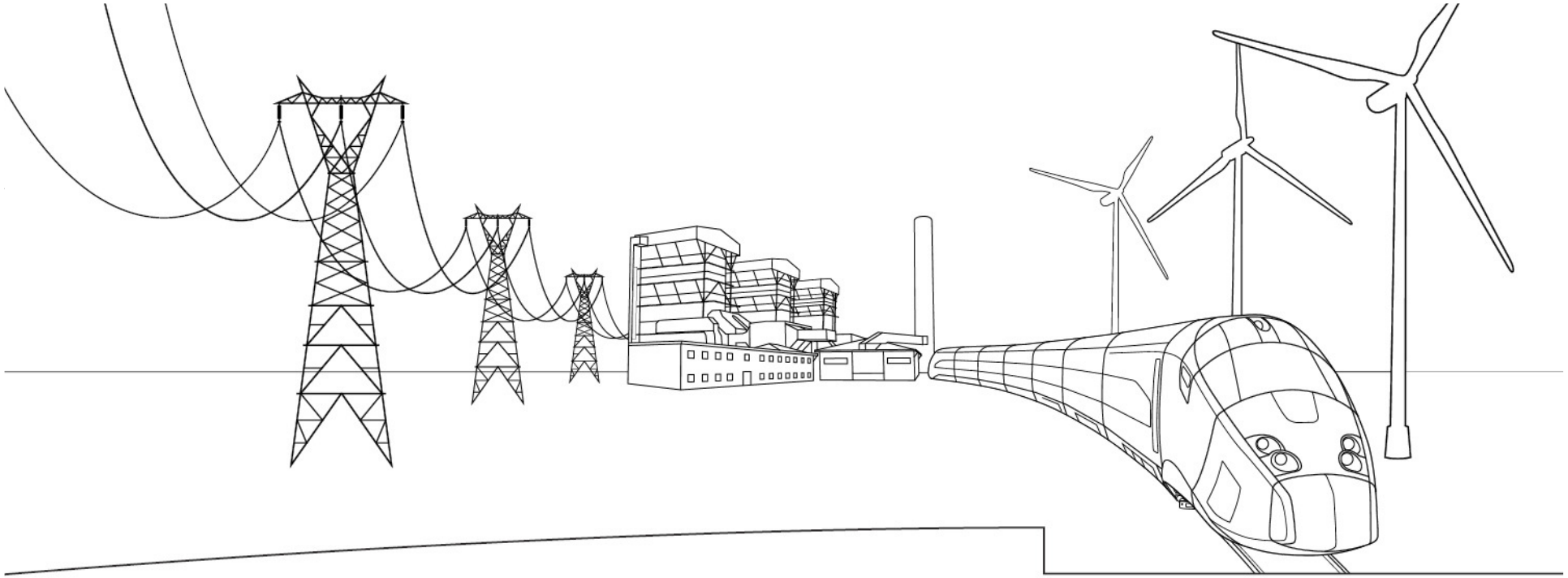

Approaches to Reduce Energy Uplift and PJM Experiences

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Shaping the future

Background

- Uplift payments ensure resources retain the incentive following RTO/ISO dispatch instructions, i.e., do not operate at a loss.
- Uplift payments occur in energy markets when the market clearing price cannot fully compensate costs of dispatched resources.
- One goal for RTOs/ISOs should be to minimize uplift payments, as uplift payments lack market transparency:
  - It can inhibit investment in areas where it may be needed;
  - The charges are not predictable and cannot be hedged on a forward basis.
- In early 2014, PJM and ALSTOM Grid launched a project to reduce uplift payment in both PJM Day-Ahead (DA) market and Real-Time (RT) Markets. The technical software has been operating in the PJM production environment since Nov.2014.

Major Causes of Uplift Payments

- Locational Marginal Price (LMP) only reflects marginal costs of delivering one more MW to any location on the system
  - Only reflected in the variable cost per MWh in energy offers;
  - Start-up and no-load costs are not included in LMP.
- Non-convexities in resource operation:
  - Long start-up time or min up/down time limits prevent unit shutdown during periods when the LMP is lower than the unit costs;
  - inflexible resources, such as Combustion Turbines (CTs), operating at economic minimum. These resources are not naturally able to set LMP
- Some resources are committed by RTOs for reactive control, black start, and so on, which are not modeled directly in the market clearing engines.
  - To the extent these resources have costs above market revenues they need to be compensated through uplift.

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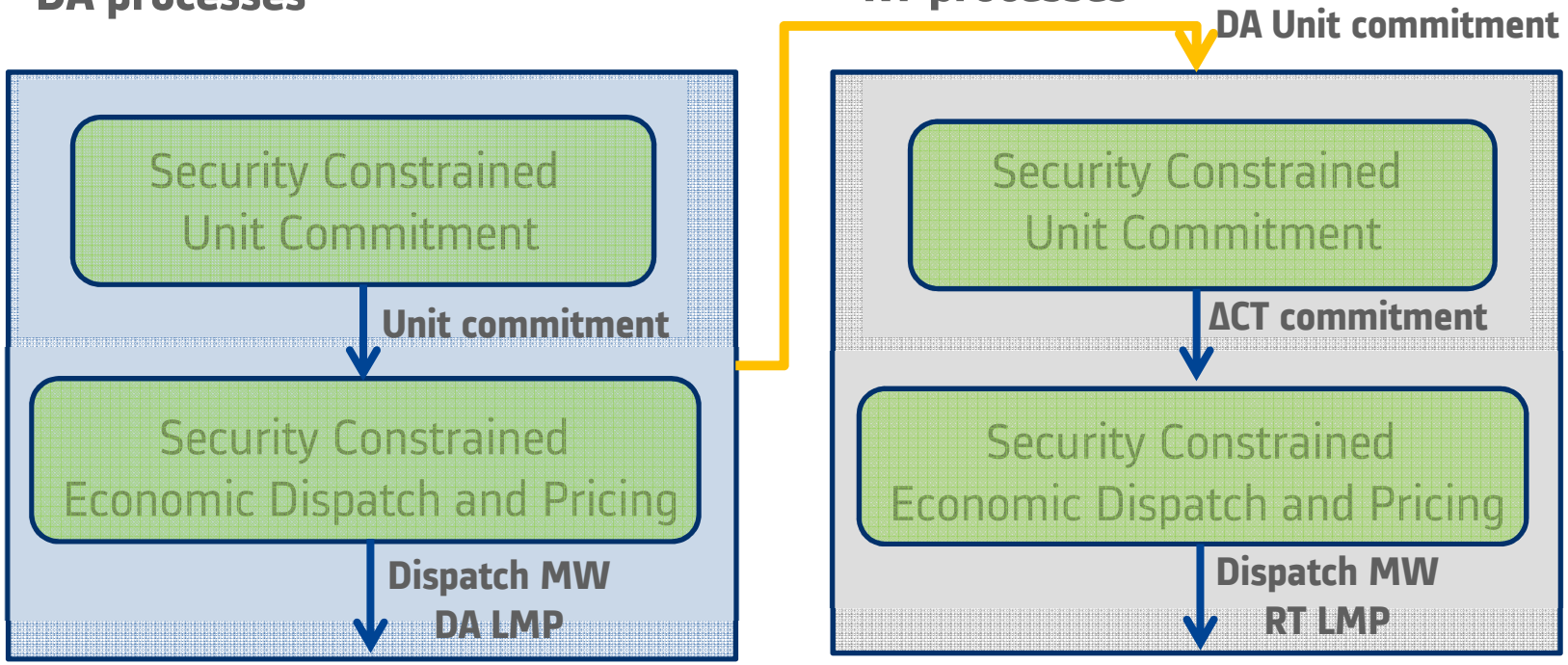
Approach 1 – Relaxing Inflexible or Non-Convex Operating Ranges of Resources

- Combustion Turbines (CTs) usually are offered as inflexible, i.e., with Ecomin= EcoMax. With this model, they cannot set price naturally;
  - For block-loaded CTs which are eligible to set price, relax its EcoMin by a factor.
  - The wider the relaxed dispatchable range, the better chance a unit has to set price. However, with a wider dispatchable range, the dispatch solution may be far below Ecomin.
- A similar problem could exist with steam resources that have a non-zero Ecomin level, and similar solutions could apply.

PJM Day-ahead/ Real-time Commitment/dispatch Pricing processes

- **DA processes**
- **RT processes**



- Within DA, SCUC may commit units for congestion. Commitment of a block-loaded unit to manage congestion may cause the constraint to no longer binding. Consequently, the unit may not set price in DA SCED. The same situation happens in RT as well;
- If units committed in DA may cause constraint not binding, RT won't be able to see the constraints, therefore, DA committed units may not set price in RT.

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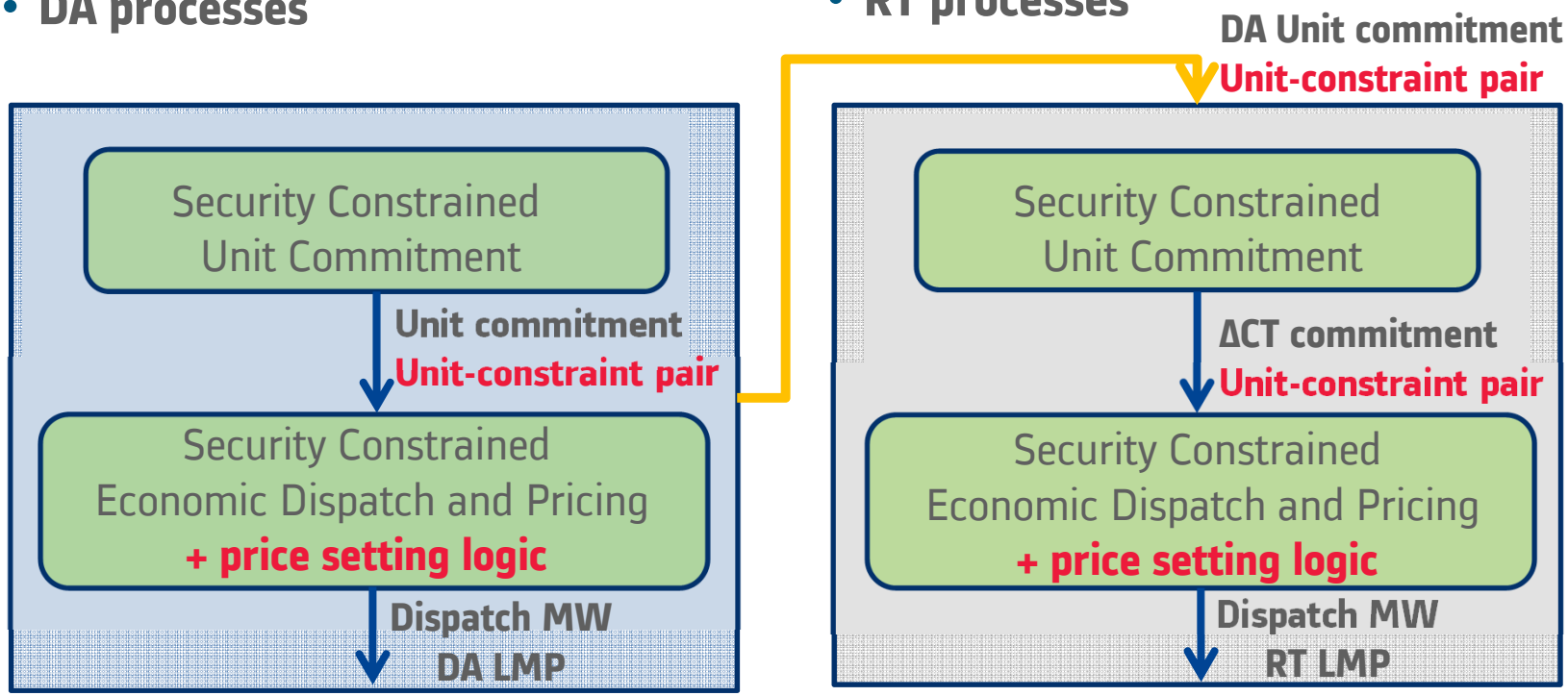
Approach 2 – Overall Price setting logic in SCED based on unit-constraint pair identified in SCUC (to be cont.)

- DA processes
- RT processes



- In DA/RT SCUCs, identify unit-constraint pair for constraints not binding due to commitment of block-loaded units;
- In DA/RT SCEDs, execute price setting logic to ensure the LMP can cover the price of those units.

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Approach 2 – step1: Identify Unit-Constraint Pair in SCUC

- If there exist any committed units satisfying all below criteria:
  - Not setting price;
  - Is dispatched at Ecomin;
  - Unit is “raise-help” on at least one transmission constraint that is not binding
- Then “relax” Ecomin to 0. Re-solve the relaxed model.
  - Check to see if some identified transmission constraints bind in the relaxed model;
  - If a transmission constraint binds, it means the constraints are relieved due to the non-convexity related to the commitment of block-loaded units;
- For each of those block-loaded units that set price in the relaxed model map to the binding transmission constraints in the relaxed model based on the magnitude of Dfax.

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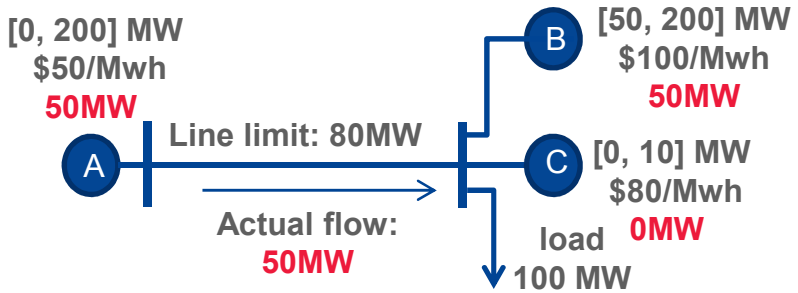
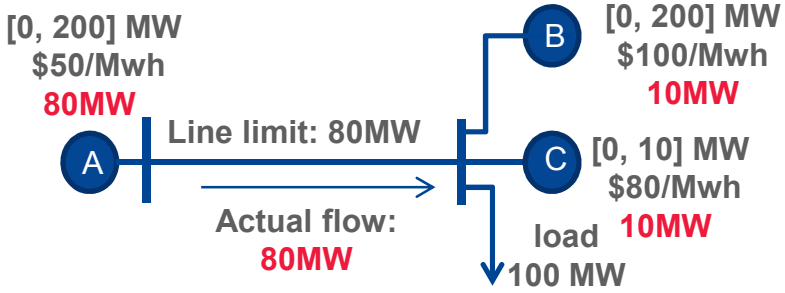
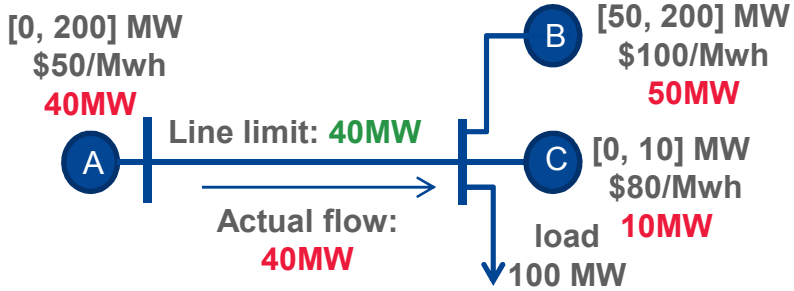
Approach 2 – step2: Based on Unit-Constraint Pairs in SCUC, SCED executes price setting logic (Scenario 1)



1. Original Solution (LMP at all busses=$50/MWh)



2. Solution with Ecomin Relaxed
(LMP @ A=$50/MWh, LMP@B,C = $100/MWh)



3. Solution with Line Limit Tightened (LMP @ A=$50/MWh, LMP@B,C = $100/MWh)

1. **Resolve with Ecomin being relaxed to 0MW;**
2. **Tighten line limit to** flow in the original solve (50)+ contribution of raise help units in the relaxed solution (-10)
3. **Re-solve the model with tightened line limit, i.e., 40MW**
4. **In the solution, check whether all the committed resources set price;**
5. **If not, need to iterate.**

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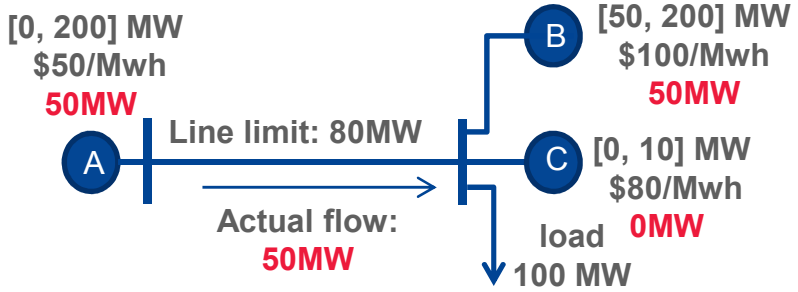
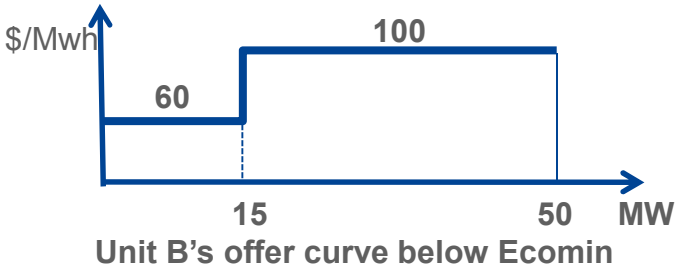
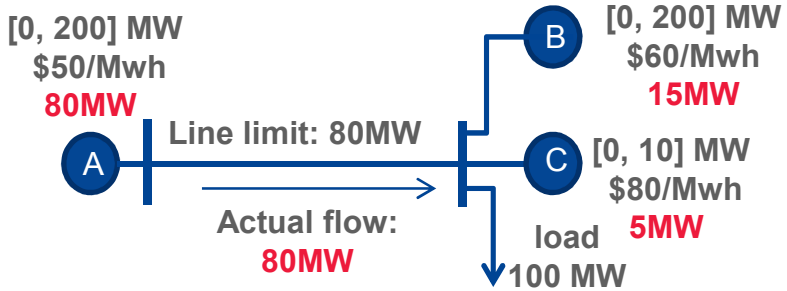
Approach 2 – step2: Based on Unit-Constraint Pairs in SCUC, SCED executes price setting logic (Scenario 2)



1. Original Solution (LMP at all busses=$50/MWh)

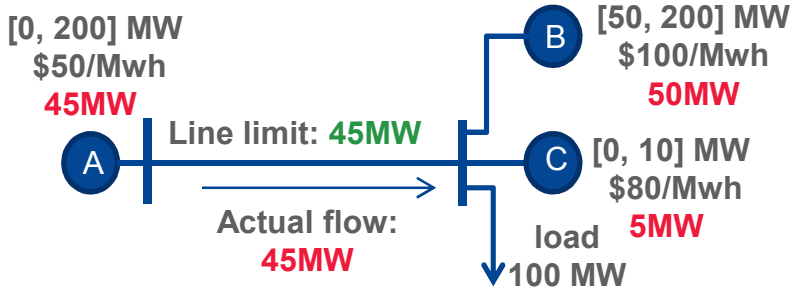


Unit B's offer curve below Ecomin



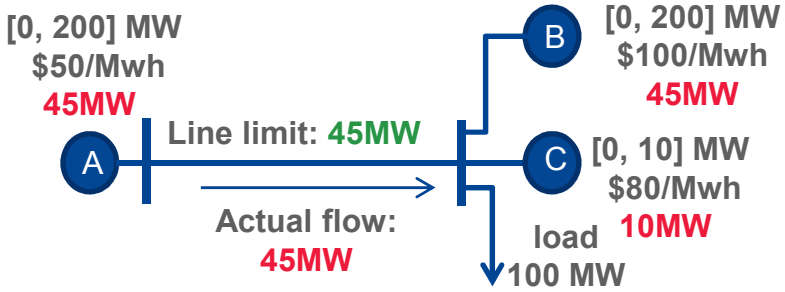
2. Solution with Ecomin Relaxed

(LMP @ A=$50/MWh, LMP@B,C = $80/MWh)



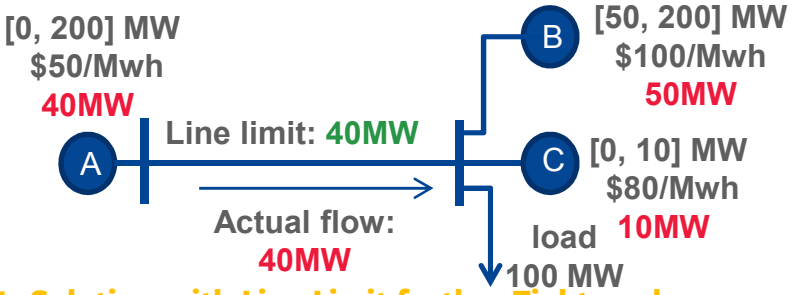
3. Solution with Line Limit Tightened

(LMP @ A=$50/MWh, LMP@B,C = $80/MWh)



4. Solution with Line Limit Tightened and Ecomin Relaxed

(LMP @ A=$50/MWh, LMP@B,C = $100/MWh)



5. Solution with Line Limit further Tightened

(LMP @ A=$50/MWh, LMP@B,C = $100/MWh)

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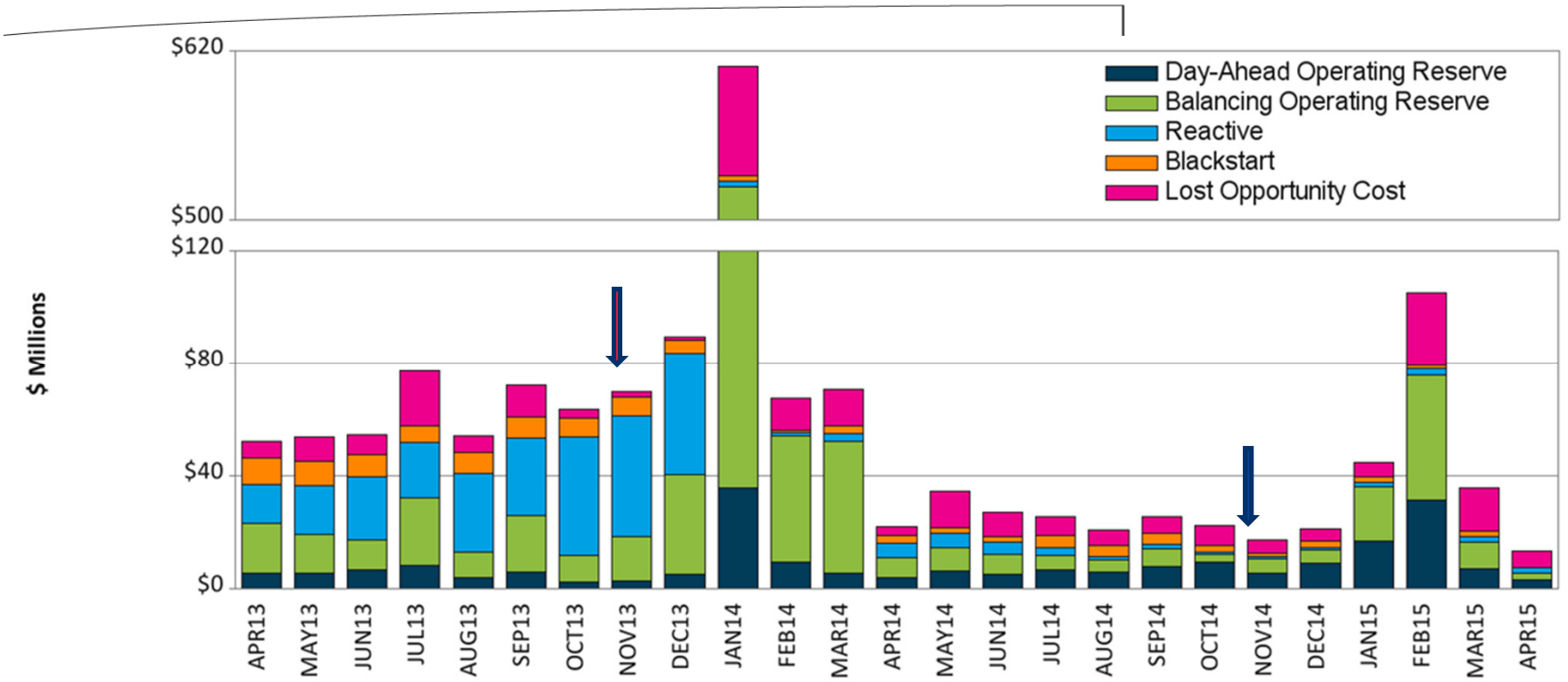
Approach 3 – Introducing Closed-Loop Interfaces

- Closed-Loop Interfaces are introduced to allow units committed for reactive/voltage support to set price by market clearing engines;
- Is a circular interface defined by a set of transmission lines that form a “pocket” with load and generation;
- By tighten line limit of close-loop constraints, the same logic as described in Approach 2 is used to ensure units for reactive/voltage support to set price.

Uplift Payments Profile



- The described reduce uplift logic was in production since Nov. 2014;
- Comparing Nov 2014 with Nov 2013, **uplift payments for reactive control resources** have been reduced from $40M to almost 0;
- **Uplift payments of RT market balancing operating reserve** are also seen significant reduction.

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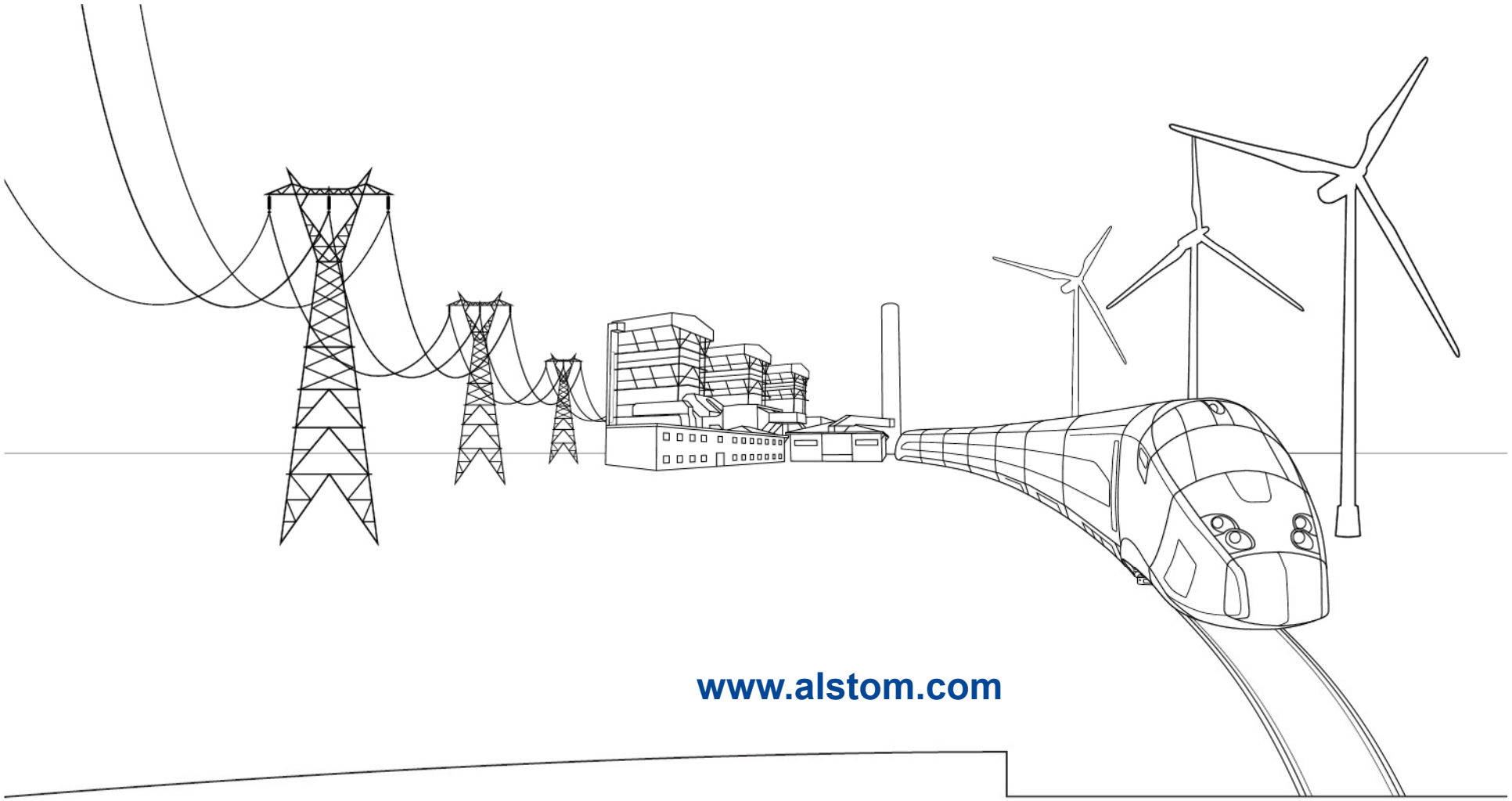

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