Topics

• Introductions and agenda (slides 1-2)

• Summary of loss factors and related information posted on AESO website (slides 3-16)

• Overview of loss factor calculations (slides 17-21)

• Loss factor results, including exclusion rates and causes (slides 22-27)

• Examples of outlier loss factors (slides 28-33)

• Shift factor results (slide 34)

• Comparisons of new and prior loss factors (slides 35-37)

• Future loss factor work, including development of 2018 loss factors (slides 38-39)

Please ask questions during presentation
AESO posted 2017 loss factors on its website on May 11, 2017

• Loss factors were posted in accordance with section 501.10 of ISO rules, *Transmission Loss Factors* ("Loss Factor Rule")
  – Rule was confirmed by Commission in Decision 790-D05-2016 issued on November 30, 2016 regarding AESO’s Phase 2 Module B compliance filing in Proceeding 790
  – Subsection 3(1.1) of Loss Factor Rule requires AESO to publish final loss factors for 2017 as soon as practicable in 2017
  – Loss factors determined under Loss Factor Rule will be effective from January 1, 2017 to December 31, 2017
• Rule requires AESO to publish additional information at same time as loss factors
AESO also posted additional information used to establish 2017 loss factors

- Information posted in accordance with subsection 3(2) of the Loss Factor Rule
  - Hourly merit order data for 2017 loss factors
  - Sample of 144 hours of load data for 2017 loss factors
  - Process for requesting access to system topologies
  - Procedure to determine transmission system losses for loss factor calculations
  - Software and scripts used to calculate hourly raw loss factors
  - Workbook showing calculations for 2017 loss factors

- Transmission system losses
  - Anticipated losses of 2,230 GWh for 2017
  - Average loss factor of 3.80% for 2017
Final loss factors show greater dispersion for smaller average net-to-grid volumes.

Average loss factor for transmission system: 3.80%
Coal generating facilities show generally less dispersion in loss factors.

Average loss factor for transmission system: 3.80%

H. R. Milner
Simple cycle gas generating facilities show more dispersion in loss factors.

Average loss factor for transmission system: 3.80%
Cogeneration gas generating facilities show more dispersion in loss factors

Average loss factor for transmission system: 3.80%
Combined cycle gas generating facilities show less dispersion in loss factors

Average loss factor for transmission system: 3.80%
Hydro generating facilities show moderate dispersion in loss factors

Average loss factor for transmission system: 3.80%
Wind generating facilities show moderate dispersion in loss factors.

Average loss factor for transmission system: 3.80%
Biomass and other generating facilities show more dispersion in loss factors.

Average loss factor for transmission system: 3.80%
Reversing distribution points of delivery show more dispersion in loss factors.

Average loss factor for transmission system: 3.80%
Interties show less dispersion in loss factors

Average loss factor for transmission system: 3.80%
Annual loss factors tend to be positive (charges) in southern Alberta

2017 annual loss factors: average by AESO planning area (southern Alberta)

Note: Some areas include only one or two locations; other areas exhibit wide dispersion
Annual loss factors tend to be negative (credits) in northwest Alberta

2017 annual loss factors: average by AESO planning area (northern Alberta)

Note: Some areas include only one or two locations; other areas exhibit wide dispersion
2017 loss factors are calculated using an incremental loss factor methodology

- Incremental methodology calculates hourly raw loss factors with merit order redispatch
  - First, transmission system losses are calculated using the historical volume for a pool asset in an hour
  - Second, transmission system losses are calculated after removing the pool asset’s volume and replacing it by redispatching other assets (regardless of location) up the historical merit order for the hour
  - Third, the hourly raw loss factor is calculated as the difference between system losses calculated in the initial and redispatched states, divided by the pool asset’s volume in the hour

- Hourly shift factors are used to ensure loss factors recover transmission system losses in each hour

- Legislation requires loss factor compression to within ±12%
“Procedure” document describes automated process used to calculate losses

- System topologies are first adjusted
  - To accommodate specific locations identified in Loss Factor Rule
    - Industrial systems, distribution-connected generation, Medicine Hat, power purchase arrangements, and Bow River hydro plants
  - To exclude facilities owned and operated by market participants
- Generation and load data are added to the system topology
  - If data is missing, hour is excluded for all locations
- Solution parameters are initialized in PSS/E power system simulation software
“Procedure” document describes automated process used to calculate losses (cont’d)

- System is solved for initial state
  - Flows on WATL and EATL HVDC lines are adjusted to minimize losses
  - Incremental changes to PSS/E settings are implemented to reach common final solution state
    - Full Newton-Raphson method, shunt adjustments enabled
  - Marginal source asset is dispatched up or down merit order to balance load plus system losses
  - System losses are recorded and solution is saved
    - If system cannot solve, hour is excluded for all locations
    - Failure to solve usually occurs if solution does not converge (sometimes during HVDC optimization) and occasionally if solution converges but does not reach flow tolerance
System is solved for re-dispatched state for each location

- If no dispatch or dispatch is less than 1.00 MW at location, hour is excluded for location
  - Net-to-grid dispatch of generating facility is reduced to 0 MW
  - Marginal source asset is dispatched up or down merit order to balance load plus system losses
  - Flows on WATL and EATL HVDC lines are reset to original values then adjusted to minimize losses
  - Incremental changes to PSS/E settings are implemented to reach common final solution state
  - System losses are recorded and solution is saved
    - If system cannot solve, hour is excluded for location
Loss factor determination attempts up to over 1.1 million PSS/E solutions

• Automated process attempts to create 8,760 solved cases for initial state

• Automated process attempts to create up to 1,165,080 solved cases for redispatched state

• Solution calculations take about two days running concurrently on five computers (with multiple instances of PSS/E on each computer)
Hourly raw loss factors show greater dispersion for smaller net-to-grid volumes.
Hourly raw loss factors are dispersed over all total load levels.
About 55% of all hours and locations had dispatch and data for loss factor calculations.

<table>
<thead>
<tr>
<th>Hours (×133)</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total hours</td>
<td>98,952</td>
<td>89,376</td>
<td>98,819</td>
<td>95,760</td>
<td>98,952</td>
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<td>95,893</td>
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<td>1,165,080</td>
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<tr>
<td>Missing data</td>
<td>(7,634)</td>
<td>(6,919)</td>
<td>(6,350)</td>
<td>(5,168)</td>
<td>(5,632)</td>
<td>(5,112)</td>
<td>(3,300)</td>
<td>(2,960)</td>
<td>(1,420)</td>
<td>(1,452)</td>
<td>(707)</td>
<td>0</td>
<td>(46,654)</td>
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<tr>
<td>Potential hours</td>
<td>55,163</td>
<td>48,610</td>
<td>53,820</td>
<td>52,106</td>
<td>55,175</td>
<td>58,610</td>
<td>61,031</td>
<td>55,055</td>
<td>46,473</td>
<td>46,701</td>
<td>51,464</td>
<td>55,675</td>
<td>639,883</td>
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</table>

<table>
<thead>
<tr>
<th>Percentages</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
<tr>
<td>Total hours</td>
<td>100%</td>
<td>100%</td>
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<td>(38%)</td>
<td>(39%)</td>
<td>(40%)</td>
<td>(39%)</td>
<td>(33%)</td>
<td>(35%)</td>
<td>(41%)</td>
<td>(50%)</td>
<td>(51%)</td>
<td>(46%)</td>
<td>(44%)</td>
<td>(41%)</td>
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<tr>
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<td>(8%)</td>
<td>(6%)</td>
<td>(5%)</td>
<td>(6%)</td>
<td>(5%)</td>
<td>(3%)</td>
<td>(3%)</td>
<td>(1%)</td>
<td>(1%)</td>
<td>(1%)</td>
<td>0%</td>
<td>(4%)</td>
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<tr>
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<td>56%</td>
<td>54%</td>
<td>54%</td>
<td>54%</td>
<td>56%</td>
<td>61%</td>
<td>62%</td>
<td>56%</td>
<td>49%</td>
<td>47%</td>
<td>54%</td>
<td>56%</td>
<td>55%</td>
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</table>
About 90% of all potential hours and locations successfully solved

<table>
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<th>Hours (×133)</th>
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<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
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<th>Jul</th>
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<td>55,055</td>
<td>46,473</td>
<td>46,701</td>
<td>51,464</td>
<td>55,675</td>
<td>639,883</td>
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<tr>
<td>Unsolved initial</td>
<td>(6,650)</td>
<td>(5,719)</td>
<td>(5,054)</td>
<td>(9,842)</td>
<td>(5,320)</td>
<td>(10,773)</td>
<td>(11,172)</td>
<td>(532)</td>
<td>(1,330)</td>
<td>(2,394)</td>
<td>(1,862)</td>
<td>(1,330)</td>
<td>(61,978)</td>
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<tr>
<td>Unsolved redispached</td>
<td>(50)</td>
<td>(251)</td>
<td>(174)</td>
<td>(115)</td>
<td>(495)</td>
<td>(26)</td>
<td>(151)</td>
<td>(29)</td>
<td>(36)</td>
<td>(30)</td>
<td>(37)</td>
<td>(68)</td>
<td>(1,462)</td>
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<tr>
<td>Solved hours</td>
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<td>42,640</td>
<td>48,592</td>
<td>42,149</td>
<td>49,360</td>
<td>47,811</td>
<td>49,708</td>
<td>54,494</td>
<td>45,107</td>
<td>44,277</td>
<td>49,565</td>
<td>54,277</td>
<td>576,443</td>
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<table>
<thead>
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<th>Percentages</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
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<th>Jun</th>
<th>Jul</th>
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<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential hours</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
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<td>100%</td>
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<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Unsolved initial</td>
<td>(12%)</td>
<td>(12%)</td>
<td>(9%)</td>
<td>(19%)</td>
<td>(10%)</td>
<td>(18%)</td>
<td>(18%)</td>
<td>(1%)</td>
<td>(3%)</td>
<td>(5%)</td>
<td>(4%)</td>
<td>(2%)</td>
<td>(10%)</td>
</tr>
<tr>
<td>Unsolved redispached</td>
<td>(0%)</td>
<td>(1%)</td>
<td>(0%)</td>
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<td>(1%)</td>
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<td>(0%)</td>
<td>(0%)</td>
<td>(0%)</td>
<td>(0%)</td>
</tr>
<tr>
<td>Solved hours</td>
<td>88%</td>
<td>88%</td>
<td>90%</td>
<td>81%</td>
<td>89%</td>
<td>82%</td>
<td>81%</td>
<td>99%</td>
<td>97%</td>
<td>95%</td>
<td>96%</td>
<td>97%</td>
<td>90%</td>
</tr>
</tbody>
</table>
Reasons for exclusion of hours are indicated by codes in workbook

• Hours excluded from calculations for all locations
  – Missing or unavailable historic data (XA-MISSIN): 0 hours
  – Insufficient source assets to balance system in initial state (XA-INSUF1): 0 hours
  – Insufficient source assets to balance system in redispatched state (XA-ISUF2): 0 hours

• Hours excluded from calculations for single locations
  – No dispatch or volume <1.00 MW (XS-NODISP): 478,543 hours
  – Missing or unavailable data (XS-MISSIN): 46,654 hours
    • Due to asset not yet in service during year
  – Cannot solve losses in initial state (XS-UNSOL1): 61,978 hours
  – Cannot solve losses in redispatched state (XS-UNSOL2): 1,462 hours
Very few hours were excluded for redispatched state at most locations

- Some locations had very few hours with dispatch greater than 1.00 MW
  - Including some distribution points of delivery with distribution-connected generation
  - Six locations had fewer than 100 hours with dispatch greater than 1.00 MW
- Losses solved in redispatched state for more than 99.5% of hours at 123 out of 133 locations (92% of all locations)
Dispersion of raw loss factors appears to be affected by several factors

- Location of generating facility on transmission system
  - Strong or weak transmission system in area
  - Whether area is net load (importing) or net generation (exporting)
- Location of next-in-merit generating facility or facilities in specific hours of dispatch (used as swing bus)
- Size of volume increase of generating facility
- Dispatch level of WATL and EATL HVDC lines in initial and redispatched states
- Magnitude of differences from original topology case
  - Can result in voltage variations
- Resolution limits of PSS/E simulation and numerical solution (usually for small dispatch volumes)
Calculation of loss for four specific cases illustrate steps of procedure

Average loss factor for transmission system: 3.80%
Hourly raw loss factor: $1.0 \, \text{MW} \div 1.0 \, \text{MW} = 101.72\%$

- Redispatched state reflects decrease in supply in Seebe and increase in supply in Lake Wabamun
  
  - Approaching resolution limits of simulation
SCR4 Wintering Hills (Sheerness)
9 Jan 2017 09:00: loss factor 28.54%

- Hourly raw loss factor: $22.2 \text{ MW} \div 78.0 \text{ MW} = 28.54\%$
- Redispatched state reflects decrease in supply in Sheerness and increase in supply in Rainbow Lake
  - Losses decrease in central east due to removal of supply
  - Losses also decrease in northwest due to decreased flow from other regions

<table>
<thead>
<tr>
<th>Procedure Step</th>
<th>Net-to-Grid Supply (MW)</th>
<th>System Losses (MW)</th>
<th>Marginal Location (MPID)</th>
<th>Marginal Supply (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original topology</td>
<td>78.0</td>
<td>394.8</td>
<td>RB5 – 1</td>
<td>39.6</td>
</tr>
<tr>
<td>Initial state</td>
<td>78.0</td>
<td>381.5</td>
<td>SD1 – 3</td>
<td>268.2</td>
</tr>
<tr>
<td>Redispatched state</td>
<td>0.0</td>
<td>359.2</td>
<td>RB5 – 1</td>
<td>81.9</td>
</tr>
<tr>
<td>Decrease (increase)</td>
<td>78.0</td>
<td>22.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IOR1 IOR Cold Lake (Cold Lake)  
31 May 2017 13:00: loss factor (55.24%)  

<table>
<thead>
<tr>
<th>Procedure Step</th>
<th>Net-to-Grid Supply (MW)</th>
<th>System Losses (MW)</th>
<th>Marginal Location (MPID)</th>
<th>Marginal Supply (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original topology</td>
<td>131.3</td>
<td>225.1</td>
<td>SD3 – 3</td>
<td>310.0</td>
</tr>
<tr>
<td>Initial state</td>
<td>131.3</td>
<td>211.9</td>
<td>SD3 – 2</td>
<td>296.9</td>
</tr>
<tr>
<td>Redispatched state</td>
<td>0.0</td>
<td>284.5</td>
<td>SH2 – 1</td>
<td>173.0</td>
</tr>
<tr>
<td>Decrease (increase)</td>
<td>131.3</td>
<td>(72.5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Hourly raw loss factor: (72.5 MW) ÷ 131.3 MW = (55.24%)  
• Redispatched state reflects decrease in supply in Cold Lake and increase in supply in Lake Wabamun and Sheerness  
  – Losses expected to increase due to removal of supply in Cold Lake  
  – However, large increase may result from an unstable PSS/E solution
**BCR2 Bear Creek (Grande Prairie)**

2 Mar 2017 19:00: loss factor (108.67%)

<table>
<thead>
<tr>
<th>Procedure Step</th>
<th>Net-to-Grid Supply (MW)</th>
<th>System Losses (MW)</th>
<th>Marginal Location (MPID)</th>
<th>Marginal Supply (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original topology</td>
<td>15.9</td>
<td>405.0</td>
<td>CRS1 – 1</td>
<td>42.5</td>
</tr>
<tr>
<td>Initial state</td>
<td>15.9</td>
<td>391.3</td>
<td>CRS1 – 1</td>
<td>28.8</td>
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<tr>
<td>Redispatched state</td>
<td>0.0</td>
<td>408.6</td>
<td>SD5 – 5</td>
<td>371.5</td>
</tr>
<tr>
<td>Decrease (increase)</td>
<td>15.9</td>
<td>(17.3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Hourly raw loss factor: \((17.3 \text{ MW}) \div 15.9 \text{ MW} = (108.67\%)\)
- Redispatched state reflects decrease in supply in Grande Prairie and increase in supply in Airdrie and Lake Wabamun
  - Losses increase in northwest due to removal of supply
  - Losses also increase in northeast due to increased flow from Fort McMurray to northwest
Almost all hourly shift factors were in range of (5%) to 10%

<table>
<thead>
<tr>
<th>Range of Hourly Shift Factors, %</th>
<th>Count of Hourly Shift Factor Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;15%</td>
<td>2</td>
</tr>
<tr>
<td>&gt;10% to ≤15%</td>
<td>6</td>
</tr>
<tr>
<td>&gt;5% to ≤10%</td>
<td>2,143</td>
</tr>
<tr>
<td>&gt;0% to ≤5%</td>
<td>5,764</td>
</tr>
<tr>
<td>&gt;(5%) to ≤0%</td>
<td>361</td>
</tr>
<tr>
<td>&gt;(10%) to ≤(5%)</td>
<td>18</td>
</tr>
<tr>
<td>≤(10%)</td>
<td>0</td>
</tr>
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</table>
Module B loss factors have greater dispersion than previous loss factors.
Module B results differ from “Old AESO” (incremental with load scaling) loss factors

<table>
<thead>
<tr>
<th>“Old AESO” Loss Factors (2015), %</th>
<th>New (Module B) Incremental Loss Factors (2017), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>(12%)</td>
<td>(12%)</td>
</tr>
<tr>
<td>(8%)</td>
<td>(8%)</td>
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<tr>
<td>(4%)</td>
<td>(4%)</td>
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<tr>
<td>0%</td>
<td>0%</td>
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<tr>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>8%</td>
<td>8%</td>
</tr>
<tr>
<td>12%</td>
<td>12%</td>
</tr>
</tbody>
</table>

Public
Module B results also differ from Milner’s proposed “generation vector” loss factors.
AAESO will next be focusing on 2018 loss factors and Module C calculations

• Over next few months, AESO will complete Module B work for 2018
  – Jun 2017: Develop process for preliminary loss factors
  – Jul-Sep 2017: Prepare 2018 loss factors

• Following Module C methodology decision, AESO will transition to Module C work
  – Oct 2017 to 2018: Module C loss factors

• Preparation of historical merit orders for 2006-2016 has been initiated
  – Greatest probability of being needed and potentially most time-consuming to prepare
Questions and discussion

• Loss factor information is posted on AESO website at www.aeso.ca
  – Grid ► Loss factors ► 2017 loss factors
  – Grid ► Loss factors ► 2017 loss factor development

• Additional questions can be directed to

  John Martin
  Senior Tariff and Special Projects Advisor
  john.martin@aeso.ca
  403-539-2465