	0.991	0.979
	3MURRAW_220A	-3.0	-3.0	1.01	1.01
	3REDCLF_220A	0.0	0.0	0.998	0.998
	3WAUBRA_220A	0.0	0.0	1.043	1.031
	HOTS 220 KV_POC	-1.177	-0.798	1.01	1.013
CWTS-BGTS-HOTS (CROWNLANDS to BULGANA to HORSHAM) 220kV line OOS	3ARAR_T_220A	1.925	2.915	1.052	1.049
	3ARAR_T_220B	1.925	2.915	1.052	1.049
	3ARAR_T_220F	1.925	2.915	1.052	1.049
	3BALRAT_220A	0.967	1.37	1.064	1.061
	3BULGTS_220A	0.0	0.0	1.027	1.015
	3CROWLA_220A	2.148	3.099	1.052	1.048
	3KIAMAL_220A	-1.757	-2.893	0.991	0.979
	3MURRAW_220A	-3.0	-3.0	1.01	1.01
	3REDCLF_220A	0.0	0.0	0.998	0.998
	3WAUBRA_220A	1.575	2.449	1.058	1.055
	HOTS 220 KV_POC	-1.42	-1.01	1.008	1.011
HOTS-MRTS-KMTS (HORSHAM to MURRAWARRA to KIAMAL) 220kV line OOS	3ARAR_T_220A	1.496	3.444	1.048	1.054
	3ARAR_T_220B	1.496	3.444	1.048	1.054
	3ARAR_T_220F	1.496	3.444	1.048	1.054
	3BALRAT_220A	1.635	2.52	1.071	1.072
	3BULGTS_220A	1.631	3.654	1.043	1.052
	3CROWLA_220A	1.587	3.581	1.046	1.053
	3KIAMAL_220A	-2.346	-2.186	0.985	0.986
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	0.998	0.998
	3WAUBRA_220A	1.728	3.263	1.06	1.063

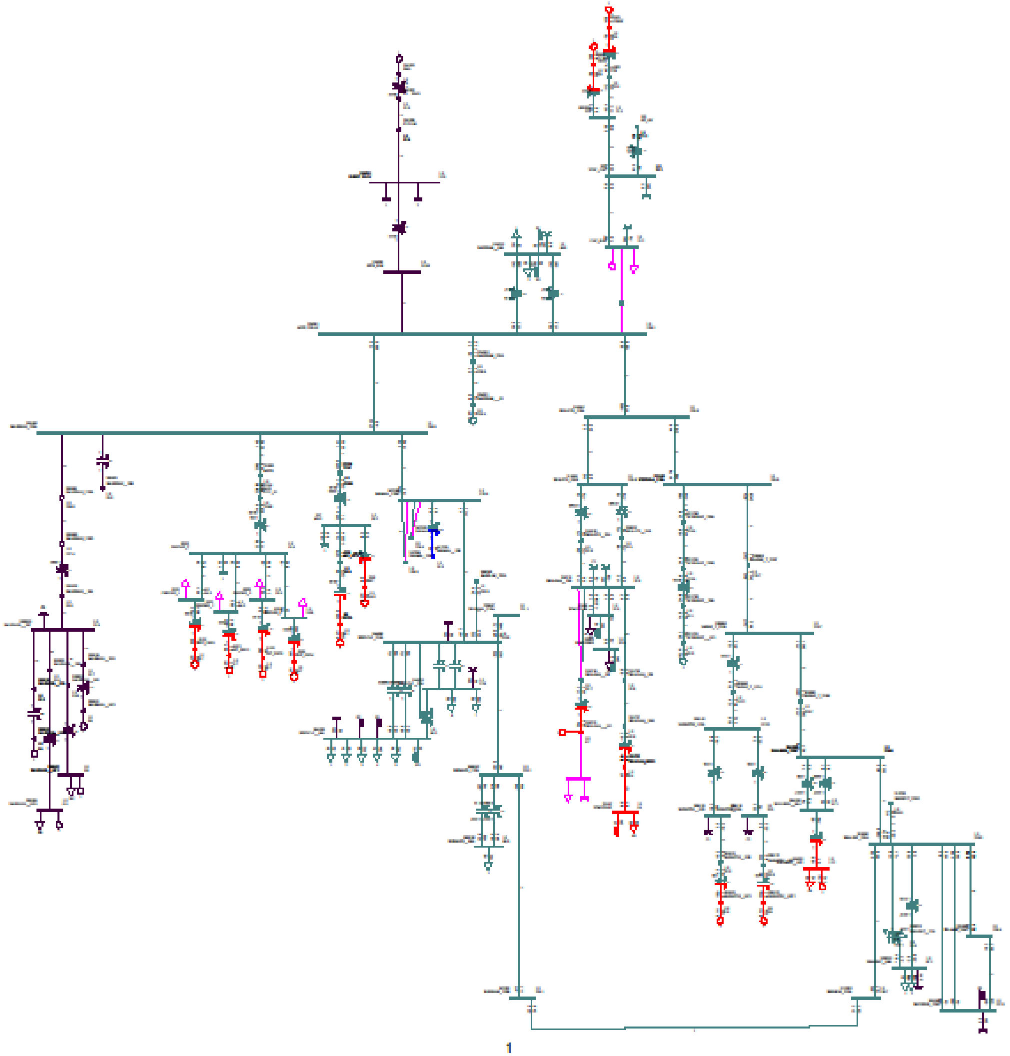
	HOTS 220 KV_POC	0.003	1.402	1.022	1.035
HOTS220 - HOTS66 kV Tx OOS	3ARAR_T_220A	-0.025	-0.053	1.033	1.019
	3ARAR_T_220B	-0.025	-0.053	1.033	1.019
	3ARAR_T_220F	-0.025	-0.053	1.033	1.019
	3BALRAT_220A	-0.01	-0.018	1.054	1.047
	3BULGTS_220A	-0.024	-0.055	1.027	1.015
	3CROWLA_220A	-0.025	-0.054	1.03	1.017
	3KIAMAL_220A	-0.001	-0.003	1.009	1.008
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	0.998	0.998
	3WAUBRA_220A	-0.021	-0.039	1.042	1.03
	HOTS 220 KV_POC	-0.002	-0.034	1.022	1.021
KMTS-RCTS (KIAMAL to REDCLIFF) 220kV line OOS	3ARAR_T_220A	0.718	1.286	1.04	1.032
	3ARAR_T_220B	0.718	1.286	1.04	1.032
	3ARAR_T_220F	0.718	1.286	1.04	1.032
	3BALRAT_220A	0.784	1.085	1.062	1.058
	3BULGTS_220A	0.538	0.97	1.032	1.025
	3CROWLA_220A	0.678	1.198	1.037	1.029
	3KIAMAL_220A	-1.673	-1.425	0.992	0.994
	3MURRAW_220A	-3.0	-3.0	1.01	1.01
	3REDCLF_220A	0.0	0.0	0.998	0.998
	3WAUBRA_220A	0.696	1.382	1.05	1.044
	HOTS 220 KV_POC	-0.96	-0.842	1.012	1.013
Network Normal	3ARAR_T_220A	0.0	-0.017	1.033	1.019
	3ARAR_T_220B	0.0	-0.017	1.033	1.019
	3ARAR_T_220F	0.0	-0.017	1.033	1.019
	3BALRAT_220A	0.0	-0.005	1.054	1.047
	3BULGTS_220A	0.0	-0.021	1.027	1.015
	3CROWLA_220A	0.0	-0.018	1.03	1.017
	3KIAMAL_220A	0.0	-0.0	1.009	1.008
	3MURRAW_220A	0.0	0.0	1.04	1.04
	3REDCLF_220A	0.0	0.0	0.998	0.998
	3WAUBRA_220A	0.0	-0.011	1.043	1.03
	HOTS 220 KV_POC	0.0	-0.028	1.022	1.021

9.1.5 Appendix 5

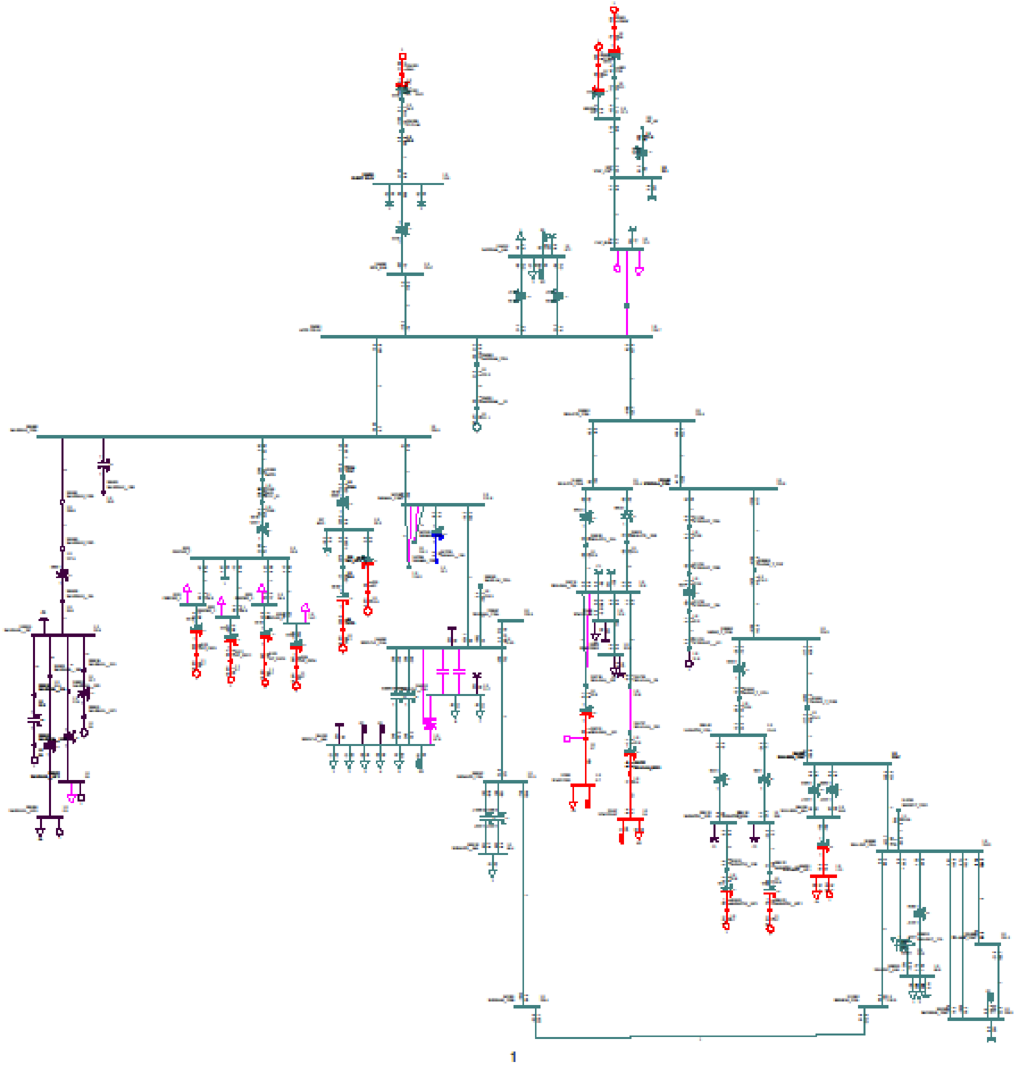
9.1.5.1 HORSF high load gen on



9.1.5.2 HORSF high load gen off



9.1.5.3 HORSF low load gen on



9.1.5.4 HORSF low load gen off