MR-00338: Economic Dispatch of Linked Wheel – Further Design Details & Examples

Introduction

Linked wheels would be modeled in the IESO-administered markets as a single transaction with equal amounts of capacity (MW) at the source and sink. Linked wheel bids are defined as the willingness to pay for the difference between the source and the sink nodal prices. Linked wheels would be evaluated and scheduled with all other available resources (domestic supply and consumption, imports and exports) in the pre-dispatch constrained sequence.

Simplified Illustration of how Linked Wheels would be Evaluated

It is important to know that solving the optimization problem (i.e., load, generation, and all transactions) is done simultaneously, and not separately. However, a good way to effectively illustrate how linked wheels are scheduled is to look at it as a "sequential scheduling", i.e., the internal control area load is solved for first, and then wheels are scheduled. The following is a description of this approach.

For all the wheels that are bid, sources and sinks are identified. For each source area, a "linked wheel bid stack" is created from highest priced bid to lowest priced bid. A higher bid price for a wheel indicates that the market participant is willing to pay a higher difference between the sink and source nodal prices.

1. Once all internal load is met (i.e., solved), shadow prices are calculated at each node in the system, including the interties. For each source and sink control area combination pair, the difference between the shadow prices of these two points is computed. This parameter could be identified as 'Sink Source Differential'.

   Sink Source Differential = sink shadow price *minus* source shadow price

2. For each pair of source/sink combination, 1 MW is "injected" into the source and 1 MW is "withdrawn" from the sink. This may or may not cause the shadow price at each external point to change (as a result of changes in congestion and losses between these two points). In either case, the Sink Source Differential is calculated, and the wheel with the highest bid price (from the "linked wheel bid stack") will be scheduled for 1 MW, as long as its bid price is equal to or greater than Sink Source Differential. Next, 1 MW is again injected in the source and 1 MW withdrawn from sink. The Sink Source Differential is again computed, and the wheel with the highest bid price is again scheduled for another MW, as long as its bid price is still greater or equal to the Sink Source Differential.

3. As long as the Sink Source Differential remains less than the wheel with the highest bid price, this process will continue until all of the MWs bid for this wheel are scheduled. At this point, if Sink Source Differential is less than the next highest bid price in the linked wheel bid stack, the wheel with the next highest bid price will be scheduled 1 MW at a time (i.e., inject 1 MW in source and

withdraw 1 MW from sink, and compute Sink Source Differential) until either all of its MWs are scheduled or Sink Source Differential becomes greater than its bid price. Thus, all wheel transactions between two control areas can be scheduled if the Sink Source Differential between these control areas is less than the lowest wheel bid in the source control area. If Sink Source Differential falls between the highest and lowest wheel bids, then all wheel MWs with bid prices greater than the Sink Source Differential will be scheduled. This can lead to partially scheduled wheels.

4. The final Sink Source Differential computed for any or all scheduled wheels is the final value of Sink Source Differential.

Even though the above examples shows the linked wheels being scheduled after the internal consumption and supply is solved, the optimization problem, in reality, would be solved simultaneously, not separately. It is inherent in the optimization that the amount of wheels scheduled is driven by difference in the shadow prices between the sink and the source.

How are Linked Wheels Evaluated Against Imports

In order to evaluate linked wheels and imports simultaneously, the "benefit" of each type of transaction is used. Linked wheels and imports can then be compared on the basis of their relative "benefit".

For a linked wheel, the benefit is defined as:
Linked Wheel Benefit = Linked Wheel Bid Price *minus* Sink Source Differential

For an import, the benefit is defined as:
Import Benefit = Source Shadow Price *minus* Import Offer Price

To illustrate how linked wheels would be evaluated against import transactions, consider the following simplified example:

- the sink shadow price is $50
- the source shadow price is $20
- the linked wheel bid stack at the source is:
    - Linked Wheel A: 100 MW, bid at $40/MW
    - Linked Wheel B: 50 MW, bid at $35/MW
- the stack of imports at the source is:
    - Import A: 75 MW, offered at $15/MW
    - Import B: 50 MW, offered at $20/MW.

The Sink Source Differential at the start of the evaluation is $50 - $20 = $30.

The benefit for the first MW from Linked Wheel A is $40 - $30 = $10.

The benefit for the first MW from Import A is $20 - $15 = $5.

As the Linked Wheel A benefit is greater than the Import A benefit, one MW of Linked Wheel A is scheduled as 1 MW injection at the source and 1 MW withdrawal at the sink. The shadow prices are recalculated. Let us assume that the shadow prices do NOT change as a result of the 1 MW of the linked wheel being scheduled.

The benefit of the next MW of Linked Wheel A is still $10. The benefit for the first MW from Import A is still $5. Again, one MW of Linked Wheel A is scheduled and the shadow prices are recalculated, and so on.

Some points to note:

1) If the source nodal price changes such that the benefit of the first MW of Import A becomes greater than the benefit of the next MW of Linked Wheel A, then the first MW of Import A would be scheduled rather than the next MW of Linked Wheel A.
2) Partial scheduling of linked wheels can occur if:
    a) The source tie-line capacity is reached before all bid linked wheels and offered imports are scheduled.
    b) The Sink Source Differential exceeds the bid price of a linked wheel before the entire linked wheel is scheduled.
3) The relative and absolute amounts of the linked wheel and imports that are ultimately scheduled depend on the source and sink prices.

How are Linked Wheels Evaluated Against Exports

Linked wheels would not be evaluated explicitly against exports at the sink. Rather, a constraint would be used in the optimization algorithm that the MW level of a linked wheel at the sink must equal the MW level of that linked wheel at the source. Referring back to the simple example above, if for the next MW of the Linked Wheel A, the constraint that the sink MW level equal the source MW level cannot be met, then the next MW of the Linked Wheel A would not be scheduled at the source.

Again, all of these evaluations and the optimization would be done simultaneously.