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# 1 Transmission Loss Factor Methodology And Assumptions Appendix 7

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Draft Revision - July 11, 2007

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## 1. Introduction

This document is a supplement to but a part of **rule 9.2** and provides details on the processes and assumptions used by the ISO to calculate **transmission loss factors**.

## 2. Methodology

The **loss factor methodology** is described in the following three sections; Load Flow Loss Factors, Energy Loss Factors, and Compressed Loss Factors.

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### 2.1 Load Flow Loss Factors ('Adjusted' Raw Loss Factors)

**Raw loss factors** are calculated for each **generating unit** for each of twelve base case **load** flow condition. Each base-case **load** flow is selected to represent a typical operating condition on the **transmission system**, based on historical system loading conditions and historical **generating unit** outputs.

The twelve base cases used to determine the **load** flows for the **interconnected electric system** are:

- used to give weighted average values of transmission system **loading** conditions and losses;
- represented over each of four - "three-month seasons" of the year (winter, spring, summer and fall); and
- the average values are taken at representative **high, medium** and low **load** conditions for each season.

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Each **generating unit** will be modeled in the twelve base cases using the following criteria (until December 31, 2008):

- Adjustments are made to the **forecasted load** if necessary to reduce imports and exports set to zero using a **generic stacking order** for generation;
- Other **generating units** will be added or removed to reduce exports to zero according to the **generic stacking order** but recognizing any constraints imposed by the **transmission system**.
- Adjustments are made to historical data to correct for major maintenance outages, and major forced outages.

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After December 31, 2008 the following conditions will apply:

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**Raw loss factors** are calculated for each **generating unit** for each of twelve base case **load** flow condition. Each base-case **load** flow is selected to represent a typical operating condition on the **transmission system**, based on historical system loading conditions, historical intertie flows, and historical **generating unit** outputs.

The twelve base cases used to determine the **load** flows for the **interconnected electric system** are:

- used to give weighted average values of transmission system **loading conditions** and losses;
- represented over each of four - “three-month seasons” of the year (winter, spring, summer and fall); and
- the weighted average values are taken at representative peak, median and low **load** conditions for each season.

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Each **generating unit** will be modeled in the twelve base cases using the following criteria:

- Add new generation forecasted for application using STS and IBCF levels for the **capacity calculations.**

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The methodology to determine a load flow based ‘**raw**’ **loss factor** for one of the **generating units** is called the “Corrected R Matrix 50% Area Load Adjustment Methodology”. In the proposed methodology, the calculation of **raw loss factors** will be done analytically with a custom program that uses the **load** flow solution as a base and computes the **raw loss factors** analytically for each **generating unit** in a single numerical process.

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In the methodology, it is assumed:

- that the **generating unit** for which the loss factor is to be evaluated is going to supply the next increment in **load** on the **AIES**;
- the **generating unit** for which the **loss factor** is to be calculated becomes the swing bus for the **transmission system**;
- every load within the **AIES** would be increased by a common factor and a loss gradient would be determined for the **generating unit** equal to the total change in **system losses** divided by the change in output of the **generating unit** for which the **loss factor** is being calculated; and
- the **raw loss factor** for the **generating unit** is set equal to  $\frac{1}{2}$  of the gradient.

Several assumptions inherent in the analytical method are:

- All bus voltages (and bus voltage angles) remain unchanged. This is a reasonable assumption if the magnitude of the power change is very small;
- The var component of the **load** is unchanged as a result of the change in MW **load**;
- The var output of the **generating units** is constant. This is consistent with the **load** var change assumption for small changes in **generating unit** output;
- The **load** change is applicable to only **loads** in the **AIES**;

- For **industrial system (ISD)** where the ISD is receiving power, the increment in **load** is based on the net **load** at the metering point; and
- For ISD's where the ISD is supplying power, the ISD is treated as an equivalent **generating unit** with output equal to net to grid at point of metering.

'**Raw loss factors**' calculated in this manner for every **generating unit** (or equivalent **generating unit**):

- when multiplied by the **generating unit** output in MW and summed for all **generating units** in Alberta will account for almost 100% of the **load** flow losses for the **AIES**;
- result in a **shift factor**, required to compensate for over or unassigned losses, which is extremely small;
- do not include Small Power Research and Development (SPRD) **generating units**; and
- include an additional small **load** flow **shift factor** component compensating for the unassigned component of the SPRD **generating units** with distribution based on their power output in the **load** flow.

## 2.2 Energy Loss Factors

The proposed process to calculate energy-based normalized **loss factors** for each of the **generating units** is as follows:

- a seasonal 'adjusted' **raw loss factor** is calculated for each **generating unit** equal to the weighted average of the three 'adjusted' **raw loss factors** determined for each of the three system loading conditions for the season;
- the seasonal 'adjusted' **raw loss factor** is multiplied by the forecast **generating unit** volumes for each **generating unit** to establish a preliminary allocation of **losses** for each season;
- the total allocation is compared to the estimated energy **losses** for the system and a seasonal **shift factor** is introduced to account for any differences between allocated and estimated energy **losses**; and
- the **normalized annual loss factor** is calculated as the weighted average of the four seasonal shifted **loss factors**.

## 2.3 Compressed Loss Factors

If a situation does arise where compression is necessary, the following methodology will be adopted:

Prior to January 1, 2009

- The **loss factors** of all **generating units** outside of the valid range (loss factor envelope of three times system average losses) will be limited to the valid range by clipping, and

- A **shift factor** will be applied to the **loss factors** for all **generating units** not on the **loss factor** limit with the first calculation to balance the energy loss.

If any **loss factors** lie outside the range as a result of application of the **shift factor**:

- the **loss factors** of all of the **generating units** that were not originally on the **loss factor** compression limits (clipped) would be 'linearly compressed'
- the difference between the shifted **loss factor** and the **system average loss factor** would be multiplied by a constant factor and the result added to the average **loss factor** to ensure that all **loss factors** are within limit; and
- the final **loss factor** will be referred to as a 'compressed' **loss factor**.

After December 31, 2008 the following conditions will apply:

- The **loss factors** of all **generating units** outside of the valid range (loss factor envelope of +/- 12%) will be limited to the valid range by clipping, and
- A **shift factor** will be applied to the **loss factors** for all **generating units** not on the **loss factor** limit with the first calculation to balance the energy loss.

If any **loss factors** lie outside the range as a result of application of the **shift factor**:

- the **loss factors** of all of the **generating units** that were not originally on the **loss factor** compression limits (clipped) would be 'linearly compressed'
- the difference between the shifted **loss factor** and the **system average loss factor** would be multiplied by a constant factor and the result added to the average **loss factor** to ensure that all **loss factors** are within limit; and
- the final **loss factor** will be referred to as a 'compressed' **loss factor**.

A MathCAD implementation of the clipping algorithm is shown on page seven.

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MathCAD Implementation of Clipping with Linear Compression Algorithm

Clipping Plus Linear Compression

$$Lf_4(Lf, E, k_{\max}, k_{\min}) := \begin{array}{l} \text{Losses} \leftarrow ((Lf)^T \cdot E \\ Lf_{\text{av}} \leftarrow \frac{\text{Losses}}{\text{Sum}(E)} \\ Lf_{\text{max}} \leftarrow k_{\max} \cdot Lf_{\text{av}} \\ Lf_{\text{min}} \leftarrow k_{\min} \cdot Lf_{\text{av}} \\ \text{if} \leftarrow \begin{array}{l} j \leftarrow -1 \\ \text{for } i \in 0..(\text{rows}(Lf) - 1) \\ \quad \begin{array}{l} Lf_1 \leftarrow Lf_{\text{max}} \text{ if } Lf_i > Lf_{\text{max}} \\ Lf_1 \leftarrow Lf_{\text{min}} \text{ if } Lf_i < Lf_{\text{min}} \\ \text{if } (Lf_i \geq Lf_{\text{min}}) \wedge (Lf_i \leq Lf_{\text{max}}) \\ \quad \begin{array}{l} Lf_1 \leftarrow Lf_i \\ j \leftarrow j + 1 \\ \text{iref}_j \leftarrow i \\ \text{lftemp}_j \leftarrow Lf_1 \\ \text{etemp}_j \leftarrow E_i \end{array} \end{array} \\ \text{if} \\ \text{sf} \leftarrow \frac{\text{Losses} - Lf_1^T \cdot E}{\text{Sum}(\text{Etemp})} \text{ if } j > 0 \\ \text{lftemp} \leftarrow \text{lftemp} + \text{sf} \\ \text{lftemp2} \leftarrow Lf_1(\text{lftemp}, \text{Etemp}, k_{\max}, k_{\min}) \\ \text{for } k \in 0..j \quad \text{if } j \geq 0 \\ \quad Lf_{(\text{iref}_k)} \leftarrow \text{lftemp2}_k \\ \text{if} \end{array} \end{array}$$

$Lf$  is a vector of uncompressed but normalized loss factors.  
 $E$  is a corresponding vector of generator energy volumes.  
 $k_{\max}$  is a scalar that when multiplied by the average loss factor defines the maximum permitted loss factor  
 $k_{\min}$  is a scalar that when multiplied by the average loss factor defines the minimum permitted loss factor  
 $Lf_1$  is the linear compression algorithm

## Linear Compression Plus Shift Factor

$$Lf_1(Lf, E, k_{max}, k_{min}) := \left\{ \begin{array}{l} \text{Losses} \leftarrow Lf^T \cdot E \\ Lf_{av} \leftarrow \frac{\text{Losses}}{\text{Sum}(E)} \\ Lf_{max} \leftarrow k_{max} \cdot Lf_{av} \\ Lf_{min} \leftarrow k_{min} \cdot Lf_{av} \\ K_s \leftarrow \max \left( \min \left( \frac{Lf_{max} - Lf_{av}}{\max(Lf) - Lf_{av}}, \frac{Lf_{min} - Lf_{av}}{\min(Lf) - Lf_{av}}, 1 \right), 0 \right) \\ \text{for } i \in 0.. \text{rows}(Lf) - 1 \\ Lf_{1_i} \leftarrow Lf_{av} + (Lf_i - Lf_{av}) \cdot K_s \\ Lf_1 \end{array} \right.$$

Lf is a vector of uncompressed but normalized loss factors.  
 E is a corresponding vector of generator energy volumes.  
 $k_{max}$  is a scalar that when multiplied by the average loss factor defines the maximum permitted loss factor  
 $k_{min}$  is a scalar that when multiplied by the average loss factor defines the minimum permitted loss factor

### 3. Loss Factor Procedures

#### 3.1 Development of Base Cases

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A single suite of up-to-date base cases for calculating the annual **loss factors** will apply from January through December. The base cases comprising **load** profiles using the **ISO load forecast** shall include:

- High, medium, and low load cases for the three month period December, January, and February (winter season),
- High, medium, and low load cases for March, April, and May (spring Season),
- High, medium, and low load cases for June, July, and August (summer season), and
- High, medium, and low load cases for September, October, and November (fall season).

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**Background:** In order to meet AESO's requirement for 12 base cases to arrive at the 2006 **loss factors**, the duration curve (Load Duration or Generation Supply) are needed to be divided into three representative segments. These three segments are – High, Medium, and Low.

The AESO's proposal for obtaining the intermediate values for load duration is as follows:

Figure 1 shows the graphic representation used in determination of the three segments. Hours are plotted in the x-axis while MWs are plotted in the y-axis from maximum to minimum. The duration curve is named  $F_c$ . Three straight lines form the three segments and these three straight lines are a linear representation of the curve.

The first and last data of  $F_c$  is known and they are  $H_1$  and  $H_4$  for Hours and  $M_1$  and  $M_4$  for MWs.

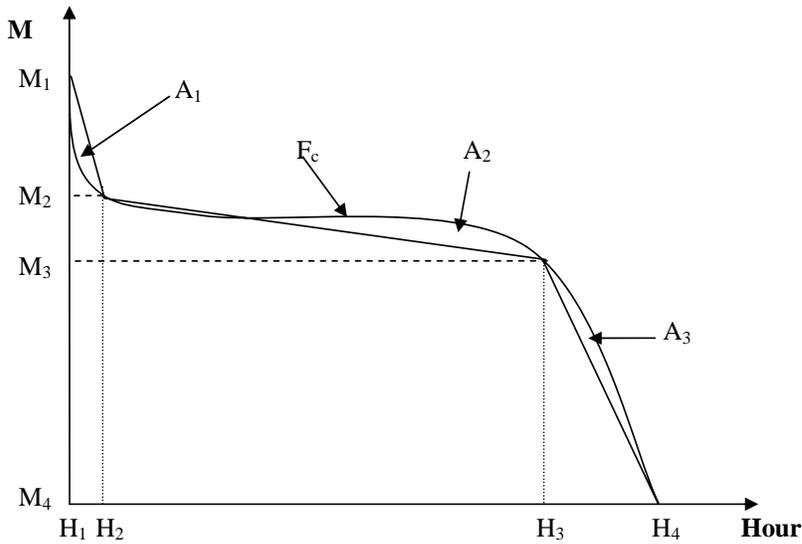


Figure 1: Graphical representation of duration curve and intermediate values.

The task is to find the intermediate hours,  $H_2$  and  $H_3$  and MWs,  $M_2$  and  $M_3$ . The procedural steps of the proposal are given below.

1. For each of the segment obtain the area under the straight line and duration curve  $F_c$ .
2. Find the difference between these two areas ( $A_x$ ).
3. Find all three  $A_x$ s and add their squares ( $A_1^2 + A_2^2 + A_3^2$ ).
4. Find  $H_2$  and  $H_3$  so that the sum of the squares of  $A_x$ s becomes minimum ,i.e.

Minimize ( $A_1^2 + A_2^2 + A_3^2$ ).

5. Duration of each segment will represent the weight for that segment and the average MW value for the segment will be the average MW value of the segment.
6. For High season the duration will be  $(H_2 - H_1)$  and the MW will be

$$M_H = \frac{\sum_{i=1}^2 MW_i}{H_2 - H_1}$$

Similarly the duration for Medium season will be  $(H_3 - H_2)$  and the MW will be

$$M_M = \frac{\sum_{i=2}^3 MW_i}{H_3 - H_2}$$

Similarly the duration for Low season will be  $(H_4 - H_3)$  and the MW will be

$$M_L = \frac{\sum_{i=3}^4 MW_i}{H_4 - H_3}$$

The twelve load flow base cases for the forth coming year will include:

- All facilities that are commissioned as of December 1 of the current year and that have no **Board** approved plan for decommissioning prior to October 15 of the second year out.
- All facilities selected by the ISO to be included in all base cases for a season, must have a planned in-service date for the facility on or before the midpoint of the season. Otherwise the facilities will be included in the following season.
- All customer initiated projects (including **load**, generation and associated transmission facilities) that have a approved Interconnection Proposal to be included in all base cases for a season, provided that the planned in-service-date for the facility is on or before the midpoint of the season. Otherwise they will be included in the following season.
- All ISO initiated projects for which the **Board** has approved the “Need” to be included in all base cases for a season, provided that the planned in-service date for the facility is on or before the mid-point of the season. Otherwise they will be included in the following season.
- The three base cases for each season will have identical physical topology and show all projects whose in-service-date falls before the midpoint of the season.

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Status of facilities (in-service or out-of-service) to be adjusted as follows:

- Normally in-service status shown on the operating single line diagram.
- Seasonally switched device status will show their normally in-service status, and be adjusted by ISO who will adjust status only as explicitly specified from the TFO.

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The **load** flows will use 1520 (WECC equivalent bus) as the swing bus. The **ISO load forecast** to be used will be the latest approved forecast created during the current year by the ISO. The same forecast will be used to provide a set of forecast **loss factors** for the fifth year subsequent to the year referenced in the foregoing.

The twelve load flow base cases for the fifth year subsequent to the year referenced in the foregoing will include:

- All facilities that are commissioned as of December 1 of the current year and that have no **Board** approved plan for decommissioning prior to October 15, of the fifth year out.
- All facilities selected by the ISO to be included in all base cases for a season, must have a planned in-service date for the facility on or before the midpoint of the season. Otherwise the facilities will be included in the following season.
- All customer initiated projects (including **load**, generation and associated transmission facilities) that have a Customer Commitment Agreement (CCA) to be included in all base cases for a season, provided that the planned in-service-date for the facility is on or before the midpoint of the season. Otherwise they will be included in the following season.
- All ISO initiated projects for which the **Board** has approved the “Need” to be included in all base cases for a season, provided that the planned in-service date for the facility is on or before the mid-point of the season. Otherwise they will be included in the following season.
- Planning **generating units** as required for the base cases and forecasted **GSO** for the fifth year.
- The three base cases for each season will have identical physical topology and show all projects whose in-service-date falls before the midpoint of the season.

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Status of facilities (in-service or out-of-service) to be adjusted as follows:

- Normally in-service status shown on the operating single line diagram.
- Seasonally switched device status will show their normally in-service status, and be adjusted by ISO who will adjust status only as explicitly specified from the TFO.

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The load flows will use 1520 (WECC equivalent bus) as the swing bus. The **ISO load forecast** to be used will be the latest approved forecast created during the current year by the ISO.

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### 3.2 Development of Generic Stacking Order

A **generic stacking order** will be developed each year by the ISO. The **GSO** shall be based on at least the following considerations:

- GSO constructed according to historical point of supply (POS) metering records.
- Determination of the four **load** points (H1, H2, H3, and H4) for the **generating unit** duration curves are selected by using the corresponding hour from the **load** duration curve for each of the seasons. For example, if H1 on the **load** duration curve for the summer season occurs at hour 1623, then H1 for each generating unit will be selected as hour 1623. The **generating unit's** other three points on the generation duration curve (H2, H3, and H4) will be selected in the same manner.
- The MWs under the duration curve for points H1 to H2, H2 to H3, and H3 to H4 will determined by the following formulas:

$$M_H = \frac{\sum_{i=1}^2 MW_i}{H_2 - H_1} ; M_M = \frac{\sum_{i=2}^3 MW_i}{H_3 - H_2} ; M_L = \frac{\sum_{i=3}^4 MW_i}{H_4 - H_3}$$

- The average value of the total MWs under each section of the curve will be used as the **generating unit's** output value for the associated season.
- The ranking order for **generating units** will be the observed (historical) generator response ([details in the annual GSO document](#)).
- For price takers, the **loss factor** will be used to rank **generating units** within a subgroup. The ISO will use two blocks of energy.
- Any new **generating units** for which a historical record is not available will be dispatched according to the ISO's analysis of the **generating unit's** technology. Its power output would be based on its **Incapability Factor**. **Industrial system** generation and hydro generation to be re-dispatched accordingly.

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### 3.3 Calculation of Loss Factors

The ISO will calculate the **loss factors** for each year using the base cases developed for Firm Service and the additional base cases developed by the ISO for Opportunity Services. For calculation of **loss factors** for firm service, the ISO will adjust the resulting generation dispatch according to the **GSO** to achieve a zero MW exchange at all interties.

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After December 31, 2008 the following conditions will apply:

The ISO will calculate the **loss factors** for each year using the base cases developed for Firm Service and the additional base cases developed by the ISO for Opportunity Services. For calculation of **loss factors** for firm service, the ISO will adjust the resulting generation dispatch according to the **GSO** to achieve the historical (previous year's) MW exchange at all interties.

### 3.3.1 Loss Factors for Firm Service

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In the proposed process in developing the twelve base cases for **loss factors**:

- the ISO would use historical production data to determine the power level to be used for existing **generating units**;
- STS contract levels for new **generating units**;
- each base case contains its own dispatch order based on a common annual **generic stacking order**; and
- the **generic stacking order** stays the same in each base case with respect to the order of dispatch, but the amount of power dispatched by each **generating unit** varies because of seasonal considerations.

The ISO, through discussions with owners of new generating units:

- would add the new **generating unit** to the existing **generic stacking order**;
- base its power output on its **Incapability Factor** where the **Incapability Factor** (ICBF) = 1 – **Available Capacity Factor**;
- would establish the same **loss factor** as existing **generating units** if the new **generating unit** is an addition to an existing plant using the same connection configuration;

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Prior to January 1, 2009, the base cases used to calculate the **loss factors** for the **generating units** would all contain a zero **flow** for the exchange across the **interties**. **Loss Factors** calculated with **interties** set to zero power flows reflect the **losses** associated with the supply of energy for domestic load.

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After December 31, 2008 the base cases used to calculate the **loss factors** for the **generating units** would all contain a **historical flow** for the exchange across the **interties**. **Transmission line losses across the import and export paths will be set to zero for the purpose of calculating **loss factors** for **generating units****. The ISO will review the base cases with owners of **generating units** to ensure that the data used is accurate.

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### 3.3.2 Loss Factors for Firm Import Service (not currently available)

Prior to January 1, 2009, determination of a **loss factor** for firm import service will be calculated with the contracted value of the transaction (in MWs) represented as a **generating unit** located at the appropriate **intertie** border. The base cases used for the determination of STS **loss factors** will be modified to include the firm import transaction. This contract **loss factor** will apply to all transactions not exceeding the contract limits for the party requesting firm import service.

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### 3.3.3 Loss Factors for Opportunity Import/Export Service (Prior to January 1, 2009)

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The following conditions for opportunity imports and exports will apply:

- export transactions will be represented as a negative **generating unit** on the appropriate intertie at the Alberta border;
- import transactions will be represented as **generating units** on the appropriate intertie at the Alberta border;
- the base cases used to determine the system **loss factors** would be adjusted to include the proposed transaction(s) and the **loss factors** for the export or import will be calculated;
- the import and export levels for loss calculations will be calculated as annual numbers and based on a weighted average of the forecast transactions for the year; and
- **loss factors** for opportunity import and export transactions are subject to compression.

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### 3.3.4 Loss Factors for Import (After December 31, 2008.)

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The following conditions for imports will apply:

- the import **loss factors** will be calculated in the same manner as for generating units.
- for the Alberta - B.C. intertie, the **Loss Factor** will be calculated at the 500 kV bus #158 in the Langdon Substation; the 138 kV bus #329 at the Pocatera substation; and the 138 kV bus #232 at the Coleman substation using historical import data and representing the import as a **generating unit**. After calculating the **Loss Factors** for each substation the ISO will use the weighted average of the 3 Loss Factors to determine the **Import loss factor** the the Alberta – BC intertie.
- for the Alberta –Saskatchewan intertie, the **Loss Factor** will be calculated at the 138 kV bus #1473 in the McNeill Converter Station

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### 3.3.5 Import/Export Transmission Losses (After December 31, 2008.)

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Importers and exporters of electric energy must pay transmission line loss charges representing the average level of losses incurred in transporting electric energy on an import path or export path. The ISO defines the paths as follows:

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(i) Alberta – BC Intertie:

Tie	From Bus	To Bus
BCH	158 (LANGDON2)	90000 (1201L)
	329 (POCATER7)	819 (BRITT TP)
	232 (COLEMAN7)	1501 (NATAL 7)

(ii) Alberta - Saskatchewan Intertie

Tie From Bus \_\_\_\_\_ To Bus

SPC McNEILL Convertor Station

(iii) Alberta – MATL Intertie

Tie From Bus \_\_\_\_\_ To Bus

MATL 167 (N LETHB4) – This is the interface bus to MATL system

Average losses for import and export transactions will be calculated as follows:

(i) Alberta – BC Intertie

- For the 138 kV circuits average losses will be determined by comparing the revenue metering data at the each terminus of the flow path, the difference being transmission line losses.
- For the 500 kV flow path average losses will be determined by comparing the revenue metering data at the each terminus of the flow path, the difference being transmission line losses

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(ii) Alberta – Saskatchewan Intertie

- Revenue class meters will be added to both the Alberta and Saskatchewan terminuses of the McNeill converter. A comparison of the time stamped metering data will be used to determine the average transmission losses.

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(iii) Alberta – MATL Intertie

- Revenue class meters will be added to bus #167 in the North Lethbridge Substation and to the terminus of the MATL tieline. A comparison of the time stamped metering data will be used to determine the average transmission losses.

3.3.6 Loss Factors for Demand Opportunity Service (DOS)

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Prior to January 1, 2009 **Loss Factors** for DOS are location based and are calculated:

- on an annual basis;
- based on the three load cases for each of the four seasons;
- with the interties set to zero exchange; and
- as a negative **generating unit**.

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DOS **loss factors** are subject to compression, i.e. DOS **loss factors** can not exceed the **loss factor** envelope of three times system average losses.

After December 31, 2008 **Loss Factors** for DOS will be calculated on the same basis as **generating units**.

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### 3.3.7 Loss Factors for Merchant Transmission Lines

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The **loss factors** for merchant lines connected to the Alberta grid will be calculated using the same base cases as the calculation of **loss factors** for **generating units**. Opportunity exports would be modeled as a negative **generating unit** and opportunity imports would be modeled as a **generating unit**. The **loss factors** would be location based. If the merchant line has a mid-terminus within Alberta, it would be treated the same as the end of the line (terminus), i.e. imports as **generating units** and exports as negative **generating units**. A merchant line will be treated the same as existing interties.

**Deleted:** The twelve base cases used would contain zero exchange across each inter-tie.

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