Transmission Planning Guideline

Consideration of Transmission System Losses in the Evaluation of Plan Alternatives

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1. Purpose and Scope

This planning guideline describes the process for evaluating transmission network losses (or "system losses") when IESO planners develop power system plans. It is applicable to IESO bulk transmission system and regional planning studies, and IESO transmission planning studies in general, where different possible solutions are evaluated to address system reliability or supply needs. The scope of these possible solutions may include fundamentally different approaches, such as transmission facilities, generation resources, energy efficiency and/or demand management alternatives, etc. In addition, this document informs stakeholders as to how the IESO will account for system losses when making planning decisions.

Whenever electricity is transported across the transmission system, some electricity is lost in the form of dissipated heat. This is due to the electrical resistance of the wires, cables, transformers, and other types of electrical equipment. System losses are inversely proportional to the square of the voltage at which power is transmitted, and thus, reduced losses is a primary benefit of the high-voltage transmission network. While transporting electricity at higher voltages can minimize losses, they cannot be completely eliminated. To account for these losses, more power needs to be generated to supply the electricity demand of consumers, and this increases the cost of operating the power system. System wide, losses are typically in the order of two percent of the power generated and transported across the transmission network.

For the purpose of this guideline, system losses are represented by the difference between the amount of energy injected into the transmission system and the amount of energy withdrawn from the system. In planning studies, a forecast of the losses associated with each alternative being considered can be quantified over a study period. The forecasted losses can be expressed in terms of the energy that is lost, in megawatt-hours (MWh), as well as the amount capacity needed to supply them during the system peak, in megawatts (MW). Using forecasted energy and marginal capacity prices, the system losses can be considered in the economic assessment of each alternative.

This guideline provides direction to IESO system planners as to when and how to include an evaluation of losses in comparing alternatives to address a system reliability need. Because the cost of system losses tends to be a small factor relative to the overall cost of an alternative, losses are unlikely to change the cost-effectiveness ranking of specific alternatives, except possibly where two or more alternatives are close in cost. In such cases, a detailed evaluation of losses may be a deciding factor in the economic assessment.

This guideline does not apply to transmission loss evaluations that may be conducted by a transmitter for a given transmission project. Transmitters, such as Hydro One, have established methodologies to evaluate losses in this context. This guideline acknowledges this and does not seek to replace them as they fulfill a different purpose.

1.1 Determining When to Evaluate System Losses

The IESO is concerned with the impact of planning alternatives on transmission losses from a broader system perspective, with a focus on system losses as a possible determinant in choosing between fundamentally different approaches for addressing system reliability needs. If a transmission solution is recommended by the IESO in a plan or study, then transmission losses may be further considered by the transmitter in the context of the facility design. A transmitter would not go back and compare transmission to generation, for example. The transmitter process, if carried out, may focus on different facility design factors such as conductor size, tower design, and/or route selection.

The IESO planner will complete a detailed system loss evaluation based on a two-step analysis of: (1) the estimated cost differential between planning alternatives; and (2) the potential for system losses to impact the choice of the preferred alternative.

A detailed loss evaluation may be carried out where the estimated cost of the least-cost or otherwise preferred alternative is within $20 million of another feasible alternative, such that the value of system losses could change the relative cost of the alternatives.[1] This economic threshold takes into account the IESO's experience evaluating planning alternatives to address bulk transmission network reliability issues, and the expected magnitude of savings from reducing system losses that could be realized. Generally, a cost differential of more than $20 million between two alternatives is not likely to change their ranking order based on the inclusion of system losses.

Judgment should be exercised in applying the $20 million economic threshold, since the cost of transmission and other alternatives can vary by orders of magnitude. For example, alternatives to minor system reinforcements in the range of $20 million or less will require judgement to determine if losses would have a material impact on costs. In cases where the cost differential between alternatives is greater than, but still close to the $20 million threshold, then it is advised to go on to the second screening step described in the next paragraph. The results of all loss evaluations should be documented to inform periodic review of the economic threshold.

Where the relative cost of the alternatives is at or below the economic threshold, the alternatives will be reviewed and ranked according to their potential to result in reduced system losses. This review will be completed based on judgement and engineering principles by system planners familiar with the alternatives and their technical attributes. If the least-cost or otherwise preferred alternative is likely to result in more system losses than another feasible alternative within the $20 million threshold range, then a detailed loss evaluation is likely warranted. Some considerations are listed as follows:

- It can generally be assumed that transmission at higher operating voltages will result in inherently fewer losses than transmission at lower operating voltages, and longer transmission lines will have more losses than shorter lines, etc.;
- Generation resources close to a load centre will generally result in fewer transmission system losses as compared to generation resources sited farther away from the load; and

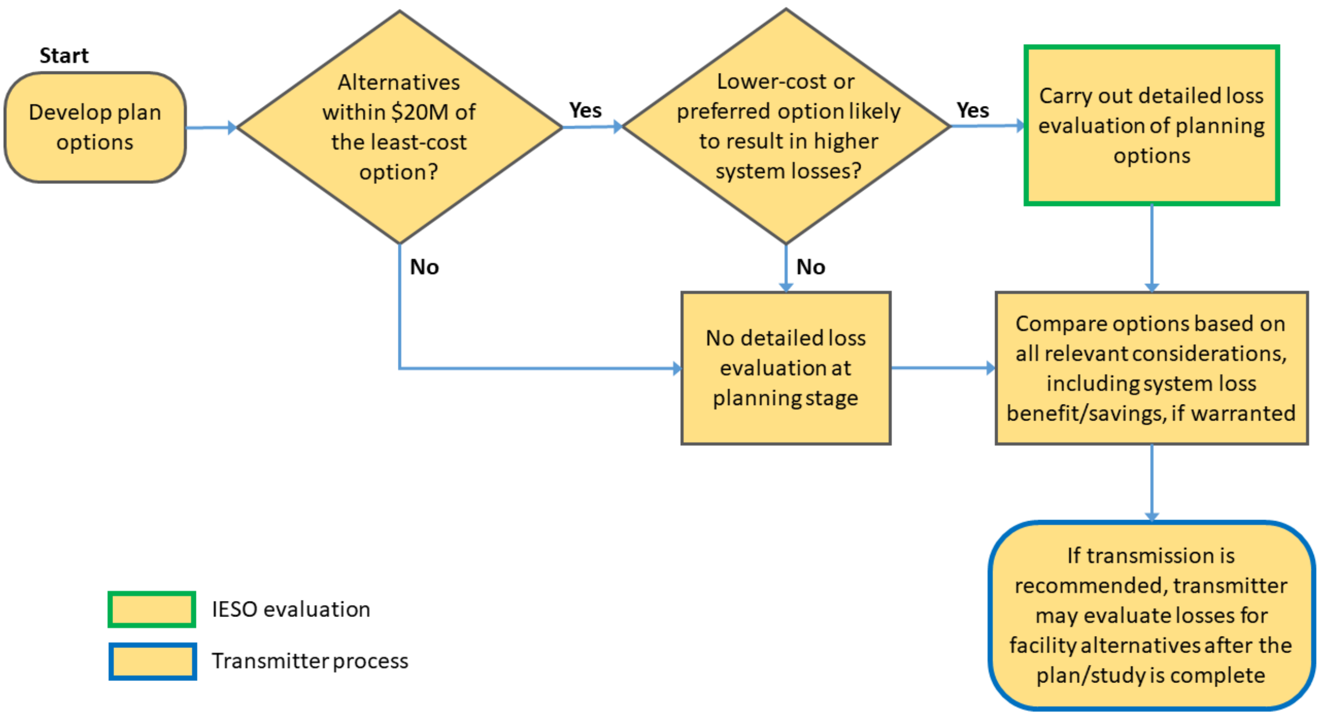
[1] It should be noted that economic consideration is one factor used to compare alternatives; there may be other rationale for selecting a preferred solution (e.g., expected implementation lead-time, technical feasibility, feedback from communities, other system benefits, etc.).

- Demand-side management alternatives such as energy efficiency and demand response are likely to result in reduced system losses by reducing the amount of power that must be generated and transmitted to supply the load.

The IESO's process for determining when it may be warranted to undertake a detailed system loss evaluation is illustrated in Figure 1. This process should be completed after:

- A list of feasible alternatives for addressing the identified need have been developed; and
- Planning-level cost estimates for the alternatives have been prepared.

Figure 1 | Screening Process for Determining When to Evaluate System Losses



2. Guideline for Transmission Losses Evaluation

Where a detailed system loss evaluation must be completed, the evaluation approach may vary based on the scope of the planning study and the types of solutions being compared. Approaches may rely on the use of energy simulations to assess losses for each option (e.g., a new transmission line versus a new local generator), and/or power flow simulations. Simpler methods are possible and may be employed in limited situations when simulations have not been done.

As system losses represent a portion of the demand on the system that must be met by provincial generation resources, the provincial (and zonal) electricity demand forecasts produced by the IESO typically account for transmission network losses as a factor that is added to the demand forecast. By contrast, regional planning forecasts are developed by the participating Local Distribution Companies at the load station and/or transmission delivery point, and typically do not include a factor for system losses. This must be considered when incorporating demand forecasts into the analytical model being used to perform system simulations to ensure that losses are accurately represented in the model.

2.1 Detailed Loss Evaluations

This section describes the IESO's approach for carrying out detailed loss evaluations. As described above, this approach applies to the consideration of different alternatives at the planning stage, for example, transmission, non-wires alternatives, generation, demand management, etc. This is materially different from the transmitter process that would then focus on evaluating losses in respect to transmission alternatives.

2.1.1 Evaluation Procedures

A detailed loss evaluation aims to determine the total economic loss savings relative to a baseline, consisting of both energy and capacity (peak demand) savings. For comparing different alternatives, the calculations of loss savings should be done in terms of their net present value. Assumptions for net present value calculations, including the time period, should be consistent with the assumptions used in the relevant plan or study. The basic process steps for carrying out a detailed loss evaluation are summarized as follows, and described further detail in the remainder of this section.

1. Determine the forecasted hourly electricity flows, or electricity transfers across a transmission line, transmission interface, or the system as a whole, for each alternative under consideration. Then calculate the hourly system losses for each alternative to produce a loss profile for each alternative.
2. Compare to the baseline to produce a forecast of the hourly energy savings for each alternative.
3. Multiply the hourly energy savings by the appropriate marginal energy cost forecast to determine the energy cost savings associated with each alternative.
4. Take the losses at the peak hour and multiply by the appropriate forecasted marginal capacity value to estimate the capacity (peak demand) cost savings for each alternative.

5. Add the energy and capacity (peak demand) cost savings together to estimate the total cost savings associated with transmission loss reductions for each alternative.
6. If, after accounting for the total cost savings associated with transmission loss reductions, the total economic value of two alternatives is very close, consider carrying out a sensitivity analysis to ensure that changes in planning assumptions such as the forecasted load or energy/capacity costs do not materially change the outcome.

The first step in the detailed loss evaluation is to determine the forecasted hourly electricity flows or transfers across the transmission system or interface of interest. Once the forecasted electricity flows have been assessed, the associated system losses can be determined.

The hourly electricity flows can be extracted from an energy simulation using tools such as *UPLAN* or *PLEXOS*. However, if the planning is for a simple system, where the hourly electricity flows on only a few transmission elements are affected under each alternative, then a full energy simulation may not be necessary. There may also be other technical limitations or constraints preventing a full energy simulation from being performed. In these cases, it may be possible to calculate the hourly energy flows on the relevant transmission elements using historical electricity flows and conservative resource assumptions in conjunction with the planning forecast for the area.[2] The calculation can be completed manually or by using power flow simulation tools such as *Power System Simulation for Engineering* (*PSS/E*) or the *DSA Tools* suite.

The associated losses are a function of the resistance of the transmission path (or broader system or interface) for each alternative. If an energy simulation is used to determine the hourly electricity flows, the hourly losses can be extracted from the simulation. If an energy simulation is not used, it may be possible to calculate the losses using the following formula, where (R) is the impedance/resistance of the transmission element, and (I) is the current through the transmission elements.

$$P_{loss} = I^2 R$$

Alternatively, power flow simulations can be carried out to determine the losses associated with the hourly electricity flows.

The first step will generate an hourly energy loss profile for each alternative. Comparing it to a baseline will produce the hourly energy savings for each alternative. The sum of the hourly energy savings for each year will give the annual energy savings, as shown below.

$$\text{Annual energy savings} = \sum \text{hourly energy savings}$$

To calculate the energy cost savings, the hourly system production marginal cost forecast is multiplied by the hourly energy savings forecast as derived above. If an energy simulation was conducted, the forecast future marginal costs from the energy simulation should be used. Alternatively, the marginal cost forecast from the most recent Annual Planning Outlook (APO) can be

[2] For example, if the assessment is being done as part of a regional plan, then the regional plan forecast growth rate and/or load forecast should be used; if the assessment is focused on a radial line supplying a single load station, then the forecasted growth rate for that station can be used; if the assessment is being done as part of a bulk planning study, then the appropriate provincial or zonal forecast should be used.

used. If an hourly marginal cost forecast is required, the APO annual rate can be indexed and mapped onto a historical hourly profile.

$$\textit{Energy cost savings} = \sum \textit{hourly production marginal costs X hourly energy savings}$$

In addition to the energy cost savings, there is potential for additional savings as a result of reduced peak demand and the consequential peak loss reduction. These peak savings are a direct result of power loss savings during the system peak hour, which could reduce the system's future generation capacity requirement and/or demand response requirement.

To find the peak loss reductions (in MW) for the purpose of determining capacity value, a forecast of the loss reductions at the time of system peak is required for the alternatives being compared. From the hourly energy savings, the savings occurring at the hour of system peak demand are taken and compared.

The capacity (peak demand) cost savings is quantified by multiplying the avoided system demand during the peak hour by the value of capacity, defined as the long-run capacity value based on the approximate cost of new entry to reflect the highest expected capacity value. The Capacity Auction Reference Price and Maximum Auction Clearing Price (MACP) Revision document provides a Reference Price and MACP that accounts for the cost of new entry. These rates are expected to be updated on a regular schedule (approximately every 2-3 years). The Reference Price is estimated to be approximately $570/MW-day as of 2021-2022 (unforced capacity, or UCAP for business days), which is updated to account for inflation. For reference, see the following report: Capacity Auction Reference Price and Maximum Auction Clearing Price Revision, January 2020.

An illustrative example of the capacity (peak demand) cost savings with the long-run capacity value for 10 MW line loss reduction at peak is as follows:

$$\textit{UCAP} = \textit{\$570/MW-day X 252 days (business days in the year)} = \textit{\$143,640/MW-year}$$

Therefore, 10 MW of line loss capacity value would be $143,640 times 10, which would equal $1,436,400.

The total cost savings from loss reduction is then calculated by adding the values for energy and capacity (peak demand) cost savings, as follows:

$$\textit{Total cost savings from loss reduction} = \textit{energy cost savings} + \textit{peak capacity cost savings}$$

If after completing a detailed loss evaluation, the savings attributable to loss reductions for the alternatives under consideration are close in net present value, e.g., if adjusting the loss savings benefit by ±50% would potentially impact the outcome, then a sensitivity analysis should be considered. A sensitivity analysis could consider, for example, additional scenarios with different load growth assumptions (which will impact the energy and capacity savings), and/or different electricity price assumptions (which will impact the economic value of the loss reductions).

The results of the loss evaluation and sensitivity analysis, if performed, should be documented and summarized for inclusion in the report for the plan or study.

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