Preserving Revenue Adequacy in FTR Markets with Changing Topology

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Outline

- Problem statement
- Key concepts
- Revenue adequacy theorem
- Topology Reconfiguration Rights (TRRs)
- Extended revenue adequacy theorem
- Calculation of TRR quantities
- Conclusions

Problem Statement per PJM Senior Task Force on FTR Revenue Adequacy

- FTR revenue inadequacy occurs when the total amount of congestion charges and excess FTR auction revenue is not sufficient to cover the value of FTR Target Allocations.
- Causes of FTR revenue inadequacy include the following:
  - I. when there is less transmission system capability available in actual operations than was assumed to be available in the FTR allocation and auction processes
  - II. when the day-ahead modeling on which FTRs are based does not match the performance of the real-time market
  - III. when revenue adequacy is impacted by certain types of FTR activity or other market product types, including but not limited to virtual transactions

Source: PJM. ARR/FTR Process Problem Statement, 2014

This presentation explicitly addresses item (i)

Key Concepts

Power network is a triplet {topology, constraints, limits}	$\mathbb{N} = \{\tau, C, F\}$
Auction network in which FTR auctions cleared and simultaneously feasible	$\mathbb{N}_a = \{\tau_a, C_a, F_a\}$
Market network in which DA prices are formed	$\mathbb{N}_m = \{\tau_m, C_m, F_m\}$
FTRs are defined by POI, POW and MW quantity	
Congestion rent in the DA market is collected on binding constraints in that market	
Constraint's original flow obligation to an FTR equal the FTR's MW quantity times the FTR's PTDF on that constraint, computed in the auction network	
Constraint's implied flow obligation to an FTR equals the FTR's MW quantity times FTR's PTDF on that constraint, computed in the market network	
Constraint's payout obligation to an FTR is the product of the constraint's shadow price and implied flow obligation to that FTR	

Simultaneous Feasibility and Revenue Adequacy

- FTRs are simultaneously feasible in a network if and only if for each constraint the sum of implied flow obligations to all FTRs does not exceed constraint's limit
- Revenue Adequacy Theorem

  If a set of FTRs is simultaneously feasible in the market network, congestion rent generated by each constraint in that network is greater or equal to the sum of payout obligations of that constraint

  Proof:

  [Constraint congestion rent]

  = [limit] x [shadow price] >= [sum of flow obligations] x [shadow price]

  QED

If auction and market networks topologies differ, simultaneous feasibility is no longer guaranteed

- Changes in topology change PTDFs
- Different PTDFs => implied flow obligations <> original flow obligations
- The sum of implied obligations may exceed the limit for a constraint
- Simultaneous feasibility could be violated
- Congestion rent could be insufficient to cover payout obligations

A Bad Solution

- "Let's pay each FTR according to original flow obligations"
- GOOD: FTRs will be revenue adequate
- VERY BAD: payments to FTRs will no longer be based on the difference of congestion components of LMPs at POW and POI
- This is VERY BAD because FTRs won't be providing the price hedge to market participants, which is their primary function

Properties of a Good Solution

- FTRs must provide an exact hedge on congestion differentials for LMPs
- FTRs must be fully funded

Therefore, if congestion rent is insufficient to fully fund FTRs, money must come from somewhere else

Change in Topology Entails Financial Responsibility

- At the FTR auction, transmission owners (TOs) are expected to guarantee to FTR buyers that the network used in the energy market settlements will remain unchanged as auctioned ("as promised")
- Auction revenues distributed to TOs through ARRs are paid in exchange for that guarantee
- Revenue inadequacy is a direct result of not being able to maintain the network "as promised"
- Entities responsible for topology deviations must pay (or receive payments) attributed to these deviations
- The key issue is how to value topology changes

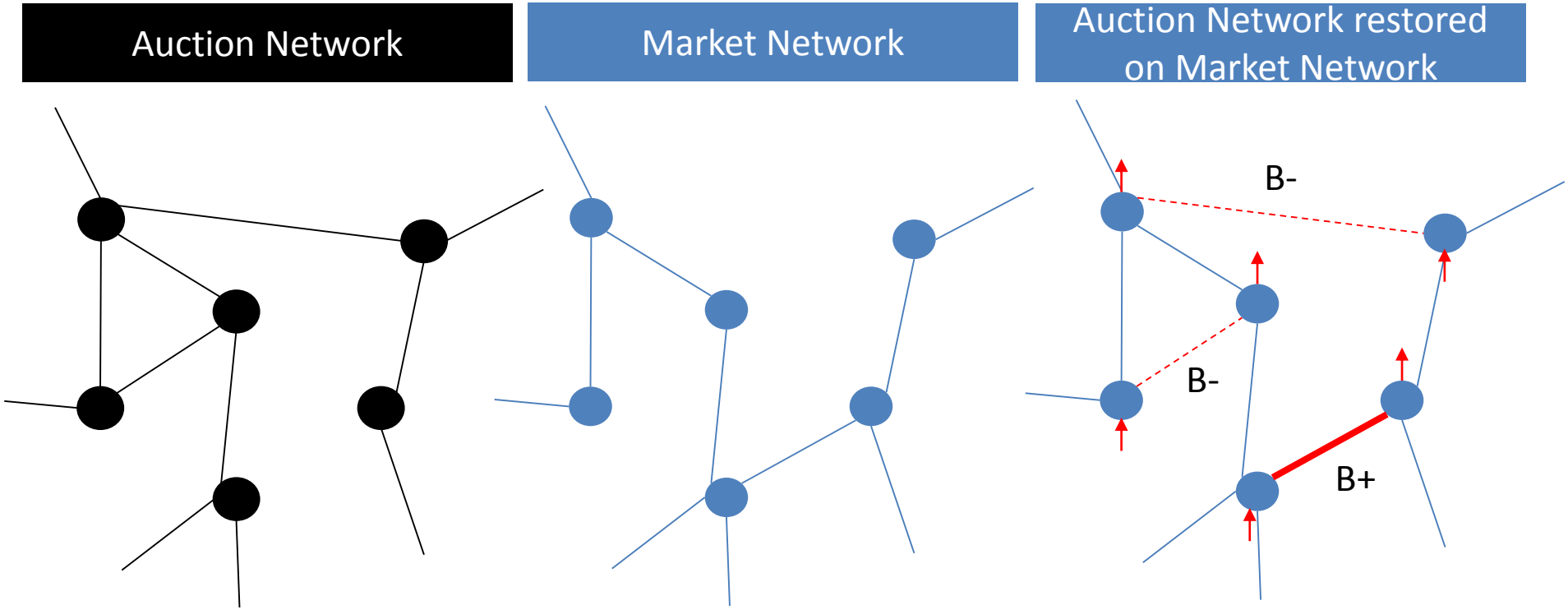
Topology Reconfiguration Rights (TRRs)

- We don't know *yet* how to value changes in topology but we do know how to value point-to-point transactions
- The major idea is to associate each topology changes with point-to-point transactions
- If a topology change generates the same impact on the network as the point-to-point transaction, both must have the same value

- The key idea is to
  - identify point-to-point to transactions replicating changes in topology,
  - identify economic value of each transaction and assign that value to corresponding topology change; and
  - make entities responsible for these changes pay or be paid in accordance with the economic value of topology changes they cause

- These point-to-point transactions replicating topology changes could be treated as Topology Reconfiguration Rights imposed on the market network in additions to FTRs
- The combination of FTRs and TRRs should be revenue adequate

Topology Reconfiguration and TRRs



B- are branches closed in the auction network but open in the market network (missing branches)
B+ are branches open in the auction network but closed in the market network (acquired branches)

The goal is to impose on the market network all FTRs and point-to-point transactions associated with branches from B- and B+ to make the resulting flows in the market network exactly match FTR induced flows in the auction network.

These point-to-point transactions (TRRs) restore the market network to the “as promised” state of the auction network

TRR Quantities are Contingency Dependent

- The “as promised” capability of the market network must be achieved not only in the base topology but also under any contingency
- This will make TRR quantities contingency dependent
- Unlike an FTR, a TRR is not a single transaction, it is a batch of transactions with the same POI, POW but with contingency-dependent quantities

Existence and Uniqueness of TRR Quantities

- Proposition 1.

  If the auction network and market network remain connected (not islanded) under all monitored contingencies, for each contingency there exists a unique set of TRR quantities restoring the market network to the "as promised" state
- See slides 15 – 16 for the proof
- Corollary: For each constraint, we can define implied flow obligation to each TRR. Indeed, under the constraint specific contingency, quantities for each TRRs could be uniquely determined. Implied flow obligation to the TRR can be calculated as a product of TRR quantity and PTDF of that TRR on the constraint in the market topology

Extended Revenue Adequacy Theorem

Under the conditions of Proposition 1, if a set of FTRs is simultaneously feasible in the auction network, congestion rent generated by each constraint in the market network is greater or equal to the sum of payout obligations of that constraint to FTRs and TRRs

Proof:

By construction, a set of FTRs and TRRs is simultaneously feasible and therefore for each constraint the sum of implied flow obligations to all FTRs and TRRs does not exceed constraint's limit.

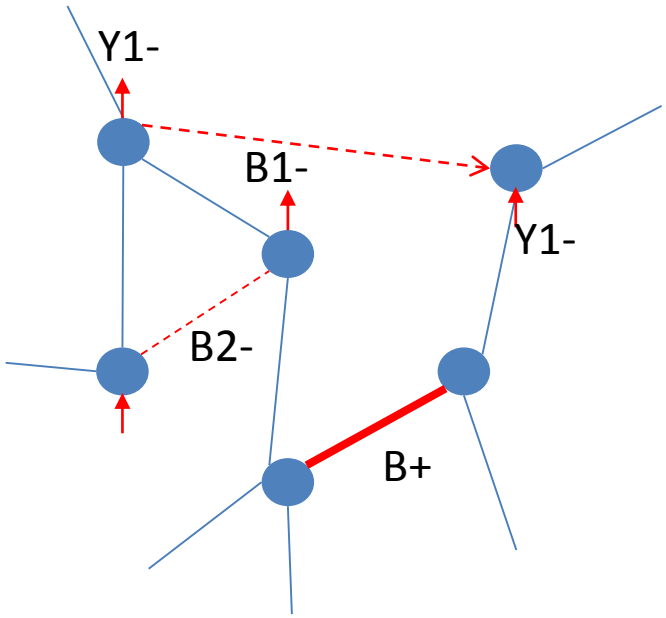
[Constraint congestion rent]

= [limit] x [shadow price] >= [sum of flow obligations] x [shadow price]

QED

With respect to FTRs and TRRs, the FTR mechanism is guaranteed to remain revenue adequate

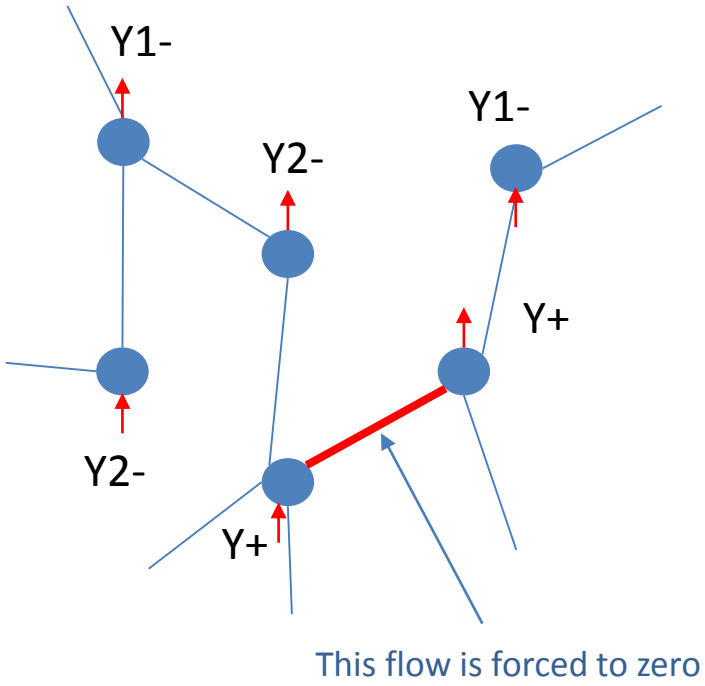
Proof of Proposition 1. Derivation of TRR quantities



- Dealing with missing branches
  - Consider market network under some contingency
  - Take a missing branch B1-. Find the flow Y1- on that branch in the auction network under that contingency
  - To replicate that flow in the market network impose a point-to-point transaction of the same magnitude Y1- but reverse points of injection and withdrawal (injection into the network must occur at the receiving end of the branch, withdrawal – at the sending end)
  - Impact of that flow on any constraint is

$$-(Y1-) \times PTDF_m$$

Proof of Proposition 1. Derivation of TRR quantities (cont'd)



- Dealing with acquired branches
  - Consider market network under some contingency
  - Take all acquired branches from B+
  - Find Flow Cancelling Transactions emulating opening of these branches under that contingency
  - Don't forget to account for the impact of imposed line closing transactions (Y1- and Y2-)
  - If after opening these branches network remains connected, FCTs exist and unique

Valuing TRRs

- Similarly to FTRs, TRR value is a sum across all constraints of payout obligations to that TRR
- However, because TRR quantities vary by contingency, payout obligations should be computed separately for each contingency and then summed across contingencies

Implementation and policy issues

- Technical implementation is relatively straightforward. When DA market settles, the DA topology in each hour should be compared to the auction topology and TRR quantities in each hour computed using standard linear algebra formulas
- Practical implementation requires political will to change the rules such that TOs will be responsible for TRR payments associated with topology deviations. Note that TRR payments can be positive and negative, some TRRs may result in revenues flowing to TOs.
- In markets where payments to FTR holders are discounted due to under-funding, implementation of this approach will restore hedging function of FTRs, reduce risk in DA market and in FTR market and increase auction revenues. This increase in revenues will likely offset payments TOs may be required to make associated to TRRs
- The implementation of this approach will provide TOs with an explicit market signal which will help them schedule transmission maintenance more efficiently

For more information

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