SEPTEMBER 30, 2020

Transmission Losses Stakeholder Engagement

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Agenda

- Context and previous engagement on transmission losses
- Nature of Ontario's transmission system
- Transmission losses cost allocation and economic evaluation
- Losses consideration in Planning, Equipment Selection and Operations
- Comparison of reports from National Grid UK and Council of European Energy Regulators (CEER) with Ontario practices
- Opportunities for improvement
- Feedback and Next steps

Context and Previous Engagement on Transmission Losses

OEB Decision and Order

- As part of settlement of the IESO's 2018 Revenue Requirement Submission, the IESO agreed with intervenors to undertake the following with respect to the issue of transmission losses:

  "engage with stakeholders regarding the IESO's transmission losses work/report including a discussion of the transmission losses processes used by National Grid UK, the recommendations of the Council of European Energy Regulators, and methodologies to assess the cost effectiveness of transmission loss reduction measures."

- The 2018 Settlement Agreement was accepted by the OEB in its EB-2018-0143 Decision and Order

Previous Engagement on Transmission Losses

- To satisfy the terms of the 2018 settlement agreement, the IESO launched a series of Public Information Sessions to engage with stakeholders on Transmission Losses in Ontario
- The first Public Information Session (September 6, 2019) discussed:
  - The purpose and objectives of the Public Information Sessions
  - Division of responsibilities in Ontario related to transmission losses
  - An educational overview of the basics of electricity transmission losses
  - The next steps for the engagement

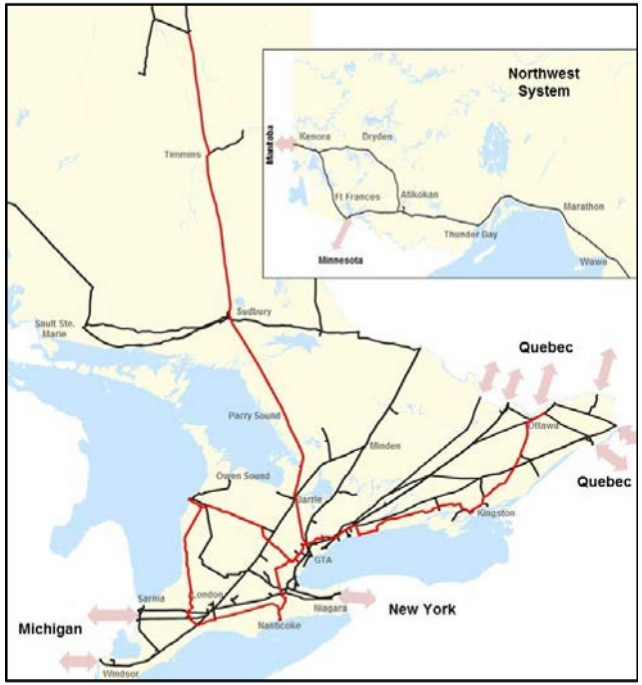
Previous Engagement on Transmission Losses (continued)

- Following this engagement session, the IESO received stakeholder feedback from Power Advisory and Environmental Defence
- The IESO has repositioned the series of public information sessions as a stakeholder engagement initiative with a dedicated engagement webpage and engagement plan to more clearly identify objectives, deliverables, and timing
- All materials, stakeholder feedback submissions and the IESO's response to feedback from the September 2019 Public Information Session can be found on the engagement webpage

Nature of Ontario's Transmission System

Nature of Ontario's Transmission System

- Compared to other jurisdictions, Ontario transmits electricity over relatively long distances; this is done via a 500 kV and 230 kV network
- Connects major generation centres to regional load centres (typically supplied at 115 kV or 230 kV)
- Power flow is mainly toward major load centres (e.g., GTA, Ottawa) but is dynamic on inter-regional ties due to the diverse nature of Ontario's resource mix



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Nature of Ontario's Transmission System (continued)

- Strong interconnections with neighbours in southern Ontario (~4000 MW with Quebec, NY and Michigan); weaker ties in the North (~300 MW with Manitoba and Minnesota)

- Planned and designed to NERC/NPCC standards

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Transmission Losses Cost Allocation and Economic Evaluation

Transmission Losses Cost Allocation and Settlement

- Losses are an inherent part of electricity transmission and distribution which are paid for in Ontario by consumers and exporters on a volumetric basis
- Transmission losses are captured in the "CT150" uplift charge, defined as the annual quantity of energy generated and imported less the annual quantity of energy consumed and exported (generation + imports - loads - exports)
- The quantities are valued at the 5-minute energy market reference price for each metering interval and settled hourly.

Transmission Losses Cost Allocation and Settlement (2)

- Additional energy must be generated to deliver the correct amount of power to the end-use consumer to compensate for transmission losses
- The cost recovery mechanism for transmission losses used in Ontario is consistent with the principle of cost causality
  - Example: If no energy is required to be delivered to a customer, there is no charge for losses to the customer as the cost of losses only materializes as a result of energy flow. If there is no energy flow on the lines, no losses occur and hence no cost for losses

Transmission Losses Cost Allocation and Settlement (3)

- The fixed capacity cost of generation facilities (i.e. Global Adjustment cost) is not included in the cost recovery for losses as the capital infrastructure is not built to meet line losses
- IESO has investigated transmission loss cost recovery in other jurisdictions and is not aware of any other jurisdiction that recovers losses in an alternative manner
  - Hydro Quebec, NYISO, and PJM appear to be consistent to Ontario
  - Jurisdictions with capacity markets do not factor losses into capacity charges

Economic Evaluations for System Planning

- Generation capacity is typically installed to meet a system and/or local capacity need and not constructed for the purpose of meeting line losses
- When local or system capacity needs are identified for the system, the economic evaluation of technically feasible alternatives is conducted based on costs and benefits

Economic Evaluations for System Planning (continued)

- This evaluation can include explicit and detailed consideration of relevant line loss costs when material or when loss reduction is an additional benefit to an investment that merits being quantified
  - See examples in next section of the presentation
- Implicit consideration of relevant line loss costs are often captured if energy production cost models are developed as part of the planning study and options evaluation

Losses Consideration in Planning, Equipment Selection and Operations

Losses Consideration Practices - Overview

Opportunities for loss mitigation exist throughout project development and implementation. The magnitude and opportunity for loss savings is inherently different in each step

	Planning	Equipment Selection	Operations
Activity	• Assess needs • Develop and assess options • Recommend option	• Select, procure and install equipment	• Operate transmission facilities • Run the electricity market (Dispatch Scheduling and Optimization)
Consideration of Losses	• Where key project and/or system features impacting losses are determined (e.g., operating voltage, solution technology, system configuration)	• Based on use of optimal equipment to minimize lifecycle costs, the evaluation of which includes losses	• System is operated to maintain reliability and dispatched to minimize system costs, which includes losses

Losses Consideration Practices - Planning

Transmission losses are one of many technical and economic considerations within the system planning process

- Develop forecasts

- Perform studies and identify needs
- Investments solely targeting losses have proven cost ineffective

- Develop options which address needs identified

- Evaluate options based on many factors including technical and economic which includes losses as part of energy production costs

- Recommend the preferred option
- Identify implementation and monitoring plan

* All planning activities are carried out jointly by the IESO, Hydro One and area LDCs as appropriate

Planning Process – Options Developed

- Engineering expertise is used to determine technically feasible and efficient options.
- Some current practices that are followed when selecting options that inherently result in lower losses are:
  - Preference for higher voltage levels and less transformational steps.
  - Shorter routing distances.
  - Parallel lines and use of existing right-of-ways.
- Inclusion of local generation options in evaluation of options.
- Inclusion of conservation and other demand side options in evaluation of options.

Planning Process – Options Evaluation

- The relative impact on losses when evaluating proposed solutions is initially assessed by applying engineering principles
  - For example, considering voltage level, routing (i.e. resistance), configuration (i.e. resistance), asset utilization (i.e. current flow)
- Typically, a detailed quantification of losses beyond this assessment is not required as savings are often not a material consideration compared to the overall project costs under evaluation

Planning Process – Options Evaluation (continued)

- A detailed loss assessment may be undertaken when:
  - Costs of transmission options are close and the characteristics of the solutions (e.g. different voltage levels, supply points) means loss savings could be significant in identifying the least cost solution
  - Loss savings may not be material to the determination of the preferred option but still offer a significant project benefit that merits being quantified (e.g. in preparation for a Leave to Construct)

Planning Process – Options Evaluation (continued)

- When both generation and transmission options are considered, the economic comparison often includes relative energy production costs, which would include the impact of losses

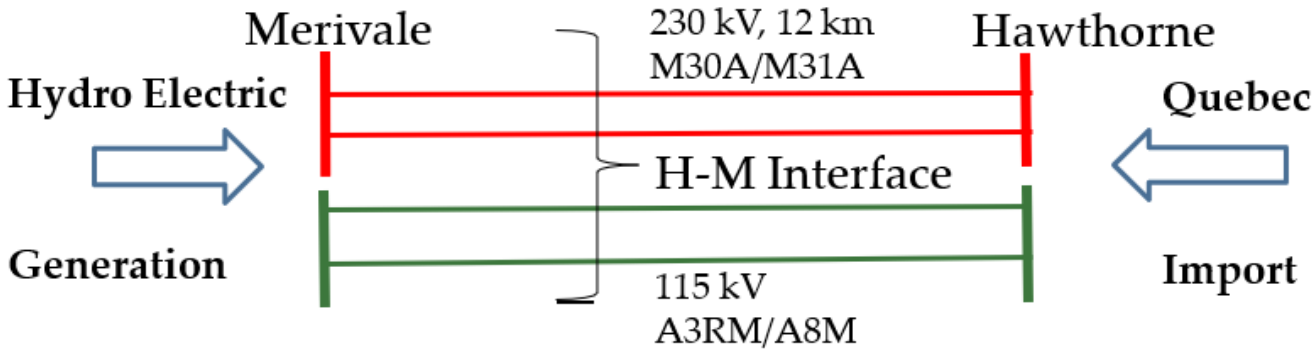
IESO Detailed Loss Assessment

- When appropriate to do so, detailed loss assessment methodologies are applied to identify energy and demand savings from transmission loss reductions
- A loss assessment involves the following steps:
  - Determining losses at different power flows to discern the relationship between power flow and losses, and creating loss simulation curves to compare options
  - Determining hourly flows over a year to compare options for realistic dispatch scenarios
  - Calculating the relative annual energy and capacity benefits/savings

IESO Detailed Loss Assessment (continued)

- Two examples of detailed loss assessments are presented next that demonstrate the potential to identify energy and demand savings in each case.
- These projects offered a high potential for loss savings (relative to the existing system) in addition to the system need(s) they are planned to address. The loss assessment was undertaken to better understand and quantify this project benefit.

IESO Detailed Loss Assessment – Example 1



The Hawthorne to Merivale 230 kV Upgrade project consists of reinforcing the existing M30A/M31A circuits between Hawthorne TS and Merivale TS in the Ottawa area

IESO Detailed Loss Assessment – Example 1 (continued)

- While the path from Hawthorne to Merivale is relatively short, it is a heavily loaded corridor. As the proposed upgrade would essentially halve the resistance of the M30A/M31A circuits it was anticipated that the loss reductions would be significant and worth quantifying as an additional benefit of the project

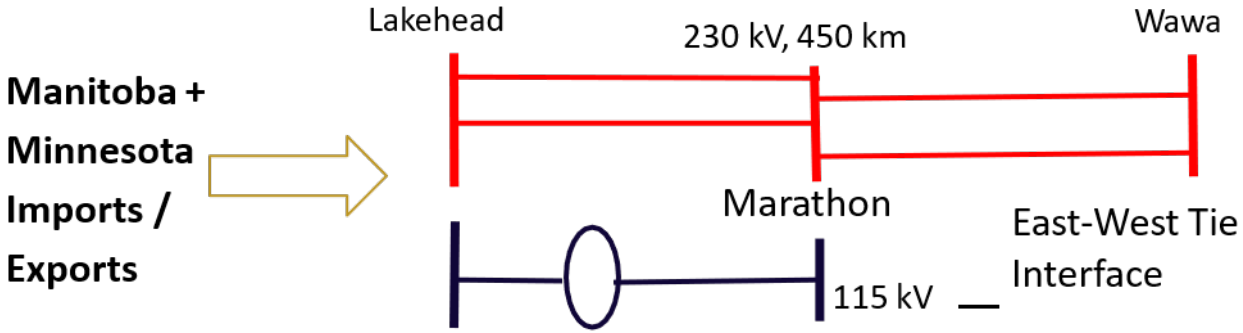
IESO Detailed Loss Assessment – Example 1 (continued)

- Power flow studies were carried out to assess the impact of losses for the "status quo" and the uprated M30A/M31A scenarios across the Hawthorne to Merivale (H-M) Interface.
- Hourly energy simulation studies were carried out for the period 2020 to 2030 taking a conservative approach, i.e., no Quebec import (which would increase loading on the interface and the associated loss savings).
- Annual reduction in energy loss and reduction in peak demand were calculated for each year between 2020 and 2030.

IESO Detailed Loss Assessment – Example 1 (continued)

- The loss reduction benefits with uprating of M30/31A are as follows:
  - **A** - 50% drop in resistance on M30/31A with a 50% reduction in losses over these circuits*
  - **B** - ≈3000 MWh annual reduction in energy on the H-M interface (average over 2020-30, 10 yrs.)
  - **C** - ≈1 MW of reduction in demand during peak hour (flow ≈1,100
  - MW) on the H-M interface

IESO Detailed Loss Assessment – Example 2



The EWT Expansion project consists of a new, double-circuit 230 kV line which parallels the existing EWT line from Lakehead TS to Wawa TS (with switching at Marathon TS).

IESO Detailed Loss Assessment – Example 2 (continued)

- The new EWT line is approximately 450 km in length. Flow levels vary considerably throughout the year as the load in the Northwest is winter peaking and the large amount of local hydro generation is often used to supply southern Ontario load in the summer months.
- As the proposed upgrade would add a parallel path (decreasing resistance and distributing flow amongst 4 circuits opposed to 2) it was anticipated that the loss reductions would be significant due to the length of the line and worth quantifying as an additional benefit of the project.

IESO Detailed Loss Assessment – Example 2 (continued)

- The following high-level steps were followed to assess and compare losses for the expanded and existing EWT:
  - Carry out loss simulations to develop loss curves (i.e. power flow versus losses) for both scenarios at the interface
  - Determine hourly flows over a year for realistic dispatch scenarios considering all constraints
  - Calculate the relative annual energy and demand benefits/savings

IESO Detailed Loss Assessment – Example 2 (continued)

- The loss reduction benefits associated with the expanded EWT (for year 2025):
  - **A** - 33% reduction in losses along the interface, from 4.5% to 3%*
  - **B** - 13.8 GWh of annual energy savings on the EWT interface
  - **C** - 1.6 MW of reduction in demand on the EWT interface during the system's winter peak hour

Questions for Stakeholders

- Are there aspects of the current approach to options development and evaluation that don't sufficiently consider transmission losses? How could these be improved?
- Other feedback on how losses are considered in the planning process?

Losses Consideration in Equipment Selection - Overview

- Material transmission losses occur in two main components: transmission lines and transformers
- Hydro One follows similar practices to National Grid and other utilities to minimize losses
- Hydro One considers losses during conductor selection and the procurement of transformers

Losses Consideration in Conductor Selection - Example

Project need:

D6V/D7V conductor between Fergus TS and Guelph North Jct at End of Life

Project requirements:

Supply foreseeable forecast load and long term load growth

Conductor Selection:

1. Determine incremental cost of selecting a larger (and lower resistance) conductor
2. Determine annual power flow
3. Calculate losses and associated cost
4. Select the preferred alternative

Losses Consideration in Conductor Selection (continued)

	Alt. 1	Alt. 2	Alt. 3	Preferrred Alternative Alt. 4
Conductor Size (kcmil)	795	997.2	1192.5	1443.7
Incremental Cost[1]	--	$203,490	$715,070	$800,000
Annual Losses (MWh)[2]	6,828	5,565	4,801	3,997
Annual Cost of Losses[3]	$163,359	$133,154	$114,873	$95,625
Incremental Losses Savings	--	$30,205	$48,487	$67,734

Losses Consideration in Conductor Selection (continued)

Alt. 4 provides the largest loss reduction while recovering the incremental expenditure in less than 12 years

Notes:

- Includes all costs associated with any structure modifications as well
- Losses based on 2018 flows
- Losses calculated based on 2018 Hourly Ontario Energy Price of $23.925/MWh

Losses Consideration in Transformer Procurement

- Transformer purchases compare the effective equipment cost
- Effective Equipment Cost = Initial Equipment Cost + Lifetime Cost of Losses
- To be competitive, manufacturers use high quality low loss silicon steel, with thinner laminations and lower core losses

Losses Consideration in Transformer Procurement (2)

- Consequently, new transformers have lower losses than older units

Size	Voltage (kV)	Average Load Flow	Existing Units Approx. Annual Losses (MWh)	New Units Approx. Annual Losses (MWh)	% Loss Reduction
50 MVA	121/28	60%	1,230	815	34%
75 MVA	245/44	60%	1,887	1,134	40%

Questions for Stakeholders

- Is any further information/clarification required on how transmission losses are accounted for in conductor or transformer selection?

IESO Losses Consideration in Real-time Operations

- The IESO's Dispatch Scheduling and Optimization (DSO) algorithm determines the least cost scenario for dispatch of resources to meet demand while respecting constraints (e.g., system limits) for the secure operation of the grid
- The DSO optimizes many inputs provided by market participants, such as bids and offers of energy and operating reserve, and those provided by the IESO such as the model of the transmission system, including transmission losses

IESO Losses Consideration in Real-time Operations (2)

- Transmission losses are accounted for in system operations through two means:

1. Including transmission system losses in power balancing and determining real-time dispatch of resources (Generation + Net Imports = Demand + System Losses)
2. Accounting for the impact of generators, loads and intertie connections on transmission losses, represented as Loss Penalty Factors (LPF)

IESO Losses Consideration in Real-time Operations (3)

- The LPF associated with each resource is the amount of additional power (MW) that needs to be generated/consumed at the resource in order to supply/consume one additional MW at the load centre.
- The IESO operates the grid at higher than nominal voltage ratings for system stability, which results in decreasing system losses

Losses Consideration Practices - Conclusions

- **Planning (IESO and Hydro One):** While planning for the system, transmission options are identified considering sensitivity to losses and then all options (transmission, generation, etc.) are compared based on many factors including technical and economic where losses are implicitly considered as part of energy production costs.
- **Equipment Selection (Hydro One):** Losses are also considered while selecting conductors for transmission lines and while procuring transformers.

Operations (IESO): The IESO's dispatch scheduling and optimization process considers losses to arrive at least cost dispatch scenarios. Furthermore, IESO operates Ontario's transmission system at higher voltages than nominal levels and this practice inherently results in reduced losses on our transmission system.

Questions for Stakeholders

- Is the materiality of losses being appropriately balanced against other system costs in the discussed processes?
- Are any clarifications required on any of the discussed processes?

Comparison of Reports from National Grid UK and CEER with Ontario Practices

Overview

- As part of the engagement, an overview of the National Grid Strategy Paper and CEER Report on Power Losses will be provided.
- Key points and recommendations of these reports are compared with the current approach to mitigating Transmission Losses in Ontario.
- In addition, Hydro One commissioned a report by the Electric Power Research Institute (EPRI) in 2018 which compares Hydro One's efforts to mitigate transmission losses to industry best practices; this report is referred to throughout this comparison of Ontario's current practices to the National Grid and CEER work.

National Grid Strategy Paper

National Grid's Strategy Paper to address Transmission Licence Special Condition 2K: Electricity Transmission Losses; Published: Nov 2013; Revised Sep 2014

National Grid Strategy Paper: Purpose and Objectives

- To present NG's strategy for considering and mitigating transmission losses, prepared in accordance with Special Condition 2K of the electricity Transmission Licence.
- To provide a review and update of the strategy to support the submission of their 2013/14 transmission losses annual report.
- It describes NG's Whole Life Value (WLV) framework and how it is used in investment decision making based on a broad range of investment criteria that include transmission losses.

National Grid Strategy Paper (continued)

Summary: Consideration of losses in NG's WLV framework is as follows:

- Options are assessed on a number of WLV themes
- One of the themes is Performance where losses are considered as a measure of efficiency

→

A detailed assessment of losses is done when:

- An initial assessment concludes whether losses could realistically impact the option decision, i.e., capital costs of options are comparable

→

- Losses are also considered through equipment specs for overhead line, cables and transformers
- Trade-offs between investments and costs of losses are noted

CEER Report on Power Issues: Purpose and Objectives

- To make an inventory of treatment of losses in Europe (definition, calculation and value of losses)
- To present the level of losses
- To highlight how smart meters and increasing DERs are likely to affect losses
- To provide findings and recommendations

CEER Report on Power Losses (continued)

SUMMARY (input from 27 countries and 21 stakeholders in the survey):

Key Areas	Summary of Responses
Definition and reporting of losses	• Losses are the difference between injected and withdrawn energy (with a few exceptions). • Losses are reported as percentage of injected energy. • For 2015: range 0.89 – 2,77 for transmission.
Regulatory treatment of losses	• Procurement of losses is the responsibility of network operators while in some countries (5), it is the responsibility of suppliers. • In almost all countries, incentives to regulate power losses apply to Distribution System Operators.
Impact of DERs on losses	DERs may decrease or increase losses depending on their proximity to load and peaking profile.
Recommendations	Six recommendations were made regarding technical transmission losses.

CEER Report Recommendations vs. Ontario Practices

No.	CEER's Technical Losses Recommendations	IESO/Hydro One Practice
1	Increase voltage levels	IESO and Hydro One follows the same practice. There are a number of projects underway where the supply voltage is being upgraded.
2	Apply less transformational steps to deliver electricity to consumers	IESO and Hydro One follow the same practice. There is only one step transformation from 230kV or 115kV transmission voltages to 27.6kV or 13.8kV for electricity delivery to customers under current standards.
3	Utilize new and improved equipment	Hydro One follows the same practice. New transformers are purchased based on lifecycle cost to minimize losses.
4	Employ distributed generation in a more efficient manner, including combining it with local storage	Distribution generation location is decided by the generator proponent, IESO operates system in as optimal a manner as possible.
5	Optimise network flows – reduce peaking	Flows depend on customer loads and available generation. IESO dispatch mechanism optimizes for least cost considering losses.
6	In general, pursue network architecture and management that promote the highest efficiency	The IESO and Hydro One follow the same practice. This work is carried out jointly between the IESO, Hydro One and LDC's as part of Regional Planning Process and by the IESO, working with Hydro One, as part of bulk planning.

Overall Comparison of Practices - Planning

Opportunity to Impact Transmission Losses	Comparison of Ontario's Current Approach to Other Jurisdictions
Transmission System Planning/Regional Planning	The EPRI, National Grid, CEER Reports identify this practice. Hydro One and the IESO work collaboratively on planning the transmission system including both the bulk transmission and regional transmission systems.
Development of Alternatives	The National Grid Report identifies this practice (called "Optioneering"). Hydro One works jointly with the IESO and LDC's during the bulk transmission and regional transmission planning process to develop alternative solutions for identified needs. Solution development considers key factors which impact line losses such as supply voltage, transmission route, local generation vs transmission.
Line Loss Assessment	The EPRI and National Grid Reports identified the practice of preparing line loss assessments. The IESO's and Hydro One's practice is similar to that of other utilities in that line losses are only considered where they could reasonably be consequential. The IESO has also quantified losses when significant loss reduction was a benefit of a recommended solution.
Raising Nominal Voltage	The National Grid, EPRI and CEER Reports identify this practice. The IESO, Hydro One and impacted LDC's evaluate opportunities to convert 115kV systems to 230kV operation for cost effectiveness and reduction of line losses when opportunities arise in the Regional Planning Process.

Overall Comparison of Practices – Planning (continued)

Opportunity to Impact Transmission Losses	Comparison of Ontario's Current Approach to Other Jurisdictions
Optimization of Voltage Profile	The EPRI identifies this practice. Ontario's transmission system is already operated at voltages that are at or near equipment limits and therefore this opportunity is limited.
Reduce Transformational Steps	The CEER Report identifies this practice. Hydro One follows the same practice. Also consideration is given to reducing the number of transformers where possible.
Network Reinforcement	The CEER report alludes to this practice. The IESO and Hydro One consider system reinforcement, or building a new line in parallel, to provide capacity or increase reliability where there is a system need; which results in reduced line losses.
Convert to DC, Bipole or Tripole or introduce HVDC Transmission	The EPRI, National Grid, CEER Reports make note of this practice. Currently there are no HVDC systems in the province. The IESO and Hydro One would consider such solutions if they were cost effective to meet the primary need of supply adequacy and reliability.

Overall Comparison of Practices – Equipment Selection

Opportunity to Impact Transmission Losses	Comparison of Ontario's Current Approach to Other Jurisdictions
Installation of Low Loss Transformers	The National grid, EPRI and CEER Reports identify this practice (for transformers). Hydro One's purchase specifications include cost of losses. Hydro One assesses the vendor transformer quotations and designs based on best overall economic benefit including losses.
Use Lower Loss Conductors	The EPRI, National Grid, and CEER Reports make note of this practice. Hydro One uses lower conductor (i.e., compact ACSR/TW conductors) to minimize losses.
Bundle Conductor Optimization	The ERPI Report identifies this practice. Hydro One currently uses bundled conductors for 500kV and some 230kV lines. For example: Merivale x Hawthorn.
Improve Corona Losses	The EPRI and CEER Reports identify this practice. Hydro One implements insular hardware systems that have been designed to eliminate corona. Conductor sizes are also selected to avoid corona.
Shieldwire Segmentation	The EPRI Report identifies this practice. Hydro One does not use shieldwire segmentation due to high tower ground potential rise.
Improve Insulation Losses	The EPRI and CEER Reports identify this practice. Hydro One considers line losses during insulation coordination design of insulator assemblies and structure configurations.

Key Takeaways

- Ontario is following current best practices for consideration of transmission losses including those identified in the National Grid, CEER and EPRI reports
- Regulation related to transmission losses differs in some jurisdictions (UK, parts of Europe), some with different incentives in place
- However, there is still a consistent approach for the consideration of transmission losses amongst identified jurisdictions

Questions for Stakeholders

- Are there opportunities to impact losses (as discussed or additional) where Ontario is taking a materially different approach than other jurisdictions?
- Are their specific aspects of the processes/approach in other jurisdictions that Ontario should emulate?

Summary and Discussion of Potential Opportunities

Summary

- The processes presented today effectively consider the impacts of losses
  - The economic and system benefits of loss reduction are assessed and considered during the planning, design and operation of the Ontario electricity system.
  - Loss reduction is assessed with an appropriate level of analysis
  - Ontario is following current best practices for consideration of transmission losses including those identified in the National Grid, CEER and EPRI reports

Potential Opportunities

- The IESO and Hydro One are seeking stakeholder feedback on opportunities to better formalize and improve existing processes beyond what was presented today
  - Incremental to the work Hydro One is already undertaking to document their processes for loss consideration

Potential Opportunities (continued)

- With the completion of the Market Renewal Program, it is the intention that Loss Penalty Factors will be calculated dynamically to further improve the economic scheduling of system resources in day-ahead, pre-dispatch and real-time timeframes
  - This improvement is underway, independent of this engagement

Questions for Stakeholders

- Are there additional measures to reduce losses, beyond what we have discussed today, that we can explore the potential benefits of as part of this engagement?
  - Related to the planning process or equipment standards

Recap of Questions for Stakeholder Feedback

- Are there aspects of the current approach to options development and evaluation that don't sufficiently consider transmission losses? How could these be improved?
- Other feedback on how losses are considered in the planning process?

(Refer to slide 32)

- Is any further information/clarification required on how transmission losses are accounted for in conductor or transformer selection?

(Refer to slide 37)

Recap of Questions for Stakeholder Feedback (continued)

- Is the materiality of losses being appropriately balanced against other system costs in the discussed processes?
- Are any clarifications required on any of the discussed processes?

(Refer to slide 42)

- Are there opportunities to impact losses where Ontario is taking a materially different approach than other jurisdictions?
- Are their specific aspects of the processes/approach in other jurisdictions that Ontario should emulate? (Refer to slide 54)

Recap of Questions for Stakeholder Feedback (continued)

- Are there additional measures to reduce losses, beyond what we have discussed today, that we can explore the potential benefits of as part of this engagement?
  - Related to the planning process or equipment standards

(Refer to slide 58)

Submitting Stakeholder Feedback

- Please provide any written feedback to engagement@ieso.ca by October 22 using the feedback form on the engagement webpage

- IESO will review stakeholder feedback and provide a response at a future engagement session

Thank You

ieso.ca

1.888.448.7777

customer.relations@ieso.ca

engagement@ieso.ca

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