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CONNECTION ASSESSMENT & APPROVAL PROCESS

Preliminary Assessment Report

Project: *Reactive Compensation at Wawa TS*

Applicant: *Hydro One Networks Inc.*

CAA ID 2002-058

Final Report

**Long Term Forecasts & Assessments Department
Consistent Information Set Department**

March 19, 2003

Preliminary Assessment Report

New Reactive Compensation at Wawa TS

Acknowledgement

The IMO wishes to acknowledge the assistance of Hydro One in completing this assessment.

Disclaimers

IMO

This report has been prepared solely for the purpose of assessing, on a preliminary basis, whether the connection applicant's proposed connection with the IMO-controlled grid would have an adverse impact on the reliability of the integrated power system and whether a System Impact Assessment of the proposed connection should be conducted under Chapter 4, section 6 of the *Market Rules*. This report has not been prepared for any other purpose and should not be used or relied upon by any person for another purpose. This report has been prepared solely for use by the connection applicant, Hydro One and the IMO in accordance with Chapter 4, section 6 of the *Market Rules*. The IMO assumes no responsibility to any third party for any use which it makes of this report. Any liability which the IMO may have to the connection applicant in respect of this report is governed by Chapter 1, section 13 of the *Market Rules*. In the event that the IMO provides a draft of this report to the connection applicant, you must be aware that the IMO may revise drafts of this report at any time in its sole discretion without notice to you. Although the IMO will use its best efforts to advise you of any such changes, it is the responsibility of the connection applicant to ensure that it is using the most recent version of this report.

1.0 Project Description

Hydro One Networks Inc. proposes to replace the four existing oil filled shunt reactors at Wawa TS with two new 40 Mvar air core reactors and to install shunt capacitors with a total reactive support capability of 80 Mvar. Two options are being considered for the installation of the new shunt capacitors. Schematic diagrams were provided by Hydro One Networks Inc. and are shown in Figures 1, 2 and 3. The figures show the existing facilities and the two options for the proposed shunt capacitors installations.

The target in-service date for the facility is December 2003.

2.0 Review of Connection Proposal

2.1 Connection Arrangement

The existing reactive compensation equipment at Wawa TS consists of two pairs each consisting of two oil filled shunt reactors rated 15 Mvar and 25 Mvar respectively. Each pair is connected to the 115/230 kV autotransformer tertiary windings as shown in Figure 1.

Hydro One Networks Inc. has proposed the following modifications and additions to the reactive devices at Wawa TS:

- to replace each pair of shunt reactors with one new 40 Mvar air core units also connected to the 13.8 kV tertiary winding of each 230/115 kV transformer, and
- install two pairs (alternative 1) of two new shunt capacitors each rated at 19.8 Mvar to the transformer's tertiaries, or
- install two (alternative 2) new shunt capacitors each rated at 39.6 Mvar and reuse two of the existing four SF6 breakers T1R1, T1R3, T2R2 and T2R4 for the connection to the transformer's tertiaries.

3.0 Assessment Scope

The main objectives of this assessment were to determine whether the proposed developments meet the *Market Rules* requirements and do not have an adverse impact on the reliability of the IMO controlled grid, and to identify the potential improvement in the power transfer capability of the East –West transmission interface. The assessment also identified ways in which the improvement in the East-West power transfers could affect the power transfer limits on the Northwest transmission interconnections.

It is to be noted that further operating studies will be performed before coming into service of the new facilities to determine detailed system operating limits.

4.0 Connectivity Arrangement and Equipment Ratings

Hydro One Networks Inc. has provided the following specifications for the proposed reactors and capacitor bank installations.

Alternative 1 (figure 2)

The first alternative involves four 19.8 Mvar, 15.2 kV moveable shunt capacitor assemblies are proposed for installation on the tertiary winding of autotransformers T1 and T2 (2 banks on each

tertiary winding). Each moveable shunt capacitor bank is to be connected to the respective tertiary winding via a current limiting series reactor and a disconnect switch. Each moveable shunt capacitor assembly is rated for 19.8 Mvar at 15.2 kV and consists of a shunt capacitor bank, a circuit breaker and ground switches to be arranged as shown in Figure 2. Hydro One Networks Inc. has provided the following specifications for the new *shunt capacitor banks*:

System frequency	: 60 Hz \pm 0.5 Hz
Rated capability	: 19.8 Mvar, 3 phase at 15.2kV
Nominal system voltage	: 13.8/27.6 kV
Maximum operating voltage	: 15.2/30.4 kV
Symmetrical Short Circuit Level	: 25 kA (min)
Configuration	: Double wye ungrounded
Insulation level	: 150 kV BIL (min)

Each capacitor unit will be equipped with the inherent 5-minute discharge resistor and no other discharge devices are required.

The *circuit breaker* will be equipped with integrated protective relays and required to meet the following specifications:

System frequency	: 60 Hz \pm 0.5 Hz
Interrupting medium	: suitable for switching the capacitor bank in all required configurations
Voltage class	: 35 kV (min)
Rated capability	: 1200 A, 3-pole capacitor switching rated
Nominal system voltage	: 13.8/27.6 kV
Maximum operating voltage	: 15.2/30.4 kV
Interrupting capability	: 25 kA (min) at 15 kV
Rated Interrupting Time	: 5 cycles (min)
Insulation level	: 170 kV BIL (min)

The purpose of current limiting reactors is to control the inrush current magnitude and frequency to an acceptable level during back-to-back capacitor switching. Twelve series reactors are to be installed (one series reactor per phase on each moveable bank) between the moveable bank and its associated disconnect switch. The *series reactor* is required to meet the following specifications:

Number required	: 12 (3 for each moveable bank)
Type	: Air-core
System frequency	: 60 Hz \pm 0.5 Hz
Nominal system voltage	: 13.8 kV
Rated voltage (line-to-line)	: 14.4 kV
Maximum Continuous Operating Voltage	: 15.2 kV
Emergency Operating Voltage	: 20 kV for 5 minutes
Inductance at rated frequency of 60 Hz	: 1 mH per phase (0.377 ohms/phase)
Continuous current (rms)	: 1200 A
Symmetrical fault current	: 25 kA at 15 kV
Insulation level: Line (both ends)	: 110 kV BIL
Insulation level: Across coil	: 110 kV BIL

Insulation level to ground : 110 kV BIL

Each moveable shunt capacitor installation will have one 3-phase disconnect that is to be installed between the 13.8 kV bus and the series reactor. This switch is to be rated as follows:

Number required : 4
 System frequency : 60 Hz \pm 0.5 Hz
 Nominal system voltage : 13.8 kV
 Rated continuous current : 1200 A
 Rated Voltage : 14.4 kV
 Maximum operating voltage : 15.2 kV
 Overvoltage capability : 10%
 Symmetrical Short Circuit Level : 25 kA (min) at 15 kV
 Insulation level (phase to phase) : 200 kV BIL (min)
 Insulation level to ground : 110 kV BIL

Switch to be able to withstand 30.4 kV RMS across open gap

Alternative 2 (figure 3)

The second alternative involves the installation of two 39.6 Mvar, 15.2 kV shunt capacitor banks connected to the tertiary winding of autotransformers T1 and T2, respectively. The new shunt capacitor bank SC1 and SC2 will be connected to the existing SF6 breakers T1R3 and T2R4 respectively. New disconnect switches are to be provided to connect each capacitor bank to the respective tertiary winding as shown in Figure 3.

A set of 3-phase ground switches is to be provided at the terminal of the new capacitor banks. A single ground switch is to be provided and installed at the neutral point of the capacitor bank.

Shunt capacitor bank is required to meet the following specifications:

Number required : 2
 System frequency : 60 Hz \pm 0.5 Hz
 Rated capability : 39.6 Mvar, 3 phase at 15.2 kV
 Nominal system voltage : 13.8 kV
 Maximum operating voltage : 15.2 kV
 Overvoltage capability : 10%
 Symmetrical Short Circuit Level : 25 kA (min)
 Configuration : Double wye ungrounded
 Insulation level : 110 kV BIL (min)

The two new 3-phase disconnect switches which connect each capacitor bank to the respective tertiary winding of the autotransformers are to be rated as follows:

System frequency : 60 Hz \pm 0.5 Hz
 Nominal system voltage : 13.8 kV
 Rated continuous current : 1800 A (min)
 Rated Voltage : 14.4 kV
 Maximum operating voltage : 15.2 kV
 Symmetrical Short Circuit Level : 25 kA (min) at 15 kV
 Insulation level (phase to phase) : 200 kV BIL (min)
 Insulation level to ground : 110 kV BIL

Switch is to be able to withstand 30.4 kV RMS across open gap.

Under Alternative 2, it is proposed to reuse all four existing circuit breakers for connecting the new shunt reactors and capacitors. Hydro One Networks Inc. should ensure that the existing breakers are adequately rated for switching the new equipment.

5.0 On-line Monitoring

The *Market Rules* (Chapter 4 section 7.4) require that each transmitter shall provide the IMO on a continual basis with on-line monitored quantities as specified in Appendix 4.16. Hydro One Networks Inc. has specified requirements for supervisory control facilities to be installed and provide breakers' status information and local and remote shunt capacitor switching.

Hydro One has specified that interlocking facilities, which will ensure that the shunt capacitors and reactors are not in service at the same time, will be provided to avoid potential resonance problems.

The IMO requires that the status of all isolating disconnects and breakers associated with the shunt reactors and shunt capacitors be monitored and available to the IMO on a continual basis.

6.0 Assessment of Impact on System Reliability

This section provides a description of the Northwest bulk power system, the power transfer limits associated with this system and the historical records of power flows, loads and generation for the area.

Descriptions of the study criteria, the selected study scenarios and the study results are also provided in this section.

6.1 Description of Northwest Power System

A schematic diagram of the Northwest Transmission system is shown in Figure 4. The Northwest bulk system is that part of the power system between Kenora TS in the west, Algoma TS in the east and Fort Frances TS. The main transmission interface between Mackenzie and Mississagi comprises of the following main facilities:

- Double circuit 230 kV line (A21L, A22L) between Mackenzie TS and Lakehead TS,
- Double circuit 230 kV line (M23L, M24L) between Lakehead TS and Marathon TS,
- Double circuit 230 kV line (W21M, W22M) between Marathon TS and Wawa TS, and
- Double circuit 230 kV line (W21M, W22M) between Wawa TS and Mississagi TS.

Parallel 115 kV systems exist between Lakehead TS to Marathon TS, and Wawa TS to Mississagi TS. The main connections to the 115 kV systems are provided by 2x250 MVA autotransformers at Lakehead TS, 2x125 MVA autotransformers at Marathon TS and 2x125 MVA autotransformers at Wawa TS.

Reactive compensation devices are present at the following point in the area bulk transmission system:

- At Lakehead TS – two synchronous condensers rated 48 Mvar each, connected to the tertiary winding of the each autotransformers,

- At MarathonTS – two shunt capacitors rated 36 Mvar each, connected to the tertiary winding of the each autotransformers,
- At Wawa TS – two 40 Mvar (1x15 Mvar, 1x25 Mvar) shunt reactors pairs, each connected to the tertiary winding of the one autotransformer.

Northwest system generation comprises of a mix of hydraulic and thermal units with a total installed capacity of about 1500 MW. Electricity demand records indicate that the load in the area could vary between 700 MW and 1100 MW, with loads exceeding 900 MW for more than 50% of the time.

6.2 Existing Operating Security Limits

The 230 kV circuit between Marathon TS and Wawa TS constitute the transmission interface commonly known as the East-West Tie (EWT). Further, The Ontario Northwest system is interconnected to:

- Manitoba via two 230 kV lines, K21W and K22W, each equipped with one regulating and phase shifting transformer, from Kenora TS to Whiteshell TS referred to as Manitoba Interconnection and
- Minnesota via two 180 MVA, 115 kV phase shifter transformers connected in series, with a phase shifting capability of 76° each providing an interconnection between Fort Frances TS and International Falls.

The present set of operating limits restrict the power flowing over these three interfaces to levels required to maintain system security. A diagram indicating the Northwest region operating limits for a system with all transmission elements in service and fair weather conditions is shown in Figure 5. The diagram shows the relationship between the power transfer limits on the three interfaces. The figure indicates that the East-West power transfer is limited to a maximum of 325 MW east and 350 MW west. However, power transfers eastbound on the EW tie could be limited to as low as 160 MW for conditions of maximum exports over the Ontario-Manitoba ties (300 MW). Similarly, power transfers westbound on the EW tie could become limited to as low as 300 MW when imports from Minnesota reach 100 MW. A summary of the phenomena which determine the operating limits shown in Figure 5 is given in Table 1.

Table 1. Basis for Operating Limits

	East West Transfer East				East West Transfer West			
OMTR	Ontario Manitoba Transfer West		Ontario Manitoba Transfer East		Ontario Manitoba Transfer West		Ontario Manitoba Transfer East	
MPF	High OMTW (a)	High EWTRE (b)	MPFS<100 (c)	MPFS>100 (d)	MPFN<50 (e)	MPFN>50 (f)	MPFN<50 (g)	MPFN>50 (h)
Critical Contingency	Loss of both OM ties	Loss of both OM ties	Loss of W21M And T12 at Marathon	Loss of Ontario Minnesota	Steady State	Loss of both OM ties	Steady State or Loss of OM ties	Loss of both OM Ties
Operating Limit Phenomenon	To prevent F3M out-of-step relay operation	Maintaining minimum voltage between Marathon – Mississagi after automatic phase shifter action at International Falls operation	Limit set to respect the relay margins along East-West tie	Min voltage between Marathon – Mississagi after automatic phase shifter action at Whiteshell	Maintaining minimum voltage at Marathon	To prevent F3M out-of-step relay operation	Maintaining minimum voltage at Marathon or To prevent voltage decline at International Falls or F3M out-of-step relay operation	To prevent voltage decline at International Falls or F3M out-of-step relay operation

6.3 Northwest System Past Performance

Historical records of power flows on the EWT from May 1, 2002 to September 1, 2002 are shown in Diagram 5.3.1, displaying actual flows and the East-West transfer east limit. The 230 kV voltage records are shown in Diagram 5.3.2 for Marathon TS and Wawa TS.

Examination of historical records indicates that:

- During this period the direction of the flow was predominantly eastbound,
- Voltages at Marathon and Wawa 230 kV were between 235 kV and 250 kV,
- Generation in Northwest region was bottled in many occasions due to East-West interface transmission limitations.

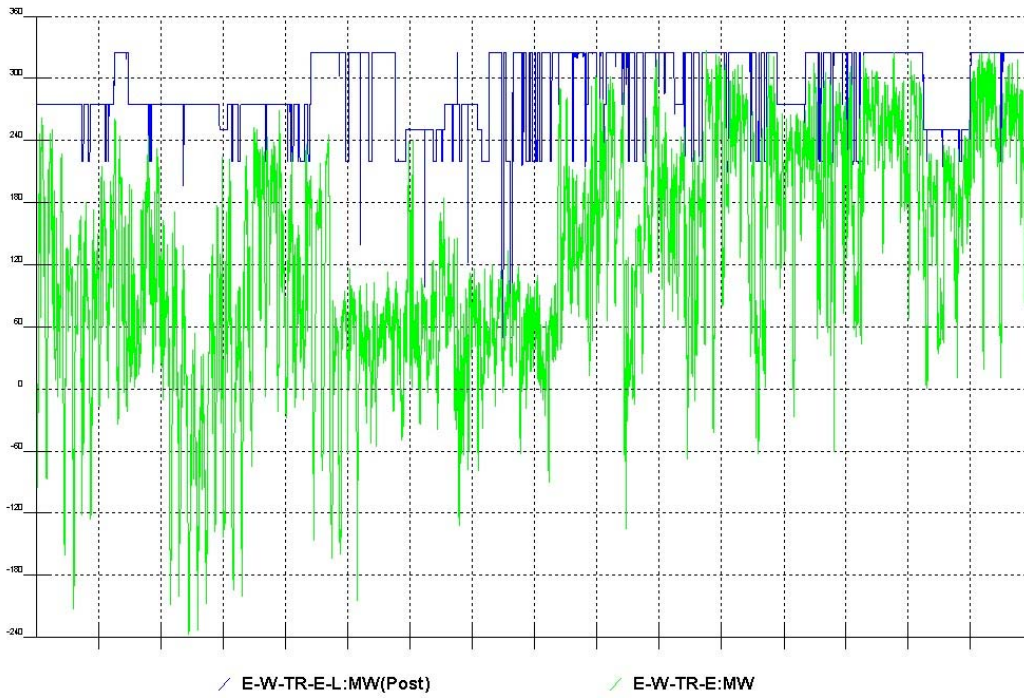


Diagram 5.3.1 Flow East, EW Transfer Limit for May1 to September 1, 2002

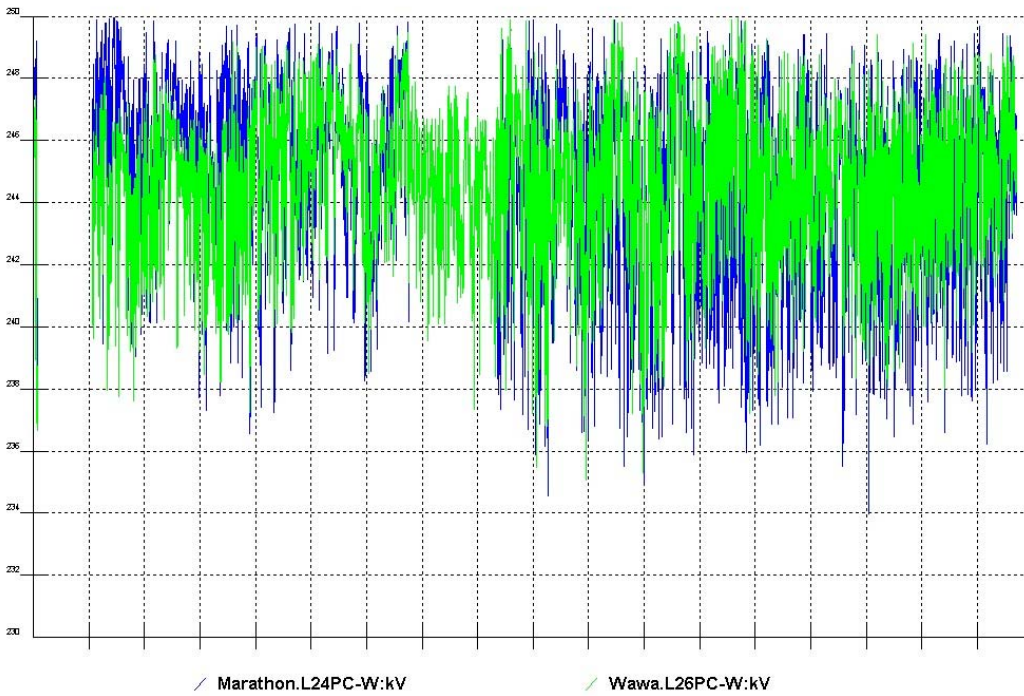


Diagram 5.3.2 Wawa and Marathon Voltages for May1 to September 1, 2002

6.4 Study Criteria

The set of reliability guidelines used in this study was formulated based on the operating practice that is currently used for the Northwest region, IMO's proposed connection assessment guidelines and the requirements of the *Market Rules*.

The current operating directives require that:

- the voltages at Lakehead TS, Marathon TS and Wawa TS be maintained above 235 kV level to ensure the validity of the operating security limits and,
- the power flows over the three main Northwest interfaces be maintained within the limits presented in section 6.2.

Additionally, IMO's proposed guidelines for evaluating the effect of new developments on the system reliability and establishing the need to reinforce the transmission system define the "design criteria contingencies" as follows:

- Single transmission element contingency,
- Double-circuit line contingency (presently applicable in the Northwest region for adverse weather conditions),
- Stuck breaker condition (presently not applicable in the Northwest region).

The proposed general guidelines specify that with all transmission elements in service in pre-contingency:

- the power flows over the transmission elements must be within their continuous thermal ratings.
- following any design-criteria contingency the power flows must not exceed the limited time ratings of the equipment.
- the steady state voltages must be within the ranges required by the *Market Rules*.
- the post-contingency decline in voltage cannot exceed 10%,
- the system shall remain stable during and after the most severe "design criteria contingencies",

The load was modelled as constant MVA in pre-contingency with a 0.92 power factor. In post contingency situations, the loads were modeled as variable active and reactive power as follows:

- 50% of the active power was proportional to the square of the voltage and 50% to the voltage
- 100% of reactive power load is proportional to the square of the voltage.

The *Market Rules* require that the immediate post contingency abrupt voltage variation due to reactive equipment switching not exceed 4%.

Because the Northwest Ontario transmission stretches over very long distances, the main phenomena which limit the transfer of power over this system are related to the system's capability to maintain adequate pre and post contingency voltages and avoid voltage collapse and to prevent the tripping of the interconnection circuits with Manitoba and Minnesota, in case of contingency. These power transfer limits are well below the continuous or LTR ratings of the transmission elements.

6.5 Study Scenarios

The system operating scenarios selected for this assessment represent stressed system conditions where the power flows over the impactful interfaces are at acceptable maximum levels. These operating points are defined in Table 2 below. The studies were performed for system configurations assuming:

- 2 x 40 Mvar shunt reactors in service at Wawa,
- no reactive devices in service at Wawa,
- 2 x 39.6 Mvar shunt capacitors in service at Wawa.

For each scenario described in Table 2 below, the system capability was verified for the corresponding most critical contingencies under fair weather conditions.

Table 2. Study Scenarios

Scenarios (figure 5)	East West Flow (MW)	Ontario Manitoba Flow (MW)	Ontario Minnesota Flow (MW)	NW Load (MVA)	NW Generation (MVA)	Selected Critical Contingency
A Lower right quadrant	356 E	196 E	100 S	920	1228	Loss of one Marathon to Wawa 230 kV circuit Table 1. (c) Loss of Ontario Minnesota Tie Table 1. (d)
B Upper right quadrant	272 E	153 W	100S	860	1450	Loss of both Ontario to Manitoba circuits Table 1.(b)
C Lower left quadrant	382 W	156 E	50 N	1352	753	Pre-contingency Voltage profile Table 1. (g)

6.6 Assessment Results

Scenario A (EW Tr East=356 MW, OM Tr East=196 MW, OntMin Tr South=100 MW)

As listed in Table 1, the operating limits for this scenario were established to respect:

- the relay margins along East- West tie for the loss of W21M and T12 at Marathon TS under conditions of Minnesota flows south less than 100 MW and
- minimum voltages between Marathon – Mississagi after automatic phase shifter action at Whiteshell for the loss of the Ontario-Minnesota interconnection under conditions of flow south higher than 100 MW.

The records of pre-contingency voltages and results of transient stability simulations and relay margin calculations for a contingency associated with the 230 kV circuit W21M are presented in this section. Table 3 summarizes these results.

Table 3. Scenario A Study Results

230 kV Voltages	Pre-contingency Voltages (kV)			Transient Stability Loss of W21M @ Marathon for Case A	Relay Margin Loss of W21M @ Marathon for Case A	Post-contingency Voltages (kV): Loss of Ontario Minnesota Interconnection & automatic phase shifter movement on Ont-Manitoba tie	
	Case A	Case B	Case C			Case B	Case C
	2x40 Mvar reactor at Wawa	No Shunt Devices at Wawa	2x39.6 Mvar Shunt Capacitors at Wawa				
Lakehead	244.6	245.4	245.7	Stable Fig A1 for Case A. Fig A2 for Case B. Fig A3 for Case C.	Well within the 10% required margin	237.3	238.4
Marathon (2 x 36MX shunt caps ON)	222.3	238.4	246.1			-3.3%	-3%
Wawa	214.6	238.3	249.9			214.5	226.2
Mississagi	227	236.8	241.3			-10%	-8.1%
						218	233.7
						-8.5%	-6.5%
						225.1	232.3
						-5%	-3.7%

The results indicate that for this particular scenario, without any reactive support the voltage at Wawa TS is about 238 kV. The two new 39.6 Mvar shunt capacitors provide a total improvement of about 10.6 kV to the Wawa 230 kV voltage.

The switching of one shunt capacitor in this case would result in a voltage change of approximately 2.2%.

It can be concluded that with the new shunt capacitors in service at Wawa the east-west interface can accommodate a flow east of about 355 MW and:

- The pre-contingency voltages at Marathon TS and Wawa TS are within the acceptable operating limits,
- The system remains stable for the loss of 230 kV circuit W21M between Marathon and Wawa,
- The relay margins on W22M relays for the loss of the companion circuit are within the 10% required margin,
- The post-contingency voltages are within the stability limits for a contingency involving the Ontario-Minnesota interconnection and following the Whiteshell phase shifter action.

Scenario B (EW Tr East=272 MW, OM Tr West=153 MW, OntMin Tr South=100 MW)

As listed in Table 1., the operating limit for this scenario was established to maintaining minimum voltage between Marathon – Mississagi in the event of a contingency associated with the loss of both Ontario to Manitoba circuits and after automatic phase shifter action at International Falls operation. Table 4 lists these results.

Table 4. Scenario B Study Results – Loss of Ontario Manitoba Interconnection

230 kV Voltages	2x40 Mvar reactor at Wawa Case A			No Shunt Devices at Wawa Case B			2x39.6 Mvar Shunt Capacitors at Wawa Case C		
	Pre-contingency	Immediate Post-contingency	Post International Falls phase shifter action	Pre-contingency	Immediate Post-contingency	Post International Falls phase shifter action	Pre-contingency	Immediate Post-contingency	Post International Falls phase shifter action
Lakehead	245.5	240.1 -2.2%	236.8 -3.6%	245.7	241.1 -1.9%	238.1 -3.0%	244.8	240.1 -1.9%	238.1 -2.8%
Marathon (1 x 36MX shunt cap ON)	240.6	225.5 -6.3%	212.1 -11.8%	249	236.7 -5%	225.7 -9.4%	253.2	241.1 -4.7%	232.3 -8.2%
Wawa	237.3	222.6 -6.2%	211.3 -10.9%	251.3	239.6 -4.6%	230.2 -8.4%	258.1	247.5 -4.1%	240.5 -6.8%
Mississagi	238.7	227.7 -4.6%	221.4 -7.3%	244.5	236.4 -3.3%	230.8 -5.6%	247.6	241.3 -2.5%	237 -4.3%

It should be noted that these cases do not necessarily correspond to the most stressed conditions of power flows over the Northwest interconnections, hence in real-time the EW tie voltages could be even lower.

These study results for Case A show that with 2 x 40 Mvar reactors in service at Wawa the pre-contingency voltage at Wawa is close to the lower limit and voltage instability is likely to occur for the loss of the Ontario-Manitoba ties.

These study results for Case B show that with no reactive support device in service at Wawa the pre-contingency voltage at Wawa is slightly over the normal operating voltage and the post-contingency voltage decline after the International Falls phase shifter action is under 10%.

These study results for Case C show that both shunt capacitors in service at Wawa the pre-contingency voltage at Wawa is well over the maximum acceptable operating voltage and the post-contingency voltage decline after the International Falls phase shifter action is less than 6.8%.

The resulting change in voltage due to the switching of one shunt capacitor at Wawa could be approximated by extrapolating the results for Case B and Case C, since sensitivity analysis of Wawa voltages to switching only one Wawa shunt capacitor was not performed. The results indicated that a voltage change of up 6 kV is expected to result from switching only one of the Wawa shunt capacitors.

Although, the system would not be operated as simulated in Case B and C, , these results are indicative of the improvement in voltage stability provided by the new shunt capacitors. A system configuration that would provide adequate pre and post-contingency voltages for these flow levels, would likely include the Marathon shunt capacitors switched out and one shunt capacitor in service at Wawa. This would ensure a healthy voltage over the East-West transmission interface in pre-contingency and post-contingency situations.

Scenario C (EW Tr West=382 MW, OM Tr East=156 MW, OntMin Tr North=50 MW)

As listed in Table 1., the operating limits for this scenario were established to respect minimum pre-contingency voltages on the East-West interface. The effect on voltage of the switching of the Marathon and Wawa shunt capacitors was also studied.

Table 5. Scenario C Study Results

230 kV Voltages	80 Mvar reactor at Wawa	Shunt Capacitor Switching			
		2 x 36 Mvar Shunt Caps at Marathon and No Shunt Devices at Wawa	Switching One Marathon Shunt Capacitor Out	Switching First 39.6 Mvar cap at Wawa	Switching Second 39.6 Mvar cap at Wawa
Lakehead	Load Flow solution was not obtained	243.3	243.9	244.7 0.6%	246.1 0.6%
Marathon (2 x 36MX shunt caps ON)		241.3	230.8 -4.3%	245.8 1.9%	250.6 2%
Wawa		242.4	233.4 -3.7%	248.2 2.4%	254.1 2.4%
Mississagi		239.9	235.6 -1.8%	242.2 1%	244.2 0.8%

The study results show that the pre-contingency voltages are adequate when the flow westbound on the EW interface is about 380 MW. The switching of one Wawa shunt capacitor will result in a change in voltage of 2.4% or about 6 kV.

7.0 System Operation Concerns

The IMO will be performing detailed studies to establish the new operating limits and the optimum use of the reactive compensation devices.

The IMO operating experience shows that switching one Marathon shunt capacitor would result in a voltage change at Marathon of about 8 to 9 kV, and switching the existing 25 Mvar reactor at Wawa would result in 3 to 4 kV change in voltage. These values are representative of the impact on voltage of reactive compensation switching operations, but these could be higher or lower depending on the system conditions. The Marathon caps are as big as practical for this part of the power system.

It is concluded that the two 39.6 Mvar shunt capacitors meet the Market Rule requirements with respect to voltage changes for switching operations. In order to obtain higher flexibility in controlling the operating voltage at Wawa TS, the IMO prefers that Hydro One install two smaller banks (i.e. 19.8 Mvar) on the tertiary of one of the Wawa TS autotransformer. Hydro One Networks has indicated that they have considered the alternative arrangement of installing two smaller banks (i.e. 19.8 Mvar) on the tertiary of one of the Wawa TS which as suggested by IMO, but they concluded that the proposed 2 x 39.6 Mvar arrangement is the most cost-effective arrangement.

In order to ensure that voltages at Wawa are maintained within the acceptable operating range it is required that automatic tripping be provided as follows:

- for the shunt reactors when Wawa 13.8 kV voltage reaches lower than acceptable levels, and
- for the shunt capacitors when voltages at Wawa 13.8 kV are unacceptably high.

The IMO has concluded from these studies and other Northwest system performance studies that the East-West interface limit could benefit from a continuous voltage support source at Wawa TS. Although, this could be achieved by installing a Static Var Compensator at Wawa TS instead of the two pairs of reactor/capacitor devices, it is recognized that these facilities would be very expensive.

8.0 Comments on System Impact

The improvement on transfer capability of the East-West interface realized by the addition of the 2 x 39.6 Mvar shunt capacitors is likely to reduce the bottling of some of the generation in the Northwest region. However, under some system conditions the transmission limits on other interfaces, in the GLP system and between Lakehead TS and Martindale TS, may restrict the use of the 30 MW improvement in the East-West interface limit.

9.0 Conclusions and Recommendations

This Preliminary Assessment has examined the effect that Hydro One Networks Inc.'s proposal - to replace the existing four oil filled shunt reactors at Wawa TS with two new 40 Mvar air core units and install shunt capacitors with a total reactive capability of 80 Mvar - would have on system voltages in the area and the East-West interface power transfer capability. The assessment concluded the following:

1. The proposed replacement of the existing shunt reactors and the installation of two new 39.6 Mvar shunt capacitors do not have an adverse impact in the reliability of the IMO-controlled grid and meet the Market Rule requirements for sudden voltage variations. Any switching associated with the new shunt reactor or one new shunt capacitor bank of 39.6 Mvar will result in abrupt voltage changes that are less than 4%. In most cases the switching on the new 39.6 Mvar shunt capacitor resulted in a change in voltage of up to 6 kV which represents 2.5% voltage change.
2. With the new shunt capacitors in service at Wawa an increase of about 30 MW in power transfer capability of the East-West interface could be achieved under certain system conditions. The detailed operating studies that are to be initiated by the IMO will establish the new improved system security limits and system operating instructions for the incorporation of the proposed facilities.

The IMO has noted that more operating flexibility could be achieved if one of the planned shunt capacitors would be composed of 2x19.8 Mvar banks. Hydro One Networks has considered the alternative arrangement of installing two smaller banks (i.e. 19.8 Mvar) on the tertiary of one of the Wawa TS but they concluded that the proposed 2 x 39.6 Mvar arrangement is the most cost-effective arrangement.

10.0 IMO Requirements

The IMO requires that the status of all isolating disconnects and breakers associated with the shunt reactors and shunt capacitors be monitored and available to the IMO on a continual basis.

IMO requires that the new shunt capacitor banks and the new shunt reactors be switched off automatically when Wawa voltage is too high or too low respectively.

11.0 Customer Impact Assessment

Hydro One Networks Inc. has performed the Customer Impact Assessment and concluded that the proposed installation of 2 x 39.6 Mvar capacitor banks at Wawa TS will result in no adverse impact on the supply reliability to the customers in the area, and enhanced voltage control in the area.

12.0 Notification of Approval

It is recommended that Notification of Approval be granted for the connection of the new reactive compensation facilities to the tertiary windings of each of the two autotransformers at Wawa TS, subject to the implementation by Hydro One Networks Inc. of all the requirements specified in section 10.0.

Figure 1 Wawa TS - Existing Facilities

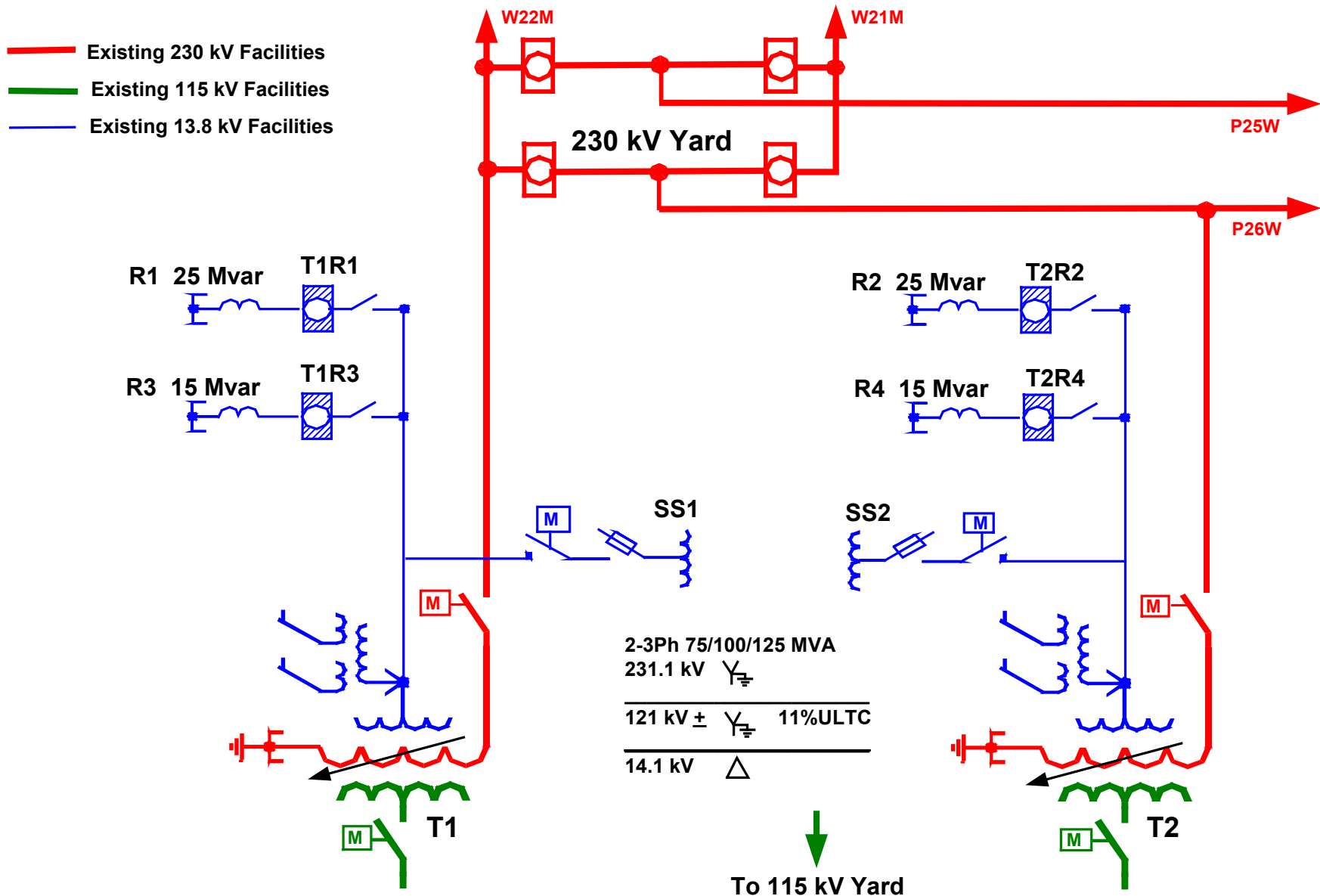


Figure 2 Wawa TS - Proposed 13.8 kV facilities for Alternative # 1

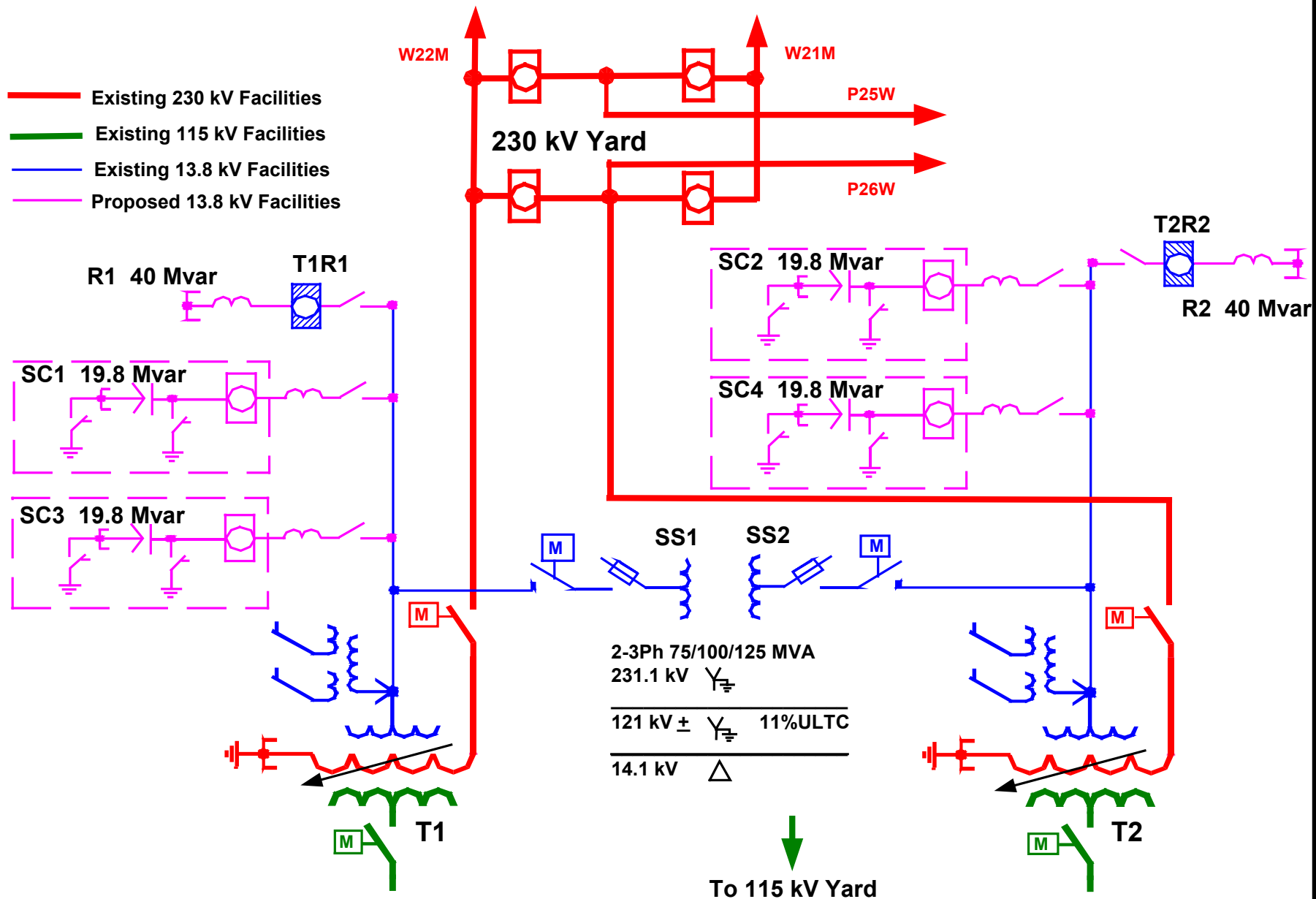
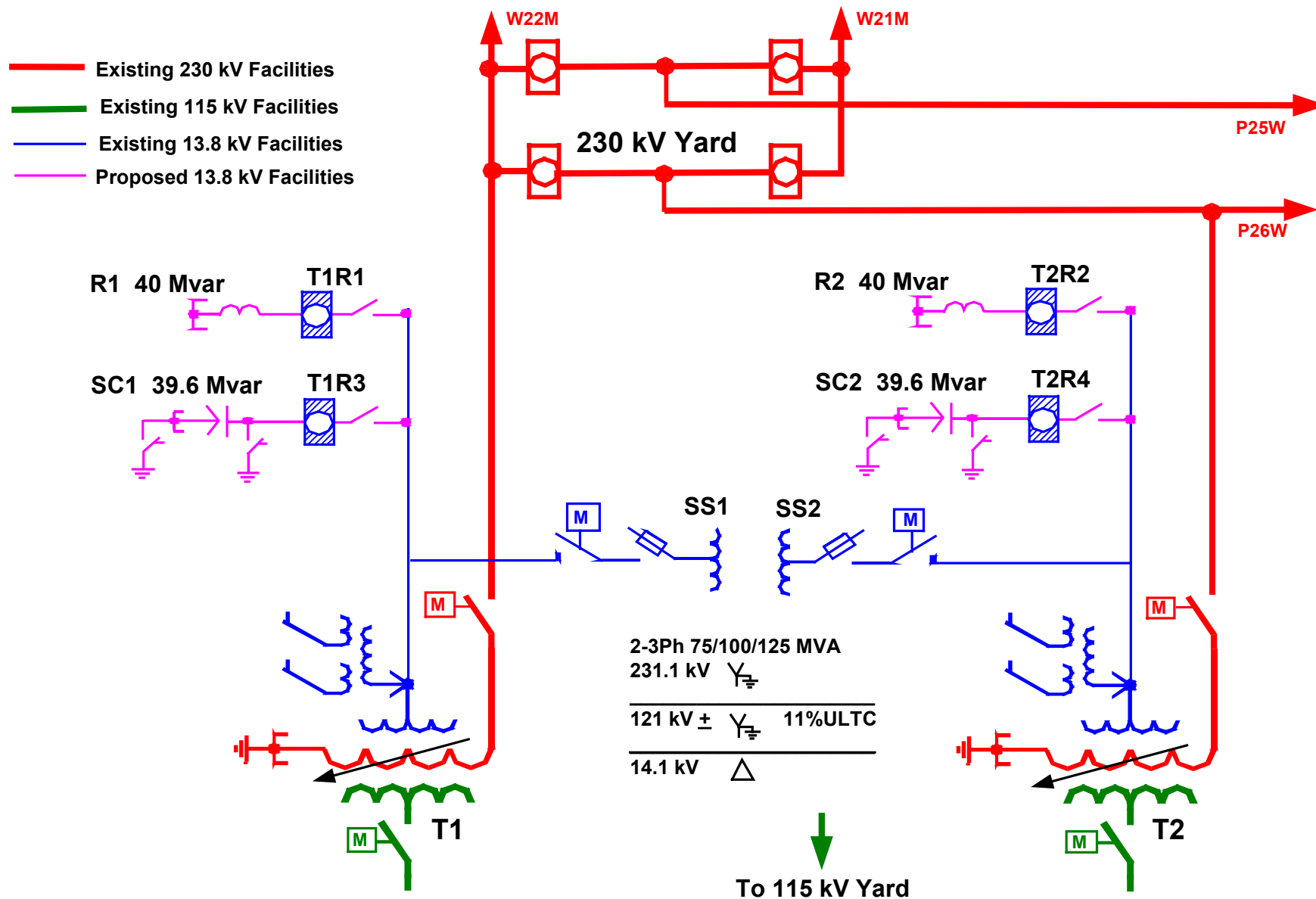


Figure 3 Wawa TS - Proposed 13.8 kV facilities for Alternative # 2



Preliminary Assessment Report for Reactive Compensation at Wawa TS

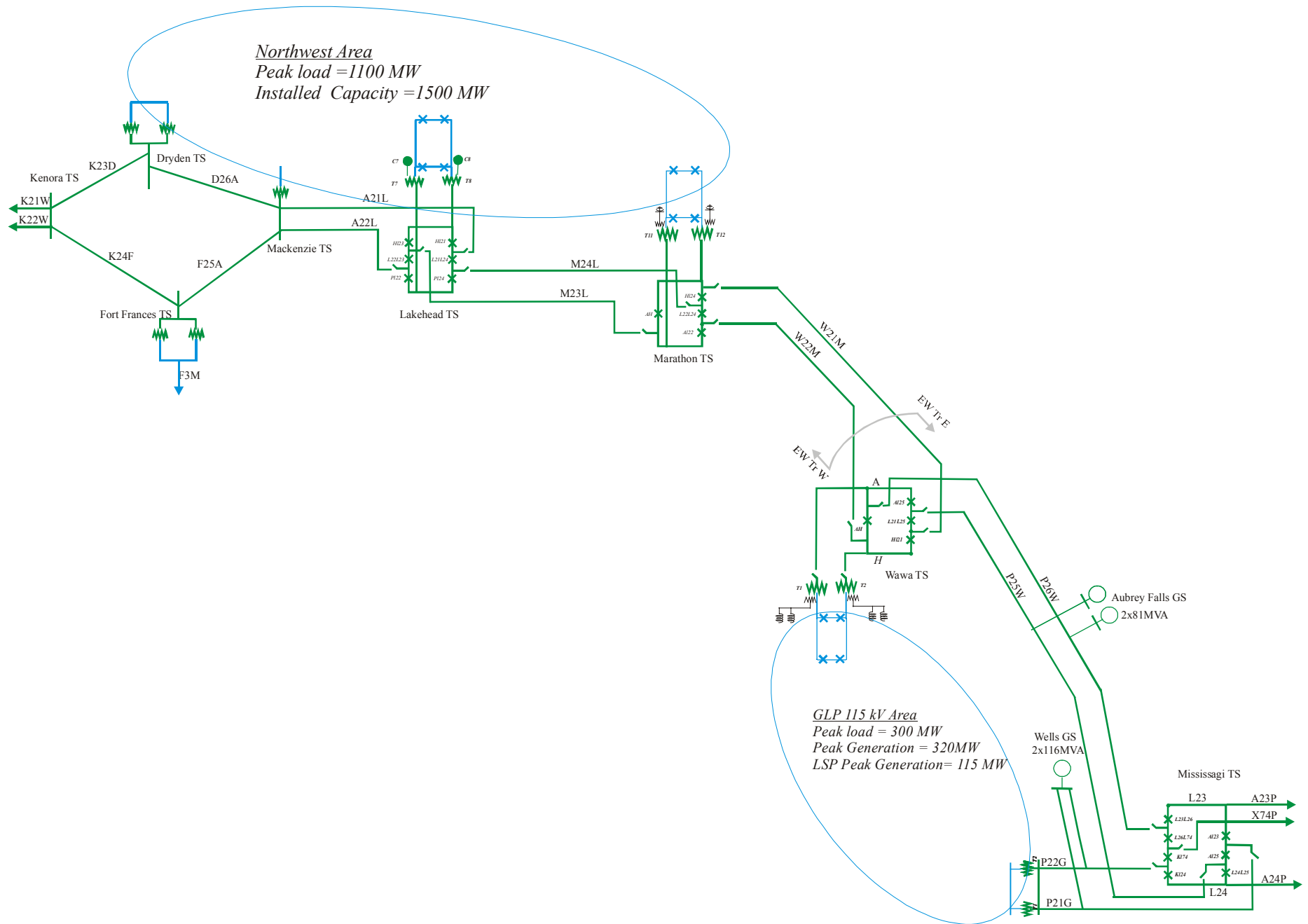


Figure 4. Existing Northwest System Diagram

Preliminary Assessment Report for Reactive Compensation at Wawa TS

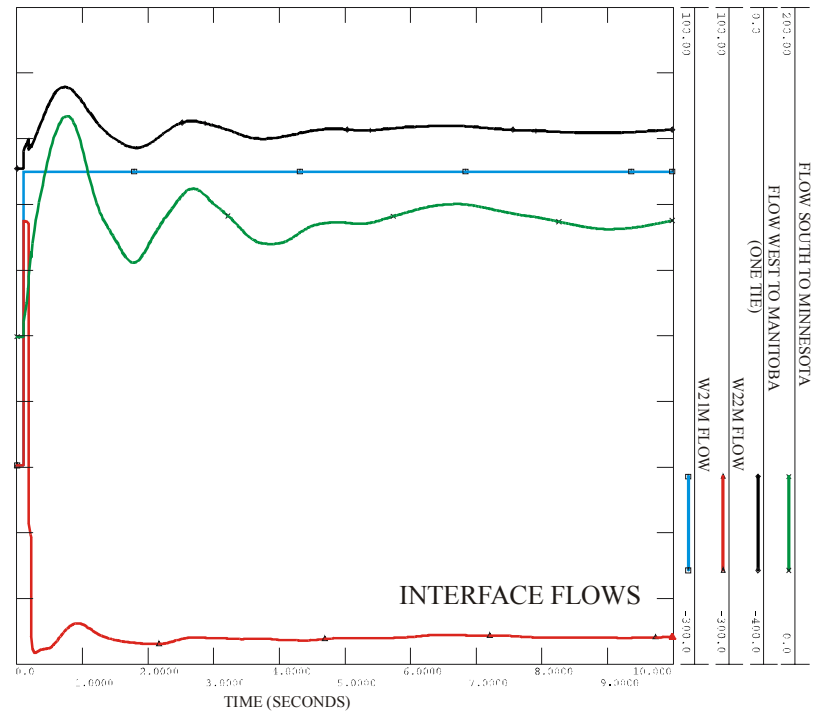
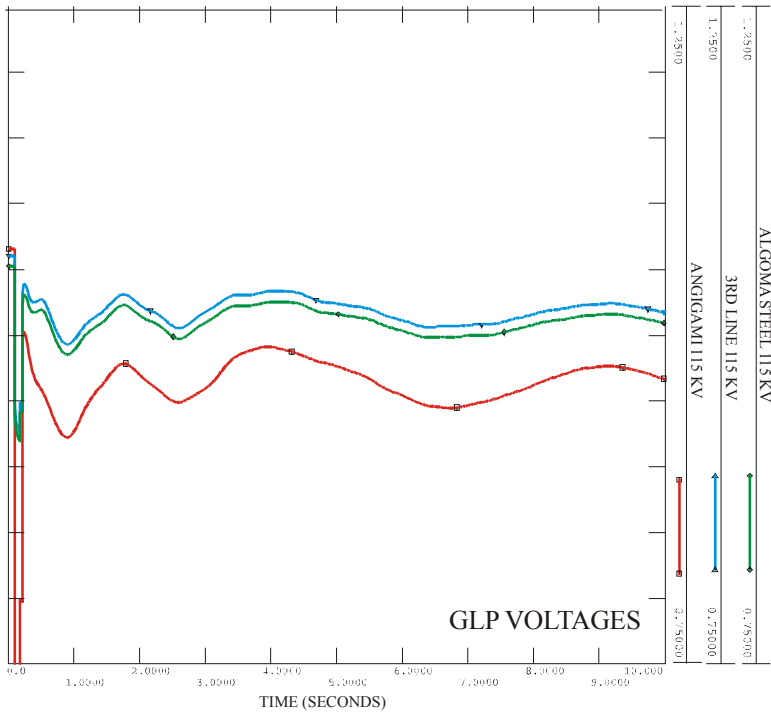
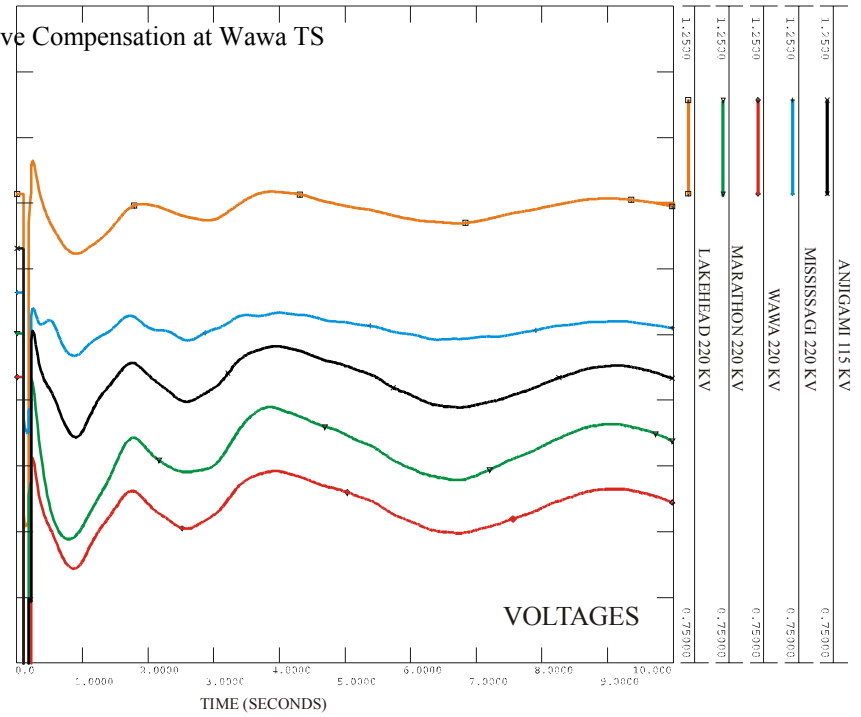
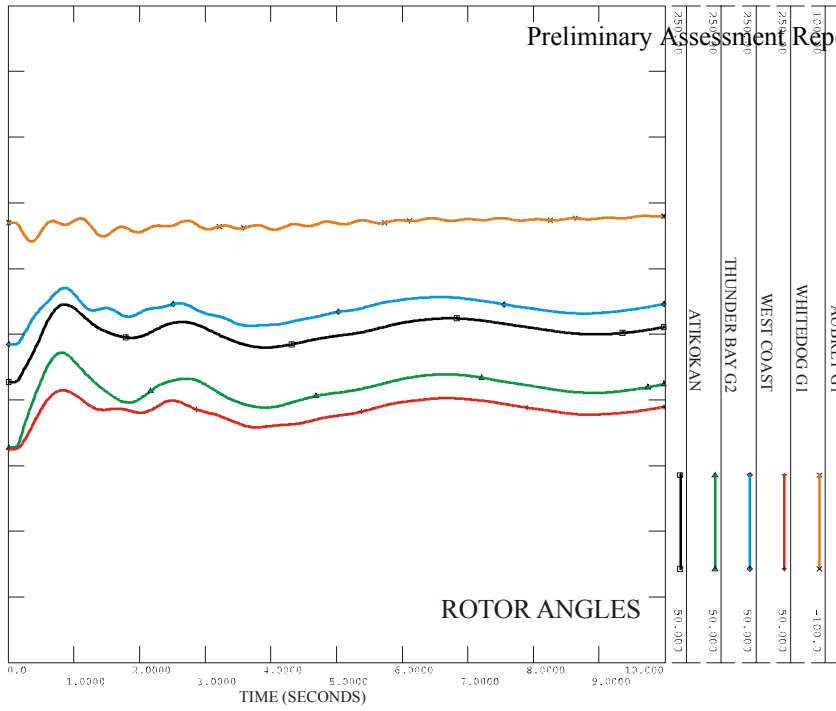


FIGURE A1. LOSS OF W21M @ MARATHON WITH 2X40 RECTORS I/S AT WAWA

Preliminary Assessment Report for Reactive Compensation at Wawa TS

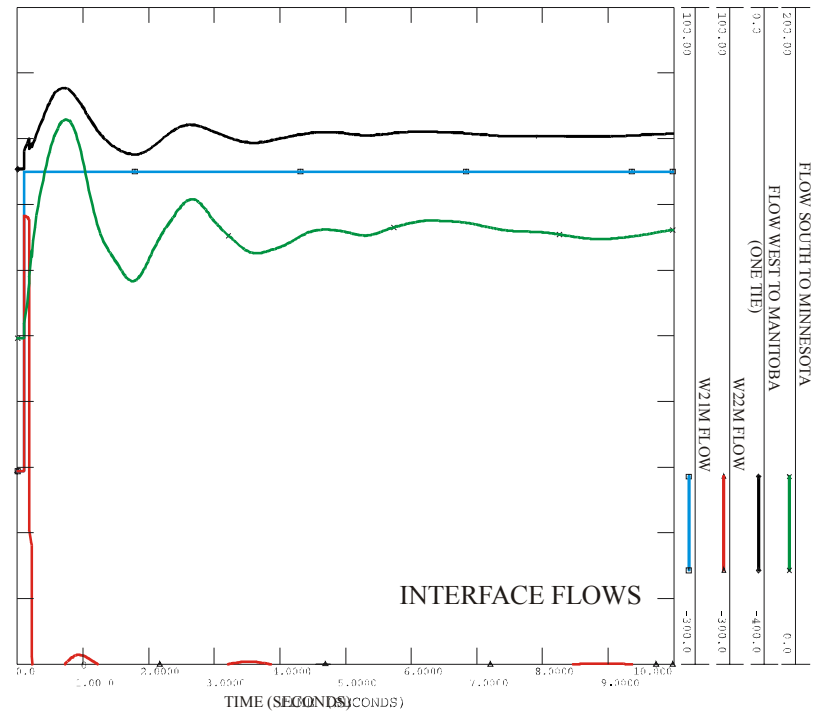
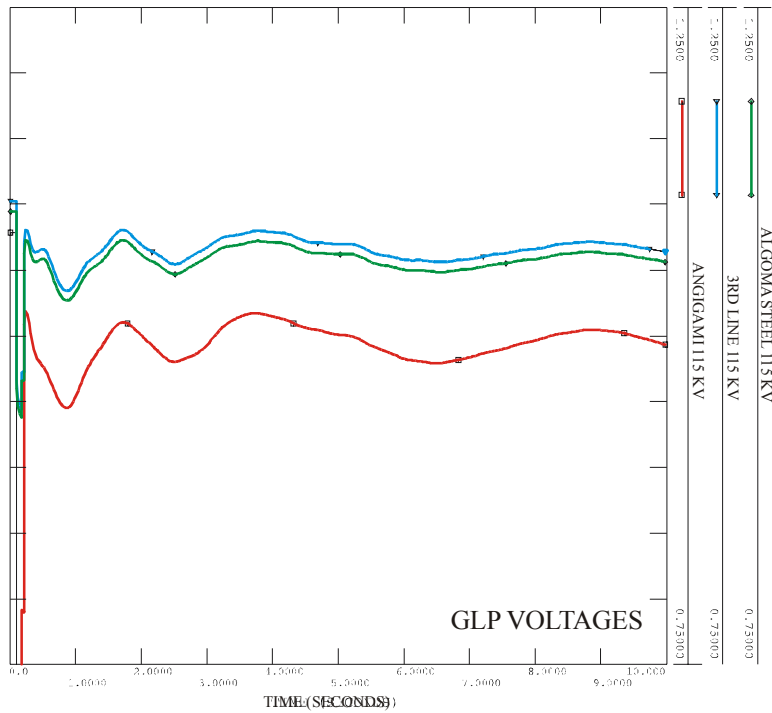
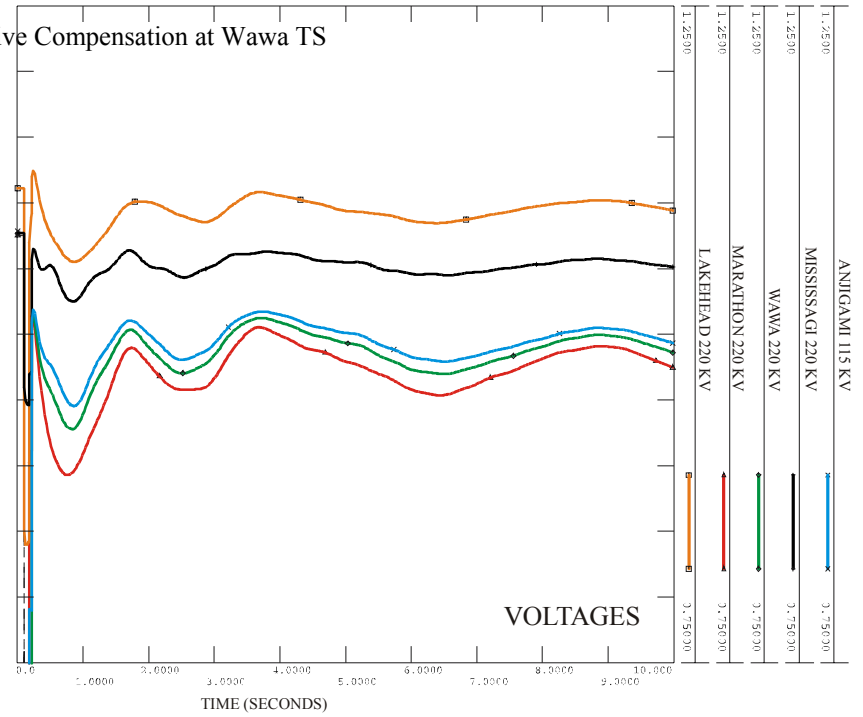
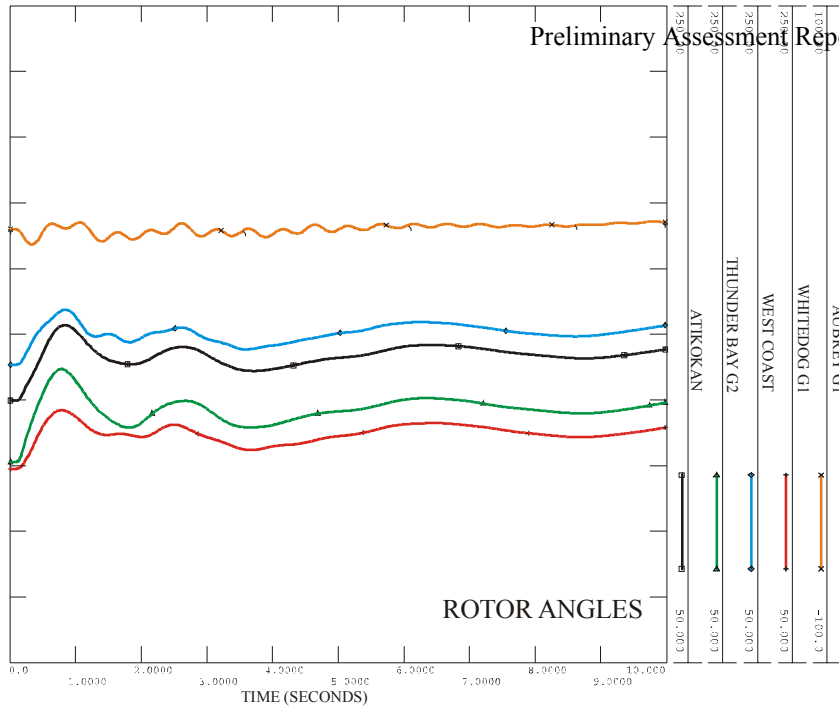


FIGURE A2. LOSS OF W21M @ MARATHON WITHOUT Reactive Compensation AT WAWA

Preliminary Assessment Report for Reactive Compensation at Wawa TS

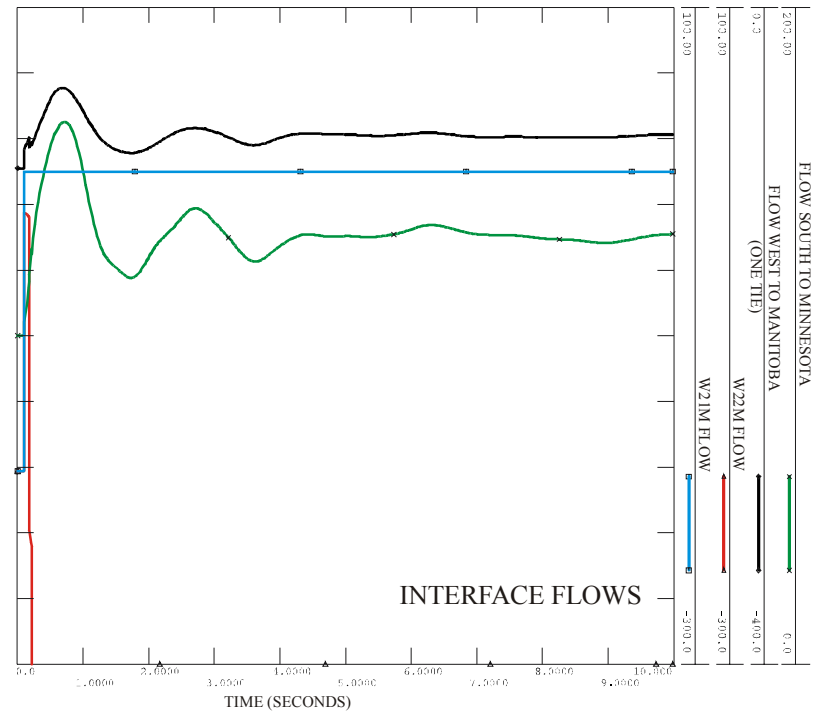
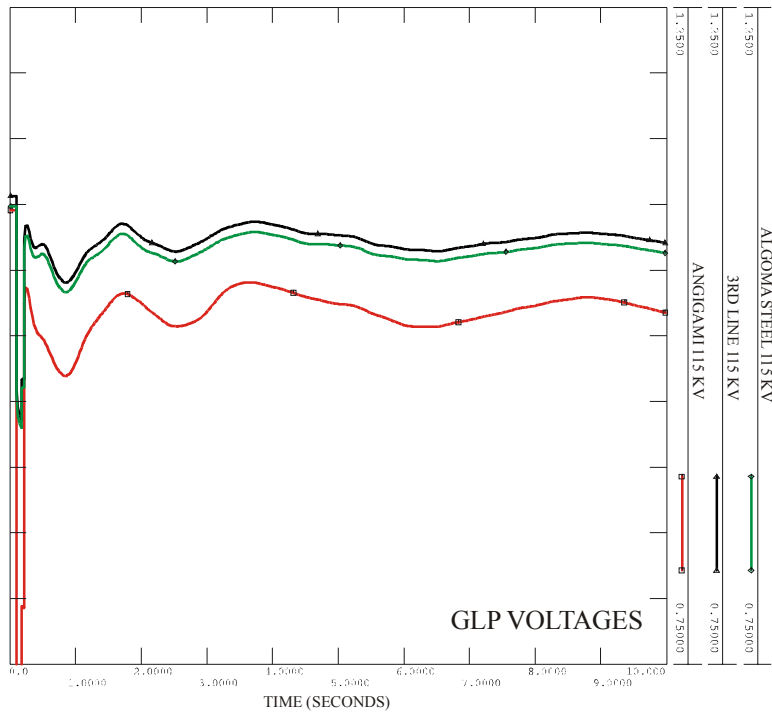
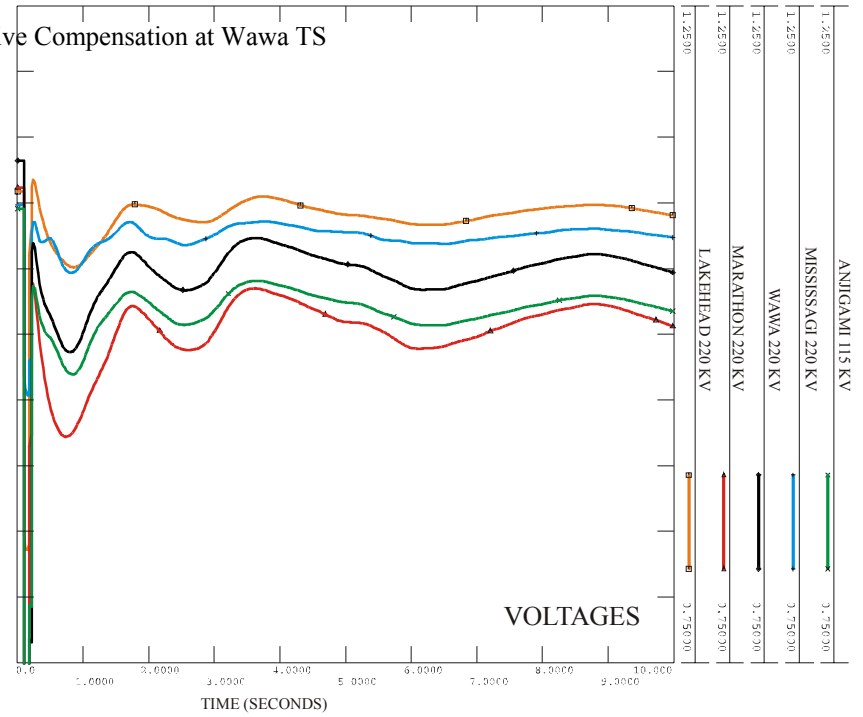
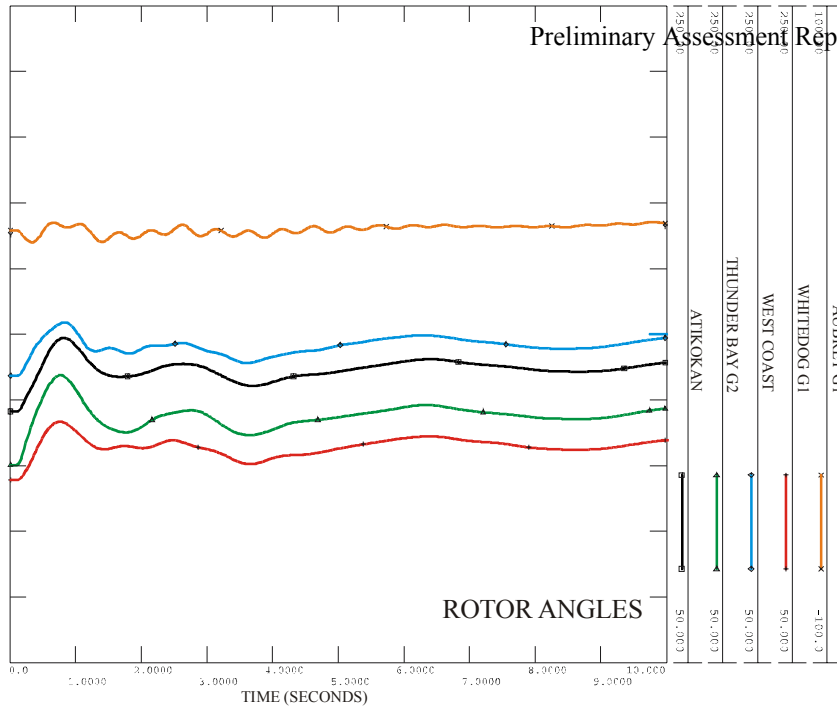


FIGURE A3. LOSS OF W21M @ MARATHON WITH 2X40 SHUNT CAPACITORS I/S AT WAWA