Stakeholder Engagement Pre-Reading

Linked Wheel Transactions – November 15, 2019

The external stakeholder engagement session on November 15, 2019 will cover the following topic(s):

- Linked Wheel Transactions

The purpose of this document is to provide stakeholders with information on the detailed design for Linked Wheel Transactions and set expectations for the session. These materials are required reading for the session.

Contents

Disclaimer

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1. Session Objective

The detailed design engagement meetings are to be considered technical working sessions. The sessions will focus on specific topics that external stakeholders either expressed an interest in during the high-level design phase or where the IESO has identified the need for further stakeholder input to inform the draft detailed design. Each session will concentrate on the proposed design for one specific aspect of the energy market detailed design.

The IESO is publishing materials for each engagement session no later than two weeks in advance of the session. This information is being shared in advance to provide stakeholders the opportunity to review and consider the potential impacts on their organization. The material should also help stakeholders identify who from their respective organizations may be most appropriate to attend the session and provide feedback. Stakeholders are encouraged to submit questions in advance of the sessions that will be addressed either at or before the session.

Stakeholder feedback, questions or concerns can be sent directly to engagement@ieso.ca.

These sessions will allow for interactive discussions with stakeholders regarding the reading material which will be focused on the questions identified below.

Stakeholders may also submit written feedback after the session if they choose to do so. However, these engagement sessions are designed to collect stakeholder feedback in-person and to facilitate a discussion with other stakeholders on that feedback. The IESO will use the input from these sessions to inform the detailed design decisions. Following each engagement session, the IESO will publish a brief summary of the discussion and allow for a short window for feedback for those not able to participate.

In the pre-engagement session, the IESO will be asking the following questions:

- What questions do stakeholders have on the proposed design?
- What questions do stakeholders have on the rationale for the proposed design?
- Do stakeholders agree that the proposed design is consistent with the Market Renewal principles? If not, what changes would be required to better align with the principles?

Figure 1 - Principles of Market Renewal

PRINCIPLES				
Efficiency Lower out-of-market payments and focus on delivering efficient outcomes to reduce system costs	**Competition** Provide open, fair, non-discriminatory competitive opportunities for participants to help meet evolving system needs	**Implementability** Work together with our stakeholders to evolve the market in a feasible and practical manner	**Certainty** Establish stable, enduring market-based mechanisms that send clear, efficient price signals	**Transparency** Accurate, timely and relevant information is available and accessible to market participants to enable their effective participation in the market

2. Background

In the Single Schedule Market (SSM) high-level design (HLD)[1], the IESO made decisions that raised questions from stakeholders about the impact to linked wheel intertie transactions. These decisions introduced locational marginal pricing (LMP) to the interties. The design also included changes to intertie congestion prices (ICP) that will apply for real-time (RT) settlement.

To address stakeholder questions on the high-level design decisions, this document will:

- Outline how market participants can submit individual intertie transactions to become scheduled for linked wheel transactions;
- Reiterate the components of intertie pricing from the SSM HLD that apply to linked wheels; and
- Explain how intertie prices will be used to settle linked wheel transactions.

2.1. Linked Wheel Transactions

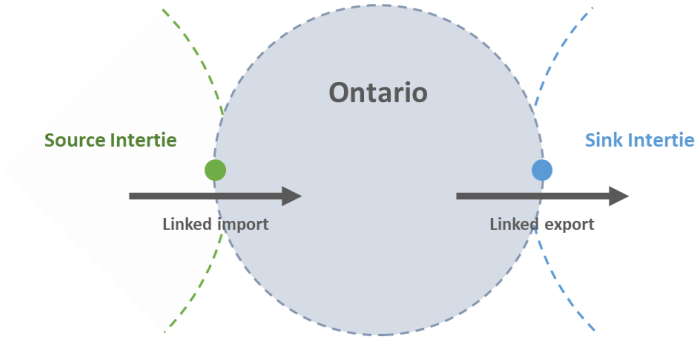
Interties are transmission lines that allow energy to move between balancing authorities or jurisdictions. Ontario is connected by interties to five other jurisdictions: Manitoba, Minnesota, Michigan, New York, and Quebec. Market participants can conduct intertie transactions to move energy between connected jurisdictions. These transactions can be energy imports from another jurisdiction into Ontario or energy exports from Ontario to another jurisdiction.

The IESO allows 'wheel-through' intertie transactions, where a market participant simultaneously imports energy into Ontario and exports it to another jurisdiction. In this document, the interties through which the import and export legs flow are referred to as the source and sink interties, respectively. The IESO provides Ontario grid access to facilitate these transactions while requiring that grid reliability requirements must be met.

For transactions to be linked, the market participant must indicate their intent to schedule two individual legs together using their data submissions into the energy market. The IESO can then schedule the linked import and export energy together.

Linked wheel intertie transactions, as depicted in **Figure 2**, consist of an energy import into Ontario and an energy export into another jurisdiction for the same quantity in a 'linked' transaction. A wheel-through transaction must contains two 'legs' – an import leg and an export leg.

Figure 2 – Linked Wheel Intertie Transaction



[1] See Section 2.5 of the Single Schedule Market High-Level Design document.

3. Participation & Scheduling

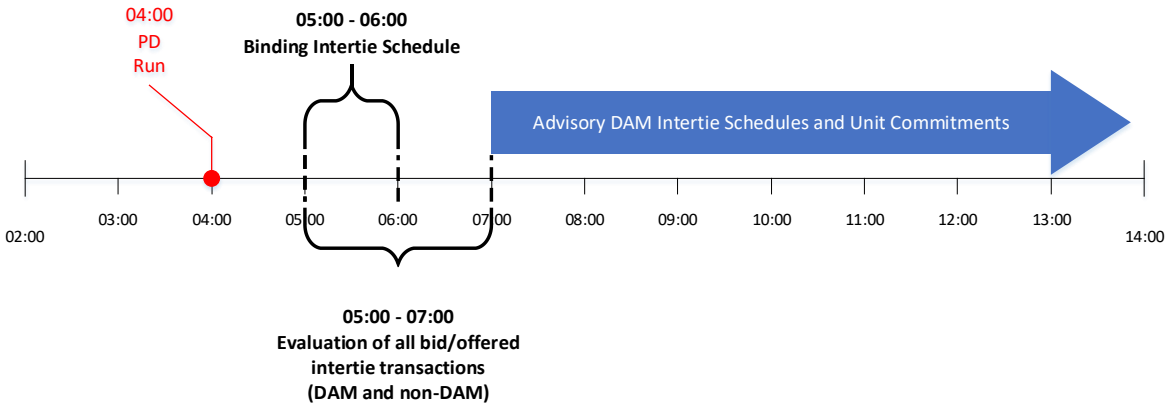
In the future market, market participants will be able to submit offers and bids for linked wheel intertie transactions through the day-ahead market (DAM) and pre-dispatch (PD) scheduling process, similar to today. The import leg of the transaction will be submitted as an energy offer and the export leg will be submitted as an energy bid for equal energy quantities.

The market participant will also submit a North American Electric Reliability Corporation (NERC) e-tag for the corresponding offers and bids to indicate the link between both components of the wheel. All offers and bids for a linked transaction require that the e-tag ID field is populated with matching syntax.

The DAM will issue financially-binding schedules to market participants, including those conducting linked wheel transactions. Market participants will be settled based on their financially-binding DAM schedule, providing price certainty.

The PD scheduling process will evaluate intertie bids and offers along with other resources as part of a multi-hour optimization, similar to the DAM. Intertie transactions, including linked wheels, that do not have a corresponding DAM schedule will only be assessed for scheduling during the PD-2 run of the PD calculation engine. This is illustrated by the example in **Figure 3**.

Figure 3 - Example - Timeline for Non-DAM Intertie Transaction Scheduling in Pre-Dispatch



In this example, the 4:00 PD run would evaluate all DAM and non-DAM intertie transactions for 5:00 to 7:00. The 4:00 PD run would also evaluate all DAM intertie transactions only for 07:00 and beyond. Using the latest intertie constraints, the 4:00 PD run would also set the binding intertie schedule for RT at 5:00. Given that PD intertie schedules are binding, certain prices during this PD timeframe are also used to calculate RT settlement.

3.1. Linked Wheel Scheduling Methods

As part of detailed design, the IESO must select a method to equally schedule the energy quantities of import and export legs for linked wheel transactions in the DAM and PD scheduling process. Currently, the IESO uses two different methods in the DACP and the PD scheduling process. In the future, the IESO will use one method in both the DAM and PD scheduling process to increase scheduling consistency across timeframes. Each method is described in further detail below.

The IESO is currently considering two options, and is seeking input from market participants to help inform its decision.

3.1.1. Method 1 – From the Current PD Scheduling Process

The first option is the method used in the current PD scheduling process. Under this method, offers and bids for linked wheel transactions must adhere to the following pricing restrictions:

- Import offers must be priced from -$2,000 to -$50 with positive energy quantities;
- Export bids must be priced at $2,000 with equal, negative energy quantities to the corresponding import offer.

The current PD calculation engine individually schedules all export and import transactions at each intertie. The pricing structure increases certainty in scheduling linked wheels to avoid incorrect intertie scheduling outcomes could impact the reliability of the grid in Ontario. The pricing restrictions place the bids and offers at the bottom of the bid and offer "stack", therefore increasing the likelihood that they will be economically scheduled.

Once the PD evaluation is complete, the resulting schedules at each intertie can be considered with corresponding e-tag ID information. If any leg of a linked wheel transaction is not fully scheduled, the IESO adjusts the export or import schedule quantities to the lower of the export or import scheduled quantities using an automated process. Given that this process occurs partly outside the calculation engine, it limits the information available to fully optimize schedules across all intertie transactions.

The primary downside of this approach is that market participants do not have control over their offer and bid prices due to the price restrictions. However, the impact of price restrictions on linked wheel transactions is minimal in the current market because the market clearing price for the import and export intertie transactions are always equal.

3.1.2. Method 2 – From the Current DACP

The second option is the method currently used in the DACP. In this method, e-tag ID information is used up front in the economic evaluation to identify intertie transactions that are associated with a linked wheel. There are no additional offer and bid price restrictions.

The DACP economically schedules each leg independently based on offer and bid prices, as well as internal and intertie congestion. If one leg of the transaction cannot be fully scheduled, either the export or import schedule with the corresponding e-tag ID will be reduced to the more restrictive quantity. In this approach, the automated linkage of the import and export legs within the calculation engine supports reliable and economic scheduling of linked wheels.

In the future DAM, without price restrictions, market participants with linked wheels would have a greater ability to determine their own offer and bid prices. As a result, linked wheel transactions could be scheduled economically according to the submitted prices, allowing better management of exposure to different locational marginal prices (LMPs) at each intertie in the future market. Intertie pricing in the future market will be described in the following section.

4. Intertie Pricing

Intertie transactions are settled based on the intertie price where the transaction occurs. For linked wheel transactions, two intertie prices are considered: the source (import) intertie price and the sink

(export) intertie price. Prices from all three operating timeframes – DAM, PD, and RT – are used to settle intertie transaction schedules for DAM and RT; DAM prices are used to settle DAM schedules, and both PD and RT prices contribute to RT settlement.

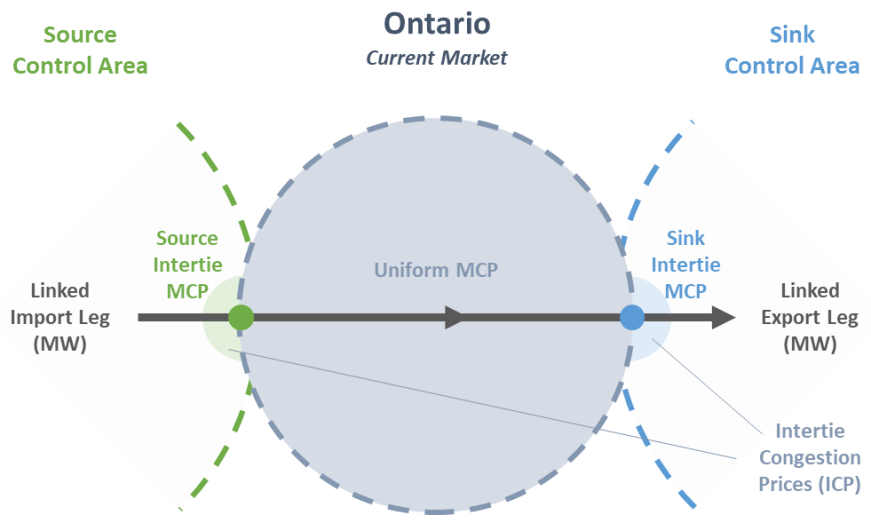
Under the SSM HLD, intertie prices will be LMPs, which will factor in additional price components that are derived from factors internal to the Ontario grid. These internal price components vary by location to reflect scheduled energy flows within Ontario, considering internal congestion and losses. With LMPs, when source and sink interties are not congested, the import and export legs will be exposed to price differences between the source and sink intertie LMPs.

The ICP is also a component of intertie LMPs that reflects the intertie congestion caused by scheduled intertie transactions exceeding transmission limits. It can be calculated as a static value from DAM and PD intertie LMPs. However, the SSM introduced new methodology to determine the ICP that will apply for RT settlement. Details will be outlined in Section 4.2.

4.1. Internal Price Components

In the current two-schedule system, energy transactions through Ontario are settled based on the uniform Market Clearing Price (MCP). **Figure 4** illustrates intertie pricing from the current market as it relates to linked wheel transactions. Because the MCP is uniform, the intertie prices for both the import and export legs of linked wheel transactions always have the same MCP component. Therefore, the only potential difference between the import and export intertie prices is the ICP at each intertie.

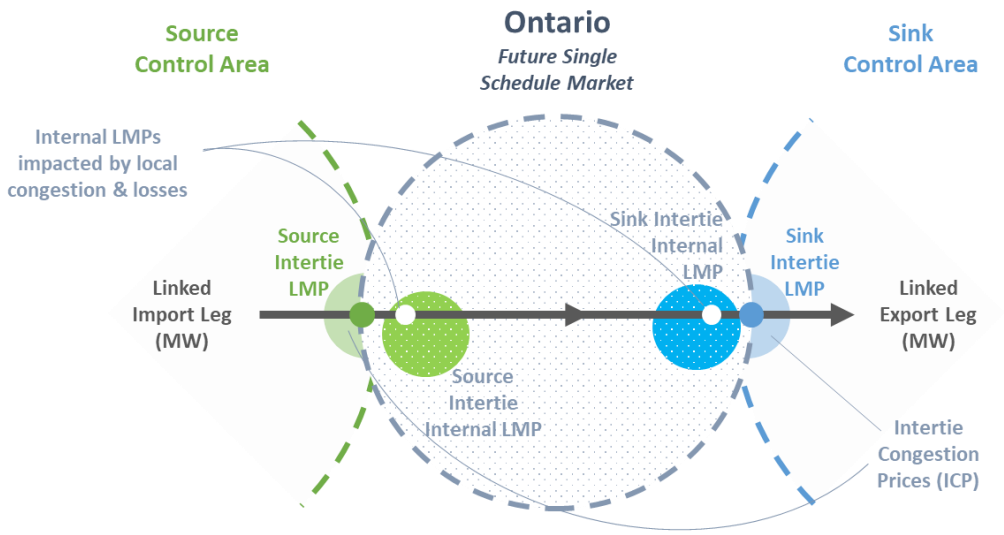
Figure 4 – Current State Pricing for Linked Wheels



In the future SSM, all dispatchable transactions, including imports and exports, will be priced using LMPs. LMPs may vary by location as a result of changes in internal congestion and losses. The internal congestion component of the LMP reflects the marginal cost of congestion caused by market transactions that exceed physical system limits. The internal losses pricing component reflects the marginal cost of power losses over the distance travelled from where an energy supply resource connects to the grid.

Given that intertie transactions contribute to congestion and losses within the Ontario system, it is appropriate for such transactions to be settled on LMPs. This includes linked wheel intertie transactions that travel through Ontario. As illustrated in **Figure 5**, the linked import leg can impact the intertie congestion, internal congestion, and internal loss components that determine the source intertie and internal LMPs. Similarly, the linked export leg contributes to the intertie congestion as well as internal congestion and losses that factor into to the sink intertie and internal LMPs.

Figure 5 – Future State Pricing for Linked Wheels



Instead of ICP being the only variable between the ISP for each leg, both the internal LMP components and the ICP components at the intertie will vary, which will more accurately reflect the reality of how intertie transaction energy flows through Ontario.

4.2. Intertie Congestion Pricing

Each of Ontario's interties has a maximum allowable import and export transmission capability that relates to its power flow limit, which is the amount of electricity it can carry. These limits are used to ensure system stability and acceptable thermal loading levels.

Interties are deemed 'congested' when the quantity of economic imports or exports offered or bid on the intertie exceeds the transmission capability of the intertie. An intertie is import-congested when the quantity of imports that could be economically scheduled exceeds the maximum capability of the intertie. Likewise, an intertie is export-congested when the quantity of exports that could be economically scheduled exceeds the maximum capability of the intertie.

When offers and bids exceed the transmission capability at an intertie location, the ICP identifies the incremental change in marginal costs at that location due to congestion. The ICP can be negative, positive, or zero, depending on the type of intertie transactions bound by an intertie constraint. The change in marginal cost due to congestion caused by intertie constraints is:

- Negative, when the intertie is import-constrained. Negative congestion reflects a decrease in the ISP due to an influx of import offers that set the intertie LMP below the LMP internal to Ontario.

- Positive, when the intertie is export-constrained. Positive congestion reflects an increase in the ISP due to an influx of export bids that set the intertie LMP above the LMP internal to Ontario.

- Zero, when an intertie is not congested. In this case, the ISP is the same as the LMP internal to Ontario because no intertie constraints were binding.

The ICP can be calculated from the intertie LMP when intertie transaction schedules can be changed in response to an incremental amount of supply or load. As a result, the DAM calculation engine will produce a DAM ICP as a static component of the DAM intertie LMP for settlement of the DAM financially binding schedules.

While intertie transactions can set price in DAM and PD, they are not eligible to set price in RT because their quantities are fixed for the hour to the amount scheduled in PD. As a result, the PD calculation engine will produce a PD ICP as a static component of the PD intertie LMP, which will be used to evaluate the ISP.

In RT, given that a RT intertie LMP does not exist, the ISP will be based on the RT Locational Marginal Price (LMP) inside Ontario. The IESO must also adjust the ISP based on intertie congestion. If the intertie is found to be import congested in PD, a dynamic ICP will be used to cap the ISP value, reflecting the changing conditions at the intertie leading up to RT. For export-congested interties, the IESO will maintain the use of the static PD ICP based on previous stakeholder feedback.

5. Settlement

The import and export legs of a linked wheel transaction will remain individually settled by the IESO. In general, the import leg of linked wheel is paid a settlement amount for the energy it provides to Ontario at the source intertie. The export leg of linked wheel pays a settlement amount for the energy it supplies outside of Ontario through the sink intertie.

The following sections outline how linked wheel intertie transactions will be settled. Section 5.1 describes how transactions scheduled through the DAM will be settled based on the DAM intertie price, using the two-settlement methodology. Section 5.2 describes how linked wheels that are scheduled through the PD scheduling process will be settled based on the ISP, which includes the ICP.

It should be noted that the equations provided in this document are for illustrative purposes to support understanding of the concepts to be discussed at the session. Other settlement charges will also be applied to individual legs of the linked wheel, similar to those outlined in the current Market Rules. Full settlement equations and charge type eligibility will be provided in the Detailed Design chapters.

5.1. DAM Two-Settlement

With the introduction of a DAM, all market participants with linked wheel intertie transactions will be eligible to receive a DAM financially binding schedule for each leg of the linked wheel. Transactions scheduled in the DAM will be settled using the below two-settlement methodology:

Equation 1 – DAM Intertie Transaction Settlement

$$Intertie\ Transaction\ Settlement_{DAM} = Quantity_{DAM} \times Intertie\ LMP_{DAM}$$

Linked wheel import and export quantities will be based on the DAM financially binding schedules. Linked imports are paid for DAM scheduled injections based on source intertie LMPs. Linked exports must pay for DAM scheduled withdrawals based on the sink intertie LMPs. The DAM LMP include internal pricing components as well as a static ICP at the intertie.

Equation 2 – RT Intertie (Balancing) Transaction Settlement

$$Intertie\ Transaction\ Settlement_{RT} = (Quantity_{RT} - Quantity_{DAM}) \times ISP_{RT}$$

In RT, intertie transaction quantities are based on the RT schedules that were established in the PD timeframe. Linked exports pay for incremental RT withdrawals, but can be paid for unconsumed DAM scheduled withdrawals. Linked imports are paid for incremental RT injections, but will pay for undelivered DAM scheduled injections. Deviations from DAM obligations will be bought or sold back at the calculated ISP for each source or sink intertie. The ISP components are described in Section 4 and equations are provided in the following Section 5.2.

Appendix A contains an example to illustrate how the above equations can apply to linked wheel intertie transactions that fulfill their DAM financially binding schedules in RT.

5.2. Real-Time Market Settlement

The IESO will use a different approach to settle linked wheel intertie transactions that are scheduled through the PD scheduling process or that deviate from their DAM schedules in RT. The following price variables will be used to settle linked wheel transaction legs at source and sink interties: the PD Intertie Internal LMP, the RT Intertie Internal LMP, and the PD Intertie LMP.

Using these PD and RT prices, the RT settlement will be calculated in three main steps:

1. determine the PD ICP at each intertie;
2. determine the ISP in RT at each intertie;
3. determine the RT settlement for each leg of the linked wheel based on the RT schedules.

Step 1: Calculate the PD Intertie Congestion Price

First, intertie congestion will be assessed at each intertie based on the PD ICP value from the final PD run before RT. The equation to determine each PD ICP is as follows:

Equation 3 – PD ICP

$$ICP_{PD} = Intertie\ LMP_{PD} - Intertie\ Internal\ LMP_{PD}$$

It should be noted that PD ICP values will not be directly factored into RT settlement, except in cases where an intertie is export-congested. The determination of the PD ICP at each source or sink intertie as either positive, negative, or zero will dictate how to proceed with Step 2.

Step 2: Calculate the Intertie Settlement Price (ISP)

From Section 4.2, the type of congestion at an intertie can be determined based on the PD ICP, where zero is no congestion, positive is export-congested, and negative is import-congested. Depending on the

type of congestion at each intertie that was found in Step 1, the ISP that applies to RT schedules will be calculated using one of three formulas as outlined below:

No Congestion

At uncongested source or sink interties, the ICP is zero. Therefore, the ISP at each intertie will equal the RT Intertie Internal LMP. In this case, the equation for each ISP will be:

Equation 4A – ISP at an Uncongested Intertie

$ISP_{RT} = Intertie\ Internal\ LMP_{RT}$

Export-Congested

For export-congested source or sink interties, the ISP calculation at each intertie will use the static ICP as calculated in Step 1, Equation 3 for the corresponding source or sink intertie. In this case, the formula for each ISP will be:

Equation 4B – ISP at an Export-Congested Intertie

$ISP_{RT} = Intertie\ Internal\ LMP_{RT} + ICP_{PD}$

Import-Congested

For import congested source or sink interties, a dynamic ICP will select the lesser of the PD Intertie LMP and RT Intertie Internal LMP as the ISP at each intertie. In this case, the formula for each ISP will be:

Equation 4C – ISP at an Import-Congested Intertie

$ISP_{RT} = Min\ \{Intertie\ LMP_{PD}, Intertie\ Internal\ LMP_{RT}\}$

Step 3: Calculate RT Intertie Settlement at Each Leg

Once the applicable ISP values are determined, each leg of the linked wheel intertie transaction will be settled individually based on the corresponding RT schedule using the following equation:

Equation 5 – RT Intertie Transaction Settlement

$Intertie\ Transaction\ Settlement_{RT} = Quantity_{RT} \times ISP_{RT}$

Appendix B contains four examples that illustrate how the above steps and equations will apply to linked wheel intertie transactions under different intertie congestion scenarios.

6. Conclusion

In advance of the engagement session on linked wheels, stakeholders are encouraged to submit any questions or requests for clarification that would benefit the interactive session.

For questions or feedback, please email engagement@ieso.ca.

Appendix A – Example: DAM Two-Settlement of Linked Wheel Transactions

The following example applies equations introduced in Section 5.1 on the DAM two-settlement. This example illustrates how linked wheel transactions that receive DAM financially binding schedules and remains economically scheduled in RT will be settled in both markets.

Scenario:

A market participant is scheduled for a linked wheel transaction in DAM and RT that consists of a **20 MW** import from the source intertie and a **20MW** export to the sink intertie. In the DAM, the Source Intertie LMP is equal to **$30/MW** and the Sink Intertie LMP is equal to **$20/MW**. In RT, as a result of changing internal and intertie congestion conditions, the Source ISP is calculated to be **$15/MW** and the Sink ISP is **$40/MW**.

Variables:

Linked Wheels	DAM Settlement Variables	RT (Balancing) Settlement Variables
1) Import Leg	DAM Import Schedule: 20 MW DAM Source Intertie LMP: $30/MW	RT Import Schedule: 20 MW RT Source ISP: $15/MW
2) Export Leg	DAM Export Schedule: -20 MW DAM Sink Intertie LMP: $20/MW	RT Export Schedule: -20 MW RT Sink ISP: $40/MW

Import Leg Two-Settlement:

DAM Settlement [From Section 5.1, Eq. 2]

Intertie Transaction Settlement $_{DAM}$ *= Quantity* $_{DAM}$ *x Intertie LMP*$_{DAM}$

Import Leg Settlement $_{DAM}$ = Import Scheduled Quantity $_{DAM}$ x Source Intertie LMP$_{DAM}$
= 20MW x $30 **= $600**

RT (Balancing) Settlement [From Section 5.1, Eq. 3]

Intertie Transaction Settlement $_{RT}$ *= (Quantity* $_{RT}$ *– Quantity* $_{DAM}$*) x ISP*$_{RT}$

Import Leg Settlement $_{RT}$ = (Import Metered Quantity $_{RT}$ – Import Scheduled Quantity $_{DAM}$) x Source ISP$_{RT}$
= (20MW – 20MW) x $15 **= $0**

The net energy settlement for the import leg of the linked wheel transaction is **$600**.

Export Leg Two-Settlement:

DAM Settlement [From Section 5.1, Eq. 2]

Intertie Transaction Settlement $_{DAM}$ = Quantity $_{DAM}$ x Intertie LMP$_{DAM}$

Export Leg Settlement $_{DAM}$ = Export Scheduled Quantity $_{DAM}$ x Sink Intertie LMP$_{DAM}$

= -20 MW x $20 **= -$400**

RT Export (Balancing) Settlement [From Section 5.1, Eq. 3]

Intertie Transaction Settlement $_{RT}$ = (Quantity $_{RT}$ – Quantity $_{DAM}$) x ISP$_{RT}$

Export Leg Settlement $_{RT}$ = (Export Metered Quantity $_{RT}$ – Export Scheduled Quantity $_{DAM}$) x Sink ISP$_{RT}$

= [-20MW – (-20MW)] x $40 **= $0**

The net energy settlement for the export leg of the linked wheel transaction is **-$400**.

Net Settlement:

In conclusion, the linked wheel transaction is paid $600 for the import leg and pays $400 for the export leg. The net settlement for the linked wheel transaction is **$200**.

Appendix B – Examples: RT Settlement of Linked Wheel Transactions

This section provides four examples to illustrate how linked wheel intertie transactions will be settled that do not participate in the DAM and flow only in RT. The following examples include settlement calculations for different types of intertie congestion at source and sink interties.

Each example shows a different intertie congestion scenario between the example source intertie and another sink intertie, as listed below:

1. No intertie congestion
2. Import-congested import leg
3. Export-congested export leg
4. Export-congested export leg, import-congested import leg

Example 1 – No Intertie Congestion

In this example, the source and sink interties are not congested. The RT settlement of the linked wheel intertie transaction is shown in the following tables:

Table 1 – Example 1 Variables

Linked Wheel	Schedules	Pre-Dispatch Prices	Real-Time Prices
1) Import Leg	$Quantity_{RT}$: 20MW	Source Intertie LMP_{PD}: $25 Source Intertie Internal LMP_{PD}: $25	Source Intertie Internal LMP_{RT}: $20
2) Export Leg	$Quantity_{RT}$: -20MW	Sink Intertie LMP_{PD}: $30 Sink Intertie Internal LMP_{PD}: $30	Sink Intertie Internal LMP_{RT}: $15

Table 2 – RT Import Settlement at the Source Intertie Under No Congestion

Step	Reference	Calculation	Result	Description
1) Calculate Source ICP	Section 5.2, Eq. 3	= *Intertie* LMP_{PD} - *Intertie Internal* LMP_{PD} = $25/MW - $25/MW	**= $0/MW**	The source intertie is **not congested** when the PD ICP is zero.
2) Calculate Source ISP_{RT}	Section 5.2, Eq. 4A	= *Intertie Internal* LMP_{RT} = $20/MW	**= $20/MW**	Under **no congestion**, the source ISP is equal to the RT source intertie internal LMP.
3) Calculate Settlement	Section 5.2, Eq. 5	= $Quantity_{RT}$ x ISP_{RT} = 20MW x $20/MW	**= $400**	The market participant will be credited $400 for the import leg schedule of 20MW.

Table 3 – RT Export Settlement at the Sink Intertie Under No Congestion

Step	Reference	Calculation	Result	Description
1) Calculate Sink ICP	Section 5.2, Eq. 3	= *Intertie* LMP_{PD} - *Intertie Internal* LMP_{PD} = $30/MW - $30/MW	**= $0/MW**	The sink intertie is **not congested** when the PD ICP is zero.
2) Calculate Sink ISP_{RT}	Section 5.2, Eq. 4A	= *Intertie Internal* LMP_{RT} = $15/MW	**= $15/MW**	Under **no congestion**, the sink ISP is equal to the RT sink intertie internal LMP.
3) Calculate Settlement	Section 5.2, Eq. 5	= $Quantity_{RT}$ x ISP_{RT} = - 20MW x $15/MW	**= -$300**	The market participant will be debited $300 for the export leg schedule of - 20 MW.

The net settlement for the linked wheel transaction is **$100**.

Example 2 – Export-Congested Export Leg

In this example, there is congestion on the sink (export) intertie. The RT settlement of the linked wheel intertie transaction is shown in the following tables:

Table 4 – Example 2 Variables

Linked Wheel	Schedules	Pre-Dispatch Prices	Real-Time Prices
1) Import Leg	$Quantity_{RT}$: 20MW	Source Intertie LMP_{PD}: $25 Source Intertie Internal LMP_{PD}: $25	Source Intertie Internal LMP_{RT}: $20
2) Export Leg	$Quantity_{RT}$: -20MW	Sink Intertie LMP_{PD}: $30 Sink Intertie Internal LMP_{PD}: $20	Sink Intertie Internal LMP_{RT}: $15

Table 5 – RT Import Settlement at the Source Intertie Under No Congestion

Step	Reference	Calculation	Result	Description
1) Calculate Source ICP	Section 5.2, Eq. 3	= *Intertie* LMP_{PD} - *Intertie Internal* LMP_{PD} = $25/MW - $25/MW	**= $0/MW**	The source intertie is **not congested** when the PD ICP is zero.
2) Calculate Source ISP_{RT}	Section 5.2, Eq. 4A	= *Intertie Internal* LMP_{RT} = $20/MW	**= $20/MW**	Under **no congestion**, the source ISP is equal to the RT source intertie internal LMP.
3) Calculate Settlement	Section 5.2, Eq. 5	= $Quantity_{RT}$ x ISP_{RT} = 20MW x $ 20/MW	**= $400**	The market participant will be credited $400 for the import leg schedule of 20MW.

Table 6 – RT Export Settlement at the Sink Intertie Under Export-Congestion

Step	Reference	Calculation	Result	Description
1) Calculate Sink ICP	Section 5.2, Eq. 3	= *Intertie* LMP_{PD} - *Intertie Internal* LMP_{PD} = $30/MW - $20/MW	**= $10/MW**	The sink intertie is **export-congested** when the PD ICP is positive.
2) Calculate Sink ISP_{RT}	Section 5.2, Eq. 4B	= *Intertie Internal* LMP_{RT} + ICP_{PD} = $15/MW + $10/MW	**= $25/MW**	Under **export-congestion**, the sink ISP is sum of the RT sink intertie internal LMP and the PD ICP.
3) Calculate Settlement	Section 5.2, Eq. 5	= $Quantity_{RT}$ x ISP_{RT} = -20MW x $25/MW	**= -$500**	The market participant will be debited $500 for the export leg schedule of -20 MW.

The net settlement for the linked wheel transaction is **-$100**.

Example 3 – Import-Congested Import Leg

In this example, there is congestion on the source (import) intertie. The RT settlement of the linked wheel intertie transaction is shown in the following tables:

Table 7 – Example 3 Variables

Linked Wheel	Schedules	Pre-Dispatch Prices	Real-Time Prices
1) Import Leg	$Quantity_{RT}$: 20MW	Source Intertie LMP_{PD}: $25 Source Intertie Internal LMP_{PD}: $30	Source Intertie Internal LMP_{RT}: $20
2) Export Leg	$Quantity_{RT}$: -20MW	Sink Intertie LMP_{PD}: $30 Sink Intertie Internal LMP_{PD}: $30	Sink Intertie Internal LMP_{RT}: $15

Table 8 – RT Import Settlement at the Source Intertie Under Import-Congestion

Step	Reference	Calculation	Result	Description
1) Calculate Source ICP	Section 5.2, Eq. 3	= *Intertie* LMP_{PD} - *Intertie Internal* LMP_{PD} = $25/MW - $30/MW	**= - $5/MW**	The source intertie is **import-congested** when the PD ICP is negative.
2) Calculate Source ISP_{RT}	Section 5.2, Eq. 4C	= *Min {Intertie* LMP_{PD}*, Intertie Internal* LMP_{RT}*}* = *Min {$25/MW, $20/MW}* = $20/MW	**= $20/MW**	Under **import-congestion**, the source ISP is the lesser of the PD intertie LMP and the RT intertie internal LMP.
3) Calculate Settlement	Section 5.2, Eq. 5	= $Quantity_{RT}$ x ISP_{RT} = 20MW x $ 20/MW	**= $400**	The market participant will be credited $400 for the import leg schedule of 20MW.

Table 9 – RT Export Settlement at the Sink Intertie Under No Congestion

Step	Reference	Calculation	Result	Description
1) Calculate Sink ICP	Section 5.2, Eq. 3	= *Intertie* LMP_{PD} - *Intertie Internal* LMP_{PD} = $30/MW - $30/MW	**= $0/MW**	The sink intertie is **not congested** when the PD ICP is zero.
2) Calculate Sink ISP_{RT}	Section 5.2, Eq. 4A	= *Intertie Internal* LMP_{RT} = $15/MW	**= $15/MW**	Under **no congestion**, the sink ISP is equal to the RT sink intertie internal LMP.
3) Calculate Settlement	Section 5.2, Eq. 5	= $Quantity_{RT}$ x ISP_{RT} = -20 MW x $15/MW	**= -$300**	The market participant will be debited $300 for the export leg schedule of -20MW.

The net settlement for the linked wheel transaction is **$100**.

Example 4 – Import-Congested Import Leg and Export-Congested Export Leg

In this example, the source (import) intertie is import-congested and the sink (export) intertie is export-congested. The net RT settlement is shown in the following tables:

Table 10 – Example 4 Variables

Linked Wheel	Schedules	Pre-Dispatch Prices	Real-Time Prices
1) Import Leg	$Quantity_{RT}$: 20MW	Source Intertie LMP_{PD}: $25 Source Intertie Internal LMP_{PD}: $30	Source Intertie Internal LMP_{RT}: $15
2) Export Leg	$Quantity_{RT}$: -20MW	Sink Intertie LMP_{PD}: $35 Sink Intertie Internal LMP_{PD}: $30	Sink Intertie Internal LMP_{RT}: $10

Table 11 – RT Import Settlement at the Source Intertie Under Import-Congestion

Step	Reference	Calculation	Result	Description
1) Calculate Source ICP	Section 5.2, Eq. 3	= *Intertie* LMP_{PD} - *Intertie Internal* LMP_{PD} = $25/MW - $30/MW	**= -$5/MW**	The source intertie is **import-congested** when the PD ICP is negative.
2) Calculate Source ISP_{RT}	Section 5.2, Eq. 4B	= *Min {Intertie* LMP_{PD}, *Intertie Internal* LMP_{RT}*}* = *Min {$25/MW, $15/MW}* = $15/MW	**= $15/MW**	Under **import-congestion**, the source ISP is the lesser of the PD intertie LMP and the RT intertie internal LMP.
3) Calculate Settlement	Section 5.2, Eq. 5	= $Quantity_{RT}$ x ISP_{RT} = 20MW x $15/MW	**= $300**	The market participant will be credited $300 for the import leg schedule of 20MW.

Table 12 – RT Export Settlement at the Sink Intertie Under Export-Congestion

Step	Reference	Calculation	Result	Description
1) Calculate Sink ICP	Section 5.2, Eq. 3	= *Intertie* LMP_{PD} - *Intertie Internal* LMP_{PD} = $35/MW - $30/MW	**= $5/MW**	The sink intertie is **export-congested** when the PD ICP is positive.
2) Calculate Sink ISP_{RT}	Section 5.2, Eq. 4C	= *Intertie Internal* LMP_{RT} + ICP_{PD} = $10/MW + $5/MW	**= $15/MW**	Under **export-congestion**, the sink ISP is sum of the RT sink intertie internal LMP and the PD ICP.
3) Calculate Settlement	Section 5.2, Eq. 5	= $Quantity_{RT}$ x ISP_{RT} = -20MW x $15/MW	**= -$300**	The market participant will be debited $300 for the export leg schedule of -20MW.

The net settlement for the linked wheel transaction is **zero**.