REPORT

Power to Ontario.
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System Impact Assessment Report

CONNECTION ASSESSMENT & APPROVAL PROCESS

Issue 1.0

Project: Tilbury West DS Second 115 kV Connection

Applicant: Hydro One Networks

CAA ID 2008-332

Final Draft Report

Transmission Assessments & Performance Department

January 28, 2009

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Disclaimers

Acknowledgement

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

IESO

This report has been prepared solely for the purpose of assessing whether the connection applicant's proposed connection with the IESO-Controlled Grid would have an adverse impact on the reliability of the integrated power system and whether the IESO should issue a notice of approval or disapproval of the proposed connection under Chapter 4, section 6 of the Market Rules.

Approval of the proposed connection is based on information provided to the IESO by the connection applicant and the transmitter(s) at the time the assessment was carried out. The IESO assumes no responsibility for the accuracy or completeness of such information, including the results of studies carried out by the transmitter(s) at the request of the IESO. Furthermore, the connection approval is subject to further consideration due to changes to this information, or to additional information that may become available after the approval has been granted. Approval of the proposed connection means that there are no significant reliability issues or concerns that would prevent connection of the proposed facility to the IESO-Controlled Grid. However, connection approval does not ensure that a project will meet all connection requirements. In addition, further issues or concerns may be identified by the transmitter(s) during the detailed design phase that may require changes to equipment characteristics and/or configuration to ensure compliance with physical or equipment limitations, or with the Transmission System Code, before connection can be made.

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 and the IESO in accordance with Chapter 4, section 6 of the Market Rules. The IESO assumes no responsibility to any third party for any use, which it makes of this report. Any liability which the IESO 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 IESO provides a draft of this report to the connection applicant, you must be aware that the IESO may revise drafts of this report at any time in its sole discretion without notice to you. Although the IESO 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.

HYDRO ONE

Special Notes and Limitations of Study Results

The results reported in this SIA study are based on the information available to Hydro One, at the time of the study, suitable for a SIA of a new generation or load connection proposal.

The short circuit and thermal loading levels have been computed based on the information available at the time of the study. These levels may be higher or lower if the connection information changes as a result

of, but not limited to, subsequent design modifications or when more accurate test measurement data is available.

This study does not assess the short circuit or thermal loading impact of the proposed connection on facilities owned by other load and generation (including OPGI) customers.

In this study, short circuit adequacy is assessed only for Hydro One breakers and does not include other Hydro One facilities. The short circuit results are only for the purpose of assessing the capabilities of existing Hydro One breakers and identifying upgrades required to incorporate the proposed connection. These results should not be used in the design and engineering of new facilities for the proposed connection. The necessary data will be provided by Hydro One and discussed with the connection proponent upon request.

The ampacity ratings of Hydro One facilities are established based on assumptions used in Hydro One for power system planning studies. The actual ampacity ratings during operations may be determined in real-time and are based on actual system conditions, including ambient temperature, wind speed and facility loading, and may be higher or lower than those stated in this study.

The additional facilities or upgrades which are required to incorporate the proposed connection have been identified to the extent permitted by a SIA under the current IESO Connection Assessment and Approval process. Additional facility studies may be necessary to confirm constructability and the time required for construction. Further studies at more advanced stages of the project development may identify additional facilities that need to be provided or that require upgrading.

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Executive Summary

Description

This System Impact Assessment (SIA) examined the impact of a second 115 kV connection to Tilbury West DS on the reliability of the IESO Controlled Grid (ICG).

The proposed project is a development project which helps improve load supply reliability in the Tilbury area.

Under this project, Hydro One proposes to convert the existing Tilbury West DS into a DESN type arrangement. For this, a second high voltage supply is required to supply one of the Tilbury West DS transformers. This is to be achieved by utilizing an idle section of the K2Z circuit from Belle River JCT to Tilbury JCT and connecting it to the K6Z circuit at Belle River JCT using the existing line disconnect switch. Further, this circuit is to be extended approximately 600 meters for connection to Tilbury West DS and supply one of the existing Tilbury West transformers.

In addition, Hydro One will split the low voltage bus by installing a new low voltage circuit tie breaker at the station, and two new breakers will be installed on the low voltage side of the Tilbury West DS transformers.

The scheduled initial in-service date is January 15, 2010, with a permanent in service date of April 30, 2010.

Findings

The study results concluded the following:

(a) The proposed project would not materially affect the reliability of the *IESO-Controlled Grid*.

(b) The addition of the new connection will have a small contribution on the short circuit levels in the area, and the interrupting capabilities of the high voltage breakers will be adequate.

(c) Not as a result of the new connection, Tilbury West DS load power factor may become lower than the required 0.9 lagging to 0.9 leading at the defined meter point.

(d) Given any contingency removing one transformer from service at Tilbury West, the loading may exceed the 32 MVA 10-day LTR of the remaining transformer. Hydro One is recommended to increase the transformation capacity at Tilbury West TS to meet the forecast load increase.

(e) Not as a result of the new connection, under the 2012 peak load conditions, the loss of K2Z or K6Z will trigger the Kingsville Voltage Dependent L/R Scheme.

(f) Not as a result of the new connection, under certain loading conditions, it is possible the short-term-emergency (STE) rating of the K2Z line from Lauzon Junction to Woodslee Junction to be exceeded following a K6Z contingency. Under these scenarios, the load is low enough not to trigger the operation of the Kingsville High Voltage Load Rejection Scheme, but high enough to overload the above mentioned line section. Pre-contingency control actions such as low voltage bus splitting at Kingsville TS may need to be taken in these circumstances. In real time operation it is recommended that the operators monitor the post-contingency thermal loading of K2Z and do not rely on the Kingsville High Voltage L/R scheme to protect the equipment.

(g) It is expected that the completion of the Leamington TS under the Windsor Reinforcement Project will eliminate the post-contingency thermal overloading by removing 60 MW of load from K2Z and K6Z in 2012.

IESO's Requirements for Connection

The following requirements were identified in this assessment:

1. Hydro One is required to have the ability to maintain a power factor within the range of 0.9 lagging and 0.9 leading as measured at the defined metered point at Tilbury West DS. If needed, reactive compensation shall be installed at Tilbury West DS to comply with this requirement.
2. Hydro One is required to confirm that the voltage reduction capability that provides 3% and 5% voltage reduction within five minutes exists for Tilbury West DS.
3. Hydro One is required to install all the equipment needed to monitor the information at Tilbury West DS as described in Appendix 4.16 of the Market Rules. The IESO requires that the above data to be available to the IESO on a continual basis.
4. The parameters for the new 115 kV and 27.6 kV equipment have to be provided to the IESO during the IESO Market Entry / Facility Registration process.
5. Hydro One has to ensure that all new 115kV equipment is capable of continuously operating in a range between 113 kV and 127 kV, as per Appendix 4.1, Reference 2 of the *Market Rules*. Transmission equipment must remain in service, and not automatically trip, for voltages up to 5% above the maximum continuous rating, for up to 30 minutes, to allow the system to be re-dispatched to return voltages within their normal range.
6. Protection systems must be designed to meet all the requirements of the Transmission System Code (TSC). They must be coordinated with the existing schemes. Existing lines protections and DESN protection settings in the area must be revised, as required.
7. Hydro One has to ensure that the existing load transfer capability between Scott and Lauzon remains available. This includes the protection settings revision for the load transfers. Switching sequence for the load transfers is to be provided to the IESO during the IESO Market Entry / Facility Registration process.
8. Hydro One is required to evaluate the impact of the proposed connection on the customers connected to the transmission system in the area.
9. Hydro One must complete the IESO Market Entry / Facility Registration process in a timely manner before IESO final approval for connection is granted. Finalized data must be provided to the IESO.

Notification of Approval for Connection Proposal

From the information provided, our review concludes that the proposed connection is expected to have no material adverse effect on the reliability of the *IESO Controlled Grid*, subject to meeting the requirements specified in this report

It is recommended that a *Notification of Conditional Approval for Connection* be issued for the proposed connection, subject to the IESO receiving from *Hydro One* written acknowledgement that the requirements described above under the heading "IESO Requirements for Connection" will be implemented.

If the new connection either does not meet the performance standards when installed or it is subsequently determined not to meet those performance standards, the IESO connection approval may be withdrawn until the performance standards or their equivalent can be demonstrated.

1. Project Description

Hydro One has proposed to convert the existing Tilbury West DS into a DESN type arrangement to improve reliability in the area. For this, a second high voltage supply is required at Tilbury West Junction to supply one of the Tilbury West DS transformers.

This is to be achieved by utilizing an idle section of the K2Z circuit from Belle River JCT to Tilbury JCT and connecting it to the K6Z circuit at Belle River JCT using the existing line disconnect switch. Further, this circuit is to be extended approximately 600 meters for connection to Tilbury West DS, and supply one of the existing Tilbury West transformers.

The scheduled initial in-service date is January 15, 2010, with a permanent in service date of April 30, 2010.

Figure1- Proposed Station Upgrades

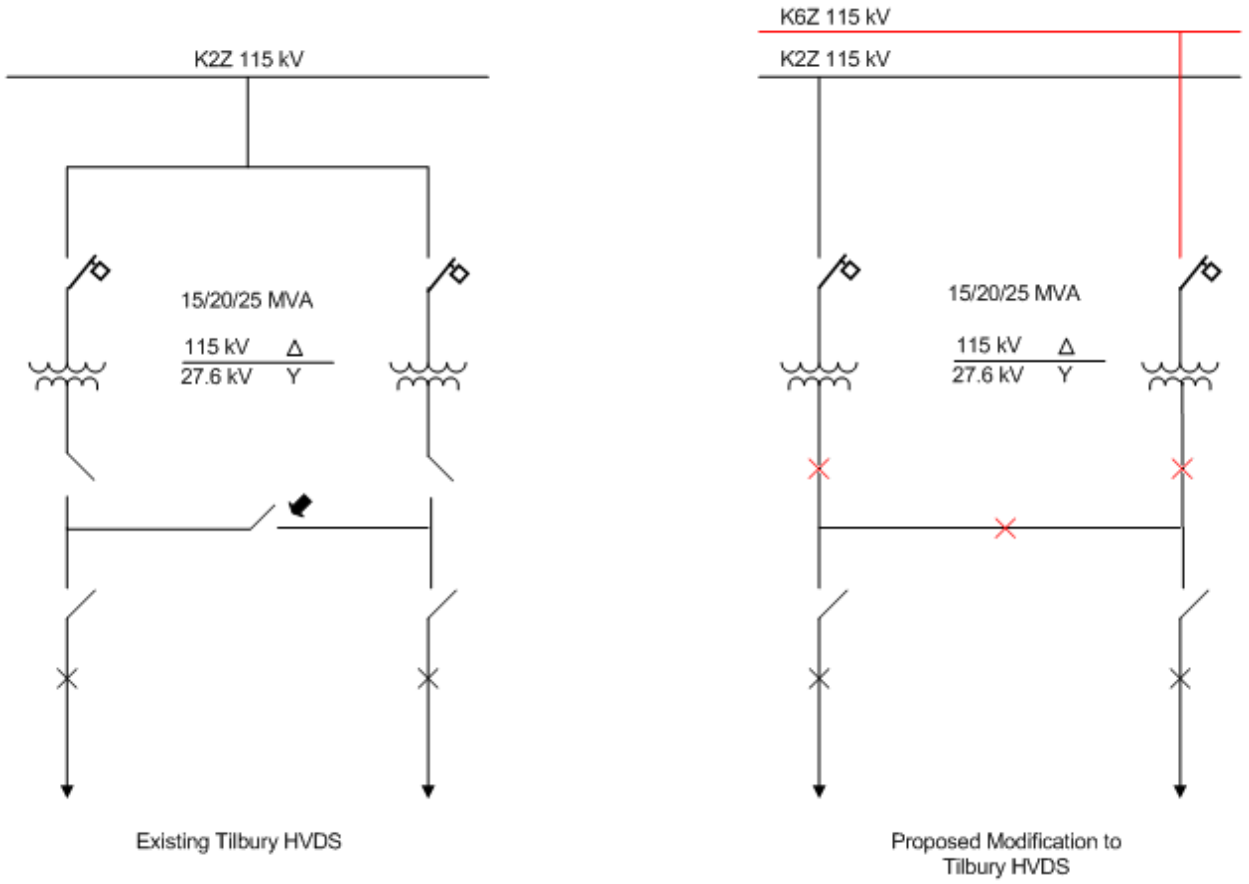

*Diagram courtesy of Hydro One

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2. Review of Connection Proposal

2.1 Connection Arrangement

The 115 kV lines K2Z and K6Z are supplied from Lauzon TS and feed Belle River TS and Kingsville TS. K2Z also supplies Tilbury TS and Tilbury West DS. In addition, K2Z connects to N5K by way of a normally open disconnect at Kent TS to the North.

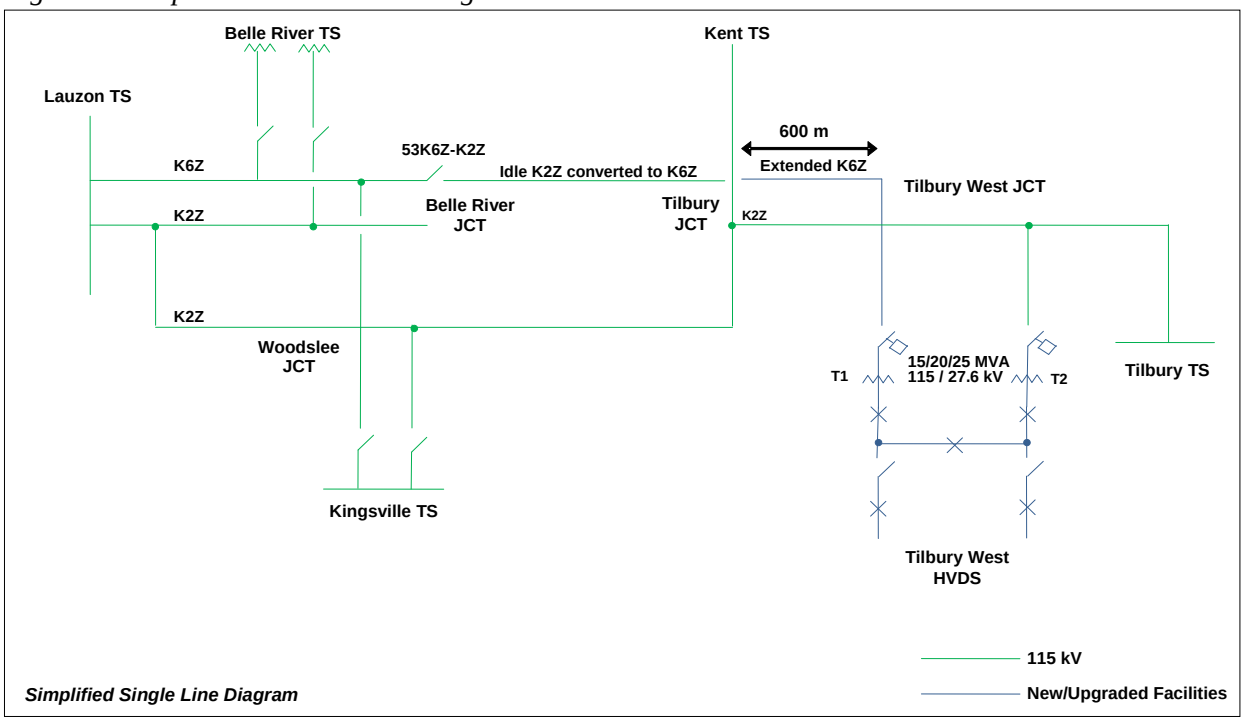
Currently, K2Z supplies Belle River TS by way of Belle River Junction, Kingsville TS, by way of Woodslee Junction, and is tapped off at Tilbury Junction to feed Tilbury TS and Tilbury West DS, before eventually connecting to Kent TS.

An idle section of 266.8 kcmil K2Z between Belle River Junction and Tilbury Junction is proposed to be commissioned as an extension to the existing K6Z circuit feeding into Belle River and Kingsville. This is facilitated by closing the normally open 53K6Z-K2Z disconnect switch. The line is then to be physically extended from Tilbury Junction by approximately 600 m of 266.8 kcmil to feed one of the transformers at Tilbury West DS.

One of the existing Tilbury West transformers will be removed from K2Z and connected to the new extension of K6Z.

In addition to the above line changes, a low voltage circuit tie breaker and two transformer breakers are to be installed at Tilbury West DS. For a simplified one-line diagram of these changes, see Figure 2 below.

Figure 2 –Proposed Connection Arrangement



2.2 Load Power Factor

The IESO requires that wholesale customers and distributors connected to the *IESO-Controlled Grid* shall operate at a power factor within the range of 0.9 lagging to 0.9 leading as measured at a defined meter point.

Hydro One has informed the IESO that Tilbury West DS operates with a peak load power factor of 0.91. Due to the reactive power losses in the transformers, the power factor as measured at the defined meter point will be lower than 0.91. Based on the Hydro One's load forecast, a time schedule for the minimum needed reactive compensation to meet the power factor requirement is given in Table 1.

Table 1- Reactive Power Compensation at the Tilbury West DS

Year	2010	2012	2014	2016	2018	2020
Load [MW]	27.8	29.1	30.4	31.7	32.5	33.1
Mvar at 27.6 kV with 0.91 p.f.	12.7	13.3	13.9	14.4	14.8	15.1
Mvar at 115kV with loss in Transformers at 0.9 p.f.	15.3	16.2	17.0	17.9	18.4	18.8
Compensation needed for 0.9 p.f. at HV [Mvar]	**1.85**	**2.06**	**2.29**	**2.53**	**2.68**	**2.80**

As it can be seen from Table 1, a minimum of 1.85 Mvar of reactive power compensation is required in 2010. Further, by 2020, the minimum reactive power compensation required is 2.80 Mvar.

Hydro One is required to have the ability to maintain a power factor within the range of 0.9 lagging and 0.9 leading as measured at the defined metered point at Tilbury West DS. If needed, reactive compensation shall be installed at Tilbury West DS to comply with this requirement.

2.3 Under-frequency Load Shedding

The *Market Rules* (Chapter 5 section 10.4) and *Market Manual 7.4* (Section 4.5) require that each distributor and connected wholesale customer, in conjunction with the relevant transmitter, make arrangements to enable the automatic disconnection of 35% of its peak demand for conditions of system under-frequency. In the Western Area, 37% of the load is connected to the UFLS relays. Tilbury West DS load does not participate in the UFLS program today.

Hydro One confirmed that UFLS facilities will be installed at Tilbury West DS.

2.4 Voltage Reduction Facilities

The *Market Rules* (Chapter 4 Appendix 4.3) requires that distributors connected to the IESO controlled grid with directly connected load facilities of aggregated rating of 20 MVA or more and the capability to regulate distribution voltage under load, shall install and maintain facilities to provide voltage reduction capability to achieve load reduction during periods when supply resources are limited. Voltage reduction capability represents the capability of reducing demand by lowering the customer voltage by 3% and 5%

and having the controlling authority to be able to effect the voltage reduction within five minutes of receipt of the direction from the IESO.

Hydro One is required to confirm that the voltage reduction capability that provides 3% and 5% voltage reduction within five minutes exists for Tilbury West DS.

2.5 On-line Monitoring

The Market Rules (Chapter 4 section 7.4) require that each transmitter shall provide the IESO on a continual basis with on-line monitored quantities as specified in Appendix 4.16. It is required that Hydro One installs all the equipment needed to monitor the information required by the IESO on a continual basis. The IESO requires that the status of all isolating disconnect switches and breakers, including breakers of LV capacitors and transformers, the 115 kV and 27.6 kV voltages, the active and reactive power flows over the transformers, the ULTC tap positions, and the capacitors Mvar output to be monitored on a continual basis.

Hydro One is required to provide the IESO with on-line monitored quantities as specified in Appendix 4.16 of the *Market Rules*.

2.6 Protection Systems

With respect to the protection and telecommunication requirements, the connection applicant will have to follow the Transmission System Code technical requirements.

The diagram that was provided by the applicant shows each transformer being separated from the transmission system via a motorized disconnect switch. For this particular arrangement, the Transmission System Code requires that the facility provide transfer trip of the Transmitter's breakers at the HV line terminal station (i.e. Lauzon TS) for transformer faults and for failure to operate of the LV breakers.

It is also required that the protection system initiate simultaneously both signals for transfer trip and the opening of the HV disconnect switch. Full opening of the disconnect switch shall then block the sending of the transfer trip signal.

The protection systems associated with K2Z and K6Z circuits are to be revised as required.

Hydro One has to ensure that the existing load transfer capability between Scott and Lauzon remains available. This includes the protection settings revision for the load transfers. Switching sequence for the load transfers is to be provided to the IESO during the IESO Market Entry / Facility Registration process.

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3. Data Verification

Hydro One has provided the specifications for the following proposed equipment for the upgrade:

- *Bus Tie Breaker, LV Transformer Breakers*

Quantity	3
Nominal voltage	38 kV
Short circuit interrupting capability	23 kA
Rated continuous current	1200 A
Cycles	3

The system performance standards listed in the *Transmission System Code* requires that 115 kV and 27.6 kV systems be designed for fault levels up to 50 kA and 17 kA, respectively, and the interrupting time should be less than 5 cycles and 8 cycles, respectively.

The 27.6 kV equipment proposed for installation at the upgraded Tilbury West TS meets the short-circuit capability recommended by the *Transmission System Code*.

The parameters for the new 115 kV and 27.6 kV equipment to be commissioned have to be provided to the IESO during the New Facility Registration process.

The *Applicant* has to ensure that all new 115kV equipment is capable of continuously operating in a range between 113 kV and 127 kV, as per Appendix 4.1, Reference 2 of the *Market Rules*. Transmission equipment must remain in service, and not automatically trip, for voltages up to 5% above the maximum continuous rating, for up to 30 minutes, to allow the system to be re-dispatched to return voltages within their normal range.

– End of Section –

4. Short Circuit Assessment

As part of the SIA, the IESO investigates the impact of the new connection on the *IESO Controlled Grid* (ICG) fault levels and the adequacy of the high voltage breakers to interrupt the faults.

The existing short circuit levels at the stations in the area were calculated by Hydro One at the IESO request. In addition to the existing generation resources, the short-circuit study included all future generation within the region.

The short circuit interrupting capability of the 115 kV breakers at Lauzon TS were obtained from the Hydro One 2002 Breaker Survey Study. Hydro One is required to verify the ratings of the breakers. If the actual breaker interrupting capabilities are different than those assumed in this SIA, Hydro One is required to send the correct ratings of the breakers listed in Table 3 below before this report is finalized.

In general, proposed DESN stations like the one assessed in this SIA do not have a significant impact on the transmission system fault levels. However, due to the additional connection between K2Z and K6Z through the LV bus at Tilbury West, an increase of up to 43 A in short circuit currents can be observed from the results presented in Table 3 below.

As can be seen in table 3, the high voltage breakers at Lauzon TS are adequate to interrupt the short-circuit currents. As well, the Tilbury West DS low voltage breakers are capable to interrupt the short circuit currents recognized at the station on the 27.6 kV side.

Table 3- Short-circuit Analysis

Station	Minimum Breaker Rating (kA)			3 Phase Fault (kA)		Line to Ground Fault (kA)	
	Symmetrical	Asymmetrical		Sym.	Asym.	Sym.	Asym.
Lauzon	39.3	45.5	*Present*	16.481	18.326	19.192	22.438
			Upgraded	16.481	18.326	19.192	22.438
Tilbury West HV K2Z			*Present*	3.138	3.167	2.037	2.059
			Upgraded	3.138	3.167	2.037	2.059
Tilbury West HV K6Z			*Present*	-	-	-	-
			Upgraded	3.378	3.383	2.068	2.072
Tilbury West LV1 (tie open)	23	23	*Present*	2.557	2.769	2.852	3.213
			Upgraded	2.6	2.771	2.887	3.191
Tilbury West LV2 (tie open)			*Present*	2.585	2.796	2.885	3.244
			Upgraded	2.585	2.796	2.885	3.244
Tilbury West LV12 (tie closed)			*Upgraded*	4.926	5.289	5.555	6.19

Hydro One is responsible to carry out a Customer Impact Assessment (CIA) evaluating the impact that the proposed connection may have on facilities owned by other load and generation customers connected to the transmission system in the area. The CIA assessment will include the evaluation of the adequacy of the LV breakers at the transformer stations in the area, including the LV breakers at Tilbury West TS.

Hydro One is required to evaluate the impact of the proposed connection on the transmission customers connected to the transmission system in the area.

– End of Section –

5. System Impact Studies

5.1 Description

This system impact assessment focused on identifying the impact of the proposed upgrades on the thermal loading of the 115 kV transmission lines K2Z and K6Z East of Lauzon, and on system voltage performance pre and post contingency. Further, it assesses the capability of the Tilbury West DS transformers to support the station's load growth into the foreseeable future.

The studies were performed for the summer of 2012, which was the forecast worst case loading scenario for the upgraded Tilbury West DS, and for the summer 2020 conditions with all elements in service and single contingencies. It is expected that the proposed 230 kV Leamington TS will reduce the loading on the 115 kV circuits K2Z and K6Z when it comes into service in 2012.

Several protection schemes exist in the Windsor area to account for various operational problems including pre contingency voltage instability, post contingency voltage declines, and thermal overloading. These include the Connectivity Based L/R Scheme, Voltage Dependent L/R Scheme, Windsor Area Overload Protection Scheme, and Kingsville High-Voltage-Switching Scheme.

In particular, the Kingsville Voltage Dependent L/R Scheme is relevant to the studied area as it directly impacts both the thermal loading and voltages seen on K2Z and K6Z. This scheme acts to reduce the Kingsville load in two stages via preselected breakers given voltage declines to 106 kV or less at the Kingsville terminal for a definite period of time.

5.2 Load Forecast

Hydro One provided the load forecast for the stations fed by the 115 kV circuits K2Z and K6Z as presented in Table 4 below. It is expected that the proposed 230 kV Leamington TS will reduce the loading on Kingsville TS and hence on the 115 kV K2Z and K6Z circuits by 60 MW when it comes into service in 2012. Following this reduction, any future increase in load at Kingsville TS is expected to be negligible. The switchover of this load is illustrated in table 4 below as a latter part of 2012.

Table 4 –Area Stations Load Forecast

Station	Load (MW)						
	2010	2012 A	2012 B	2014	2016	2018	2020
Tilbury TS	**1.7**	1.7	1.7	1.7	1.8	1.8	**1.9**
Tilbury West DS	**27.8**	29.1	29.1	30.4	31.7	32.5	**33.1**
Belle River TS	**23.0**	27.5	27.5	32.0	36.5	41.0	**45.5**
Kingsville TS	**149.0**	154.5	94.5	94.5	94.5	94.5	**94.5**
Total Area Load	**201.5**	212.8	152.8	158.7	164.5	169.8	**175.0**

5.3 Study Assumptions

To evaluate the worst case scenarios for the proposed connection, studies were performed for the year 2012 and year 2020 peak load conditions. The PSS/E software was used to carry out the thermal and voltage analyses.

(a) Base Case Configuration Changes

Based on the information provided by Hydro One, the following elements have been added to the load flow model:

- K6Z was extended to connect to one of the Tilbury West DS transformers.
- Tilbury West T2 was relocated from K2Z to K6Z.
- The following existing shunt capacitors were placed in service:
    - Lauzon TS (2x20 Mvar at 27.6 kV),
    - Kingsville TS (2x20 Mvar and 2x10 Mvar at 27.6 kV),
    - Belle River TS (2x11 Mvar at 27.6 kV)

(b) Base Case Set-Up

To conduct the computer analysis, the IESO base case model was adjusted as follows:

- The individual station loads in the studied area were scaled to the forecasted "*2012 A*" loading as per table 4. A load power factor of 0.9 was assumed.
- Kingsville Voltage Dependent Load Rejection Scheme was simulated by reducing Kingsville load by 40% given a decline in K2Z and K6Z voltage to less than 106 kV.
- Extra studies were conducted for year 2020 scenario with loading as per table 4.

(c) Thermal Ratings

The continuous ratings for the overhead conductors were calculated at the lowest of the sag temperature or 93^{o}C operating temperature, with a 35^{o}C ambient temperature and 4 km/h wind speed.

The long term emergency (LTE) ratings for the overhead conductors were calculated at the lowest of the sag temperature or 127^{o}C operating temperature, with a 35^{o}C ambient temperature and 4 km/h wind speed.

The short term emergency (STE) ratings for the overhead conductors were calculated at the sag temperature, with a 35^{o}C ambient temperature and 4 km/h wind speed.

The MVA thermal capability was calculated assuming 113 kV actual voltages at the 115 kV voltage levels.

Table 5 – K2Z Thermal Ratings

Line	From	To	Oper. Temp (˚C)	Conductor	Continuous Rating (A)	Continuous Rating (MVA)	LTE (A)	LTE (MVA)	STE_{75LTE} (A)	STE_{75LTE} (MVA)
	Kent TS	Kent JCT	60	477.0 -26/7	420	82	420	82	420	82
	Kent JCT	Tilbury JCT	82	477.0-26/7	520	102	520	102	550	108
	Tilbury JCT	Woodslee JCT	90	477.0-26/7	570	112	570	112	610	119
	Woodslee JCT	Windsor Lauzon J	150	477.0-26/7	590	115	770	151	830	162
	Tilbury JCT	Tilbury West JCT	150	266.8-26/7	410	80	530	104	620	121
	Woodslee JCT	Kingsville TS	133	477.0-26/7	590	115	800	157	860	168
	Tilbury JCT	Belle River JCT			Converted to K6Z (See below)					
K2Z	Tilbury West JCT	Tilbury West JCT	150	266.8-26/7	410	80	530	104	620	121
	Tilbury West JCT	Tilbury West JCT	150	266.8-26/7	410	80	530	104	620	121
	Tilbury West JCT	Tilbury West DS	150	266.8-26/7	410	80	530	104	620	121
	Tilbury West JCT	Tilbury TS	150	266.8-26/7	410	80	530	104	620	121
	Windsor Lauzon J	Windsor Lauzon	150	795.0-26/7	810	159	1070	209	1210	237
	Belle River JCT	Rourke Line JCT	127	795.0-26/7	810	159	1070	209	1200	235
	Rourke Line JCT	Windsor Lauzon J	127	795.0-26/7	810	159	1070	209	1200	235
	Rourke Line JCT	Belle River TS		336.4-26/7	480	94	620	121	730	143

Table 6 – K6Z Thermal Ratings

Line	From	To	Oper. Temp (˚C)	Conductor	Continuous Rating (A)	Continuous Rating (MVA)	LTE (A)	LTE (MVA)	STE_{75LTE} (A)	STE_{75LTE} (MVA)
	Kent TS	Tilbury JCT	116	266.8 -26/7	410	80	500	98	510	100
	Belle River JCT	Rourke Line JCT	127	795.0 -26/7	810	159	107	209	1200	235
K6Z	Kingsville TS	Belle River JCT	150	336.4 -26/7	480	94	620	121	730	143
	Windsor Lauzon J	Windsor Lauzon TS	127	795.0-26/7	810	159	107	209	1200	235
	Rourke Line JCT	Windsor Lauzon J	127	795.0-26/7	810	159	107	209	1200	235
	Rourke Line JCT	Belle River TS		336.4-26/7	480	94	620	121	730	143
	Tilbury JCT	Belle River JCT	116	266.8-26/7	410	80	500	98	510	100
New	Tilbury JCT	Tilbury West JCT	116	266.8-26/7	410	80	500	98	510	100

Transformer thermal ratings were obtained from Hydro One secure website and are shown in table 7 below.

Table 7 – Tilbury West Transformer Thermal Ratings

Transformer	Rated (kV)	Connection Type	Summer Continuous (MVA)	Summer 10 Day LTR (MVA)	Summer 15 Min LTR (MVA)
T1	115.5-27.6	D/Y	25	32	-
T2	115.5-27.6	D/Y	25	32	-

(d) Load Modeling

- For the thermal assessment, load was modeled as *constant MVA* for all contingencies except for the *2012- 86% peak case*—loss of K6Z—which was modelled as voltage dependent (P modeled as 50% constant current and 50% constant impedance; Q modeled as 100% constant impedance);
- For voltage decline studies, load was modeled as:
    - voltage dependant prior to tap changer response;
    - constant MVA after the tap changer response.

5.4 Thermal Analysis

Using the study assumptions above, load flow analyses were conducted for 2012 and 2020 conditions.

The *IESO Ontario Resource and Transmission Assessment Criteria* requires that all line and equipment loadings to be within their continuous ratings with all elements in service, and within their long-term emergency ratings with any one element out of service. They may be loaded up to their short-term emergency ratings immediately following contingencies to effect re-dispatch, perform switching or implement control actions to reduce the loading to the long-term emergency ratings.

The Kingsville Voltage Dependent Load Reduction Scheme was included in the simulation under 2012 loading conditions, when the post contingency Kingsville voltage dropped below 106 kV. This scheme has the impact of disconnecting 4 out of 10 feeders in Kingsville following a voltage reduction on K2Z and K6Z to below 106 kV for 7 seconds. Further, an additional 4 feeders are disconnected if the voltage stays below 106 kV for a total of 10 seconds. For the assessment, this scheme was represented by a 40% reduction in Kingsville load following a K2Z and K6Z drop to less than 106 kV (stage 1). Moreover, if the voltage still did not stabilize to a value greater than 106 kV following this 1st phase of load reduction, an additional 40% for a total of 80% load reduction at Kingsville was to be simulated (stage 2).

As latter verified in the *Voltage Analysis* section, under year 2012 peak loading, Kingsville voltage levels declined to below 106 kV at K2Z and K6Z following a single 115 kV line contingency. Thus the 1st stage of the Voltage Dependent L/R Scheme is assumed active following tap changer response (post-ULTC).

The pre-contingency flows were compared to the continuous ratings of the equipment. The post-contingency line flows were compared against both continuous ratings and long term emergency ratings, and the respective rate loadings are presented in the associated tables in Appendix A.

The following conclusions are to be mentioned:

(a) The pre-contingency flows are within acceptable limits.

(b) The proposed connection of K6Z to Tilbury West TS has no negative impact on line loading following a K2Z or a K6Z contingency.

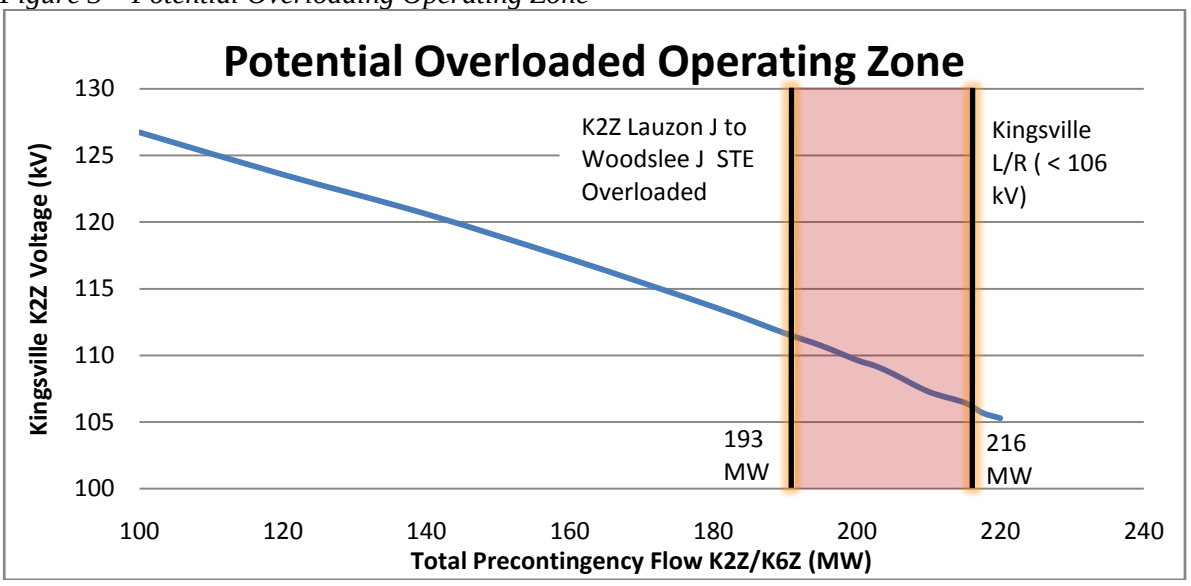
(c) Not as a result of the new connection, under the 2012 peak load conditions, the loss of K2Z or K6Z will trigger the Kingsville Voltage Dependent L/R Scheme. The stage 1 L/R following a K2Z or K6Z contingency negates most overloading of the line's 10 day LTE rating, with the exception of Lauzon Junction to Woodslee Junction on K2Z, which will be slightly loaded above the LTE. Additional manual load curtailment may be required to relieve the overloading. This is a well known problem, and Hydro One is advancing the reinforcements of the area to increase load supply capability.

(d) Not as a result of the new connection, it was identified that prior to the 2012 load transfer, a range of loading cases exists, such that the Kingsville L/R scheme is not triggered by under voltage and, as a result, the STE thermal ratings are surpassed for the Lauzon Jct to Woodslee Jct section of the 115 kV K2Z circuit. The results for a case with 86% of the 2012 peak load, which resulted in the Kingsville voltage to remain above 106 KV following the K6Z contingency, are presented in Table A2 of the Appendix A.

This is a known existing problem, which may require pre-contingency control actions such as low voltage bus splitting at Kingsville TS to be taken. In real time operation it is recommended that the operators monitor the post-contingency thermal loading of K2Z and do not rely on the Kingsville High Voltage L/R scheme to protect the equipment.

This is especially true when the load connected to K2Z+K6Z is within the range of 193 MW to 216 MW, and the ambient temperature is 35^0C with no wind, as assumed in the SIA. As presented in figure 3 below, the highlighted operating window indicates total pre-contingency flows at Lauzon along K2Z and K6Z which may result in post contingency overloading above the 162 MVA STE rating along the segment from Lauzon Junction to Woodslee Junction. This overloading ceases to occur if the voltage drops below 106 kV and the Kingsville High Voltage L/R scheme activates.

Figure 3 – Potential Overloading Operating Zone



(e) Not as a result of the new connection, any contingency removing one Tilbury West transformer, results in overloading the remaining transformer above the 32 MVA 10-day LTR. Hydro One is recommended to increase the transformation capacity at Tilbury West DS to meet the forecast load increase.

5.5 Voltage Analysis

To analyze steady state voltage performance, load flow analyses were conducted for peak 2012 and 2020 conditions, for scenarios identical to those previously presented in the thermal analysis.

Starting from a system with all elements in service, single 115 kV line contingencies were simulated and voltages at main buses were monitored.

As mentioned in the thermal analysis section, the Kingsville Voltage Dependent Load Reduction Scheme was included in the simulation under 2012 loading conditions, when the post-contingency voltage dropped below 106 kV. For the assessment, this scheme was represented by a 40% reduction in Kingsville load following a K2Z and K6Z drop to less than 106 kV.

As per *Market Rules* and *IESO Transmission Assessment Criteria*, the pre-contingency voltage at 115 kV level has to be within 113 kV and 127 kV.

IESO's Transmission Assessment Criteria states that with all *facilities* in service pre-contingency, system voltage declines after contingency are to be limited to 10%, and the voltage on the 115 kV system is to be minimum 108 kV.

All the simulations presented in the tables below were conducted with load modeled as voltage dependant (P modeled as 50 % constant current and 50 % constant impedance; Q modeled as 100% constant impedance) pre-ULTC, and as constant MVA post-ULTC, except for cases involving the activation of the Kingsville Voltage Dependent L/R Scheme.

For this scheme, load was assumed as voltage dependent until the Kingsville load was successfully dropped and tap changers responded. Following this response, load was then modeled as constant MVA.

The voltage results for the two analyzed scenarios, e.g. 2012, 2020 are presented in Tables A-4 to A-6 in Appendix A.

The following conclusions are to be mentioned.

(a) The proposed connection of K6Z to Tilbury West TS has no negative impact on voltage declines following a K2Z or a K6Z contingency.

(b) Not as a result of the new connection, in 2012, during tap changer operation post-contingency, the Kingsville voltage drops below 106 kV and initiate the Kingsville Voltage Dependent L/R Scheme. Once stage 1 L/R was activated, the scheme effectively increased all voltages in the area to acceptable levels.

(c) The likelihood of Kingsville Voltage Dependent L/R Scheme activation is significantly reduced after the 2012 in-service date of Leamington TS, due to reduced loading at Kingsville TS.

5.6 Conclusions

Load flow studies concluded that the proposed Tilbury West DS upgrade will not materially impact the reliability of the *IESO Controlled Grid*.

However, independent of the new transmission line connection, the study confirmed certain existing concerns under various load conditions in the area supplied by circuits K2Z and K6Z, as following.

(a) Given any contingency removing one transformer from service at Tilbury West, the loading exceeds the 32 MVA 10-day LTR of the remaining transformers. Hydro One is recommended to increase the transformation capacity at Tilbury West DS to meet the forecast load increase.

(b) Under the 2012 peak load conditions, the loss of K2Z or K6Z will trigger the Kingsville Voltage Dependent L/R Scheme.

(c) Under certain loading conditions, as proved in the 86 % peak load scenario, it is possible the short-term-emergency (STE) rating of the K2Z line from Lauzon Junction to Woodslee Junction to be exceeded following a K6Z contingency. Under these scenarios, the load is low enough not to trigger the operation of the Kingsville High Voltage Load Rejection Scheme, but high enough to overload the above mentioned line section. Pre-contingency control actions such as low voltage bus splitting at Kingsville TS may need to be taken in these circumstances. In real time operation it is recommended that the operators monitor the post-contingency thermal loading of K2Z and do not rely on the Kingsville High Voltage L/R scheme to protect the equipment.

(d) It is expected that the completion of the Leamington TS under the Windsor Reinforcement Project will eliminate the post-contingency thermal overloading by removing 60 MW of load from K2Z and K6Z in 2012.

– End of Section –

Appendix A: Study Results

Table A-1 – Year 2012 Pre contingency and Kingsville L/R Loading

2012 Peak			Thermal Ratings			Pre Contingency			Loss of K2Z Kingsville LR			Loss of K6Z Kingsville LR		
							Cont			Cont	LTE		Cont	LTE
From	To	ID	Cont	LTE	STE	MVA	%	LTE %	MVA	%	%	MVA	%	%
LAUZON	LAUZ J K2Z		159	209	235	119	75	57	0	0	0	183	115	88
LAUZON	LAUZ J K6Z		159	209	235	106	67	51	180	113	86	0	0	0
LAUZ J K2Z	ROURK J K2Z		159	209	235	21	13	10	0	0	0	29	18	14
LAUZ J K6Z	ROURK J K6Z		159	209	235	106	67	51	179	113	86	0	0	0
ROURK J K2Z	BEL R K2Z		94	121	143	21	23	18	0	0	0	29	31	24
ROURK J K6Z	BEL R K6Z		94	121	143	9	10	8	29	31	24	0	0	0
BEL R K2Z	BEL RIV	T1	59	59	-	21	36	36	0	0	0	29	49	49
BEL R K6Z	BEL RIV	T2	59	59	-	9	16	16	29	49	49	0	0	0
LAUZ J K2Z	WOODSLE J		115	151	162	98	85	65	0	0	0	158	137	105
ROURK J K6Z	BEL R J K6Z		159	209	235	100	63	48	148	93	71	0	0	0
WOODSLE J	KINGSV K2Z		115	157	168	79	68	50	0	0	0	117	101	74
BEL R J K6Z	KINGSV K6Z		94	121	143	83	88	69	115	123	95	0	0	0
KINGSV K2Z	KINGSVIL	T1	42	49	-	42	102	86	0	0	0	62	149	126
KINGSV K2Z	KINGSVIL	T3	42	55	-	34	83	63	0	0	0	51	122	93
KINGSV K6Z	KINGSVIL	T2	42	74	-	40	95	54	55	131	74	0	0	0
KINGSV K6Z	KINGSVIL	T4	42	58	-	40	97	70	56	134	97	0	0	0
WOODSLEJ	TILBURYJ		112	112	119	17	15	15	0	0	0	37	33	33
TILBURY J	KENT		102	102	108	2	2	2	0	0	0	2	1	1
TILBURY J	TILB W J F		80	104	121	18	23	17	0	0	0	38	47	36
BEL R J K6Z	TILBURY J K6Z		80	98	100	17	21	18	36	45	37	0	0	0
TILBURY J K6Z	TILBURY W K6Z	NEW	80	98	100	17	21	18	36	45	37	0	0	0
TILB W J F	TILBURY W K2Z		80	104	121	16	20	16	0	0	0	36	45	34
TILBURYW K6Z	TILB W LV	T2	25	32	-	18	70	55	36	143	111	0	0	0
TILBURYW K2Z	TILB W LV	T1	25	32	-	16	65	51	0	0	0	36	142	111
TILB W J F K2Z	TILB W J G K2Z		80	104	121	2	2	2	0	0	0	2	2	2
TILB W J G K2Z	TILBURY		80	104	121	2	2	2	0	0	0	2	2	2
TILBURY K2Z	TILBURY LV	T1	8	10	-	2	24	19	0	0	0	2	24	20

Table A-2 – Year 2012 86 %-peak Loading (Kingsville HV > 106 kV)

2012 Non Peak			Thermal Ratings			Loss of K6Z without Kingsville L/R			
							Cont		STE
From	To	ID	Cont	LTE	STE	MVA	%	LTE %	%
LAUZON	LAUZ J K2Z		159	209	235	203	128	97	86
LAUZON	LAUZ J K6Z		159	209	235	0	0	0	0
LAUZ J K2Z	ROURK J K2Z		159	209	235	25	16	12	11
LAUZ J K6Z	ROURK J K6Z		159	209	235	0	0	0	0
ROURK J K2Z	BEL R K2Z		94	121	143	25	27	21	18
ROURK J K6Z	BEL R K6Z		94	121	143	0	0	0	0
BEL R K2Z	BEL RIV	T1	59	59	-	25	43	43	-
BEL R K6Z	BEL RIV	T2	59	59	-	0	0	0	-
LAUZ J K2Z	WOODSLE J		115	151	162	184	160	**122**	**114**
ROURK J K6Z	BEL R J K6Z		159	209	235	0	0	0	0
WOODSLE J	KINGSV K2Z		115	157	168	142	123	90	84
BEL R J K6Z	KINGSV K6Z		94	121	143	0	0	0	0
KINGSV K2Z	KINGSVIL	T1	42	49	-	74	177	149	-
KINGSV K2Z	KINGSVIL	T3	42	55	-	60	143	110	-
KINGSV K6Z	KINGSVIL	T2	42	74	-	0	0	0	-
KINGSV K6Z	KINGSVIL	T4	42	58	-	0	0	0	-
WOODSLEJ	TILBURYJ		112	112	119	32	28	28	27
TILBURY J	KENT		102	102	108	1	1	1	1
TILBURY J	TILB W J F		80	104	121	32	41	31	27
BEL R J K6Z	TILBURY J K6Z		80	98	100	0	0	0	0
TILBURY J K6Z	TILBURY W K6Z	**NEW**	80	98	100	0	0	0	0
TILB W J F	TILBURY W K2Z		80	104	121	31	39	30	25
TILBURYW K6Z	TILB W LV	T2	25	32	-	0	0	0	-
TILBURYW K2Z	TILB W LV	T1	25	32	-	31	123	96	-
TILB W J F K2Z	TILB W J G K2Z		80	104	121	2	2	2	1
TILB W J G K2Z	TILBURY		80	104	121	2	2	2	1
TILBURY K2Z	TILBURY LV	T1	8	10	-	2	20	16	-

Table A-3 – Year 2020 Peak Loading

2020 Peak			Thermal Ratings			Pre Contingency			Loss of K2Z			Loss of K6Z		
							Cont			Cont	LTE		Cont	LTE
From	To	ID	Cont	LTE	STE	MVA	%	LTE %	MVA	%	%	MVA	%	%
LAUZON	LAUZ J K2Z		159	209	235	95	60	46	0	0	0	189	119	90
LAUZON	LAUZ J K6Z		159	209	235	83	52	40	191	120	91	0	0	0
LAUZ J K2Z	ROURK J K2Z		159	209	235	29	18	14	0	0	0	49	31	23
LAUZ J K6Z	ROURK J K6Z		159	209	235	83	52	40	191	120	91	0	0	0
ROURK J K2Z	BEL R K2Z		94	121	143	29	30	24	0	0	0	49	52	40
ROURK J K6Z	BEL R K6Z		94	121	143	19	20	16	49	52	40	0	0	0
BEL R K2Z	BEL RIV	T1	59	59	-	29	49	49	0	0	0	49	82	82
BEL R K6Z	BEL RIV	T2	59	59	-	19	32	32	49	83	83	0	0	0
LAUZ J K2Z	WOODSLE J		115	151	162	67	59	45	0	0	0	140	122	93
ROURK J K6Z	BEL R J K6Z		159	209	235	65	41	31	136	85	65	0	0	0
WOODSLE J	KINGSV K2Z		115	157	168	49	43	31	0	0	0	97	85	62
BEL R J K6Z	KINGSV K6Z		94	121	143	50	53	41	99	105	81	0	0	0
KINGSV K2Z	KINGSVIL	T1	42	49	-	27	65	55	0	0	0	53	127	107
KINGSV K2Z	KINGSVIL	T3	42	55	-	22	53	40	0	0	0	43	103	79
KINGSV K6Z	KINGSVIL	T2	42	74	-	24	58	33	47	114	64	0	0	0
KINGSV K6Z	KINGSVIL	T4	42	58	-	25	60	43	48	116	84	0	0	0
WOODSLEJ	TILBURYJ		112	112	119	20	18	18	0	0	0	45	40	40
TILBURY J	KENT		102	102	108	2	2	2	0	0	0	2	1	1
TILBURY J	TILB W J F		80	104	121	21	27	21	0	0	0	45	56	43
BEL R J K6Z	TILBURY J K6Z		80	98	100	19	24	19	44	55	45	0	0	0
TILBURY J K6Z	TILBURY W K6Z	**NEW**	80	98	100	19	24	19	44	55	45	0	0	0
TILB W J F	TILBURY W K2Z		80	104	121	19	24	19	0	0	0	43	53	41
TILBURYW K6Z	TILB W LV	T2	25	32	-	19	78	61	43	173	135	0	0	0
TILBURYW K2Z	TILB W LV	T1	25	32	-	19	77	60	0	0	0	43	172	134
TILB W J F K2Z	TILB W J G K2Z		80	104	121	2	3	2	0	0	0	2	3	2
TILB W J G K2Z	TILBURY		80	104	121	2	3	2	0	0	0	2	3	2
TILBURY K2Z	TILBURY LV	T1	8	10	-	2	27	22	0	0	0	2	27	22

Table A-4 – Year 2012 K2Z Contingency Voltage Analysis

2012 Peak				(A) Loss of K2Z		(B) Kingsville HV drops below 106 kV	(C) Kingsville L/R Scheme Activated (after 7 s)			
Pre Contingency				Pre ULTC		Post ULTC (2 steps)	Pre ULTC		Post ULTC	
Name	Base	PU	kV	kV	Δ%	kV	kV	Δ%	kV	Δ%
Lauzon TS	118.05	1.06	125.1	124.0	-0.9	123.9	125.7	0.4	125.7	0.4
Belle River K2Z	118.05	1.06	124.9	0.0	-100.0	0.0	0.0	-100.0	0.0	-100.0
Belle River K6Z	118.05	1.04	123.0	117.9	-4.1	117.6	122.0	-0.8	122.1	-0.8
Belle River LV	27.60	1.04	28.8	27.6	-4.1	27.9	29.0	0.6	29.0	0.7
Kingsville K2Z	118.05	1.00	118.2	0.0	-100.0	0.0	0.0	-100.0	0.0	-100.0
Kingsville K6Z	118.05	1.00	118.0	106.6	-9.7	105.8	115.8	-1.8	116.2	-1.5
Kingsville LV	27.60	1.06	29.2	25.8	**-11.9**	26.5	30.4	3.9	29.7	1.4
Tilbury West K2Z	118.05	1.02	120.5	0.0	-100.0	0.0	0.0	-100.0	0.0	-100.0
Tilbury West K6Z	118.05	1.03	121.2	114.4	-5.7	113.9	118.6	-2.2	118.5	-2.3
Tilbury West LV	27.60	1.07	29.4	26.5	**-10.1**	27.3	28.3	-3.8	29.1	-1.0
Tilbury K2Z	118.05	1.02	120.5	0.0	-100.0	0.0	0.0	-100.0	0.0	-100.0
Tilbury LV	27.60	1.06	29.3	0.0	-100.0	0.0	0.0	-100.0	0.0	-100.0

Table A-5 – Year 2012 K6Z Contingency Voltage Analysis

2012 Peak				(A) Loss of K6Z		(B) Kingsville HV drops below 106 kV	(C) Kingsville L/R Scheme Activated (after 7 s)			
Pre Contingency				Pre ULTC		Post ULTC (3 steps)	Pre ULTC		Post ULTC	
Name	Base	PU	kV	kV	Δ%	kV	kV	Δ%	kV	Δ%
Lauzon TS	118.05	1.06	125.1	124.1	-0.8	123.8	125.6	0.4	125.6	0.4
Belle River K2Z	118.05	1.06	124.9	124.1	-0.7	123.8	125.7	0.6	125.7	0.6
Belle River K6Z	118.05	1.04	123.0	0.0	-100.0	0.0	0.0	-100.0	0.0	-100.0
Belle River LV	27.60	1.04	28.8	29.1	1.0	29.0	29.4	2.2	29.0	0.8
Kingsville K2Z	118.05	1.00	118.2	106.7	-9.7	105.2	115.2	-2.5	115.3	-2.4
Kingsville K6Z	118.05	1.00	118.0	0.0	-100.0	0.0	0.0	-100.0	0.0	-100.0
Kingsville LV	27.60	1.06	29.2	25.6	-12.4	26.1	30.0	2.7	29.5	1.0
Tilbury West K2Z	118.05	1.02	120.5	112.7	-6.5	111.6	117.1	-2.8	116.8	-3.1
Tilbury West K6Z	118.05	1.03	121.2	0.0	-100.0	0.0	0.0	-100.0	0.0	-100.0
Tilbury West LV	27.60	1.07	29.4	26.1	-11.5	26.6	28.0	-5.1	29.1	-1.3
Tilbury K2Z	118.05	1.02	120.5	112.7	-6.5	111.6	117.1	-2.8	116.8	-3.1
Tilbury LV	27.60	1.06	29.3	27.4	-6.5	28.1	29.5	0.7	29.4	0.4

Table A-6 – Year 2020 Voltage Analysis

2020 Peak				Loss of K2Z				Loss of K6Z			
Pre Contingency				Pre ULTC		Post ULTC		Pre ULTC		Post ULTC	
Name	Base	PU	kV	kV	Δ%	kV	Δ%	kV	Δ%	kV	Δ%
Lauzon TS	118.05	1.07	126.1	125.3	-0.6	124.2	-1.5	125.4	-0.6	124.5	-1.3
Belle River K2Z	118.05	1.06	125.4	0.0	-100.0	0.0	-100.0	124.1	-1.1	123.0	-1.9
Belle River K6Z	118.05	1.06	125.1	122.0	-2.5	119.4	-4.5	0.0	-100.0	0.0	-100.0
Belle River LV	27.60	1.04	28.8	27.5	-4.4	28.5	-0.8	27.9	-2.8	28.7	-0.1
Kingsville K2Z	118.05	1.06	124.6	0.0	-100.0	0.0	-100.0	120.9	-3.0	117.6	-5.6
Kingsville K6Z	118.05	1.05	124.5	119.5	-4.0	115.6	-7.1	0.0	-100.0	0.0	-100.0
Kingsville LV	27.60	1.12	30.8	29.8	-3.1	29.0	-5.7	30.3	-1.8	29.2	-5.2
Tilbury West K2Z	118.05	1.05	123.6	0.0	-100.0	0.0	-100.0	119.4	-3.4	116.2	-6.0
Tilbury West K6Z	118.05	1.05	123.5	118.7	-3.9	115.0	-6.9	0.0	-100.0	0.0	-100.0
Tilbury West LV	27.60	1.07	29.5	26.8	-9.2	29.5	0.2	26.9	-8.7	29.4	-0.2
Tilbury K2Z	118.05	1.05	123.6	0.0	-100.0	0.0	-100.0	119.5	-3.4	116.3	-6.0
Tilbury LV	27.60	1.06	29.3	0.0	-100.0	0.0	-100.0	28.3	-3.4	29.2	-0.2

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