PowerGEM

Power Grid Engineering & Markets

Practical Security Constrained Unit Commitment Implementation Challenges

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PowerGEM

- PowerGEM has been developing SCED/SCUC software since 2001
  - PROBE - PoRtfolio Ownership and Bid Evaluation
  - Focus is on high performance and detailed models for fast and accurate solutions
  - Most experience is in day-ahead (DA), some in real-time (RT) and RUC
  - Implemented in NYISO (since 2002), PJM (2004)
  - ISO-NE, CAISO and MISO – in the delivery/initial usage state

PROBE Primary Objectives

- Exactly reproduce DA market implementation according to the rules/details of each ISO
  - Custom market rules, especially for ASM co-optimization and mitigation
  - Full network models (EMS or bus-branch), full N-1 with 1000+ contingencies per hour
  - Common solution engine for all versions
- Develop a study mode analysis tool for a variety of applications related to LMP markets
  - Transmission and generation outage evaluation; transmission planning
  - Market clearing decision support
  - Market power mitigation and various market monitoring applications
  - Testing planned market design changes and “What-if” scenario analysis and much more
  - May require hundreds of SCUC runs

Three SCUC Implementation Challenges

1. Modeling of virtual bidding
2. Should AC or DC load flow model be used for day-ahead SCUC?
3. Should non-dispatchable units be allowed to set LMP, and if so, what is the right solution?

<u>All these issues are not new</u>

- At most ISOs some solutions have been already implemented

1. Virtual Bidding Implementation

- Virtual bidding (or convergence bidding) is a critical component of the DA markets…
  - Provides DA and RT price convergence
  - Contributes to DA market liquidity and efficiency in mature LMP markets
- Virtual bids are typically modeled like physical generators and/or load bids
- However, excessive virtual bids can bring challenges from a SCUC implementation stand point which may not receive enough attention:
  A. Impact on load flow solution convergence, i.e. “virtual voltage collapse”
  B. Inefficiency of unit commitment due to excessive VB

A. Impact on Load Flow Solution Convergence

- With VB, local dispatch patterns may deviate significantly from what will happen later in RT and this can bring DA/RT convergence issues
  - Example: 200 MW of virtual load/generation at 6 KV bus; in SCUC software, such load will be modeled as a real load (or negative generation)
  - Grid was not designed for such load
- True iterative non-linear load flow (AC or DC) **should not converge** with 200 MW of load at 6 KV bus
  - If iterative load flow can't converge in this case, clearing of the DA market on time becomes a challenge
  - Convergence issues are typically localized

"Virtual Voltage Collapse" can be an everyday reality

VB Flow Convergence: Potential Solutions

Solution 1. Enforce more network constraints

- If constraint never binds in RT, should it be enforced in DA?

Solution 2. Use linear load flow (DC load flow) if iterative failed

- Major jump between solution models may lead to inconsistent results

Solution 3. Screening out excessive virtual bids before running DA

- 1000 MW in INC and DEC bid at one location may cancel each other for some LMP range and create major dispatch problem at different LMP levels

Solution 4. Limit VB to EHV network or zonal/aggregate locations

- This is a market design question to be decided by each individual ISO

Solution 5. Adaptive/hybrid solution

- As convergence issues are local, can we solve “exact” for most of the grid?
- See next slide

Solution 5. Adaptive Solution

- DA is a financial market and “financial” deviation from the precise LF model might be OK
- Adaptive solution will solve 99% of the grid exactly according to preferred non-linear load flow and provide simplified “Pseudo solution” in the “vicinity of the virtual voltage collapse”
- Has to be applied automatically without user interaction
  - We do this in PROBE today, but not automated
  - Based on the knowledge of the persistent virtual bidding patterns and offline analysis
- Challenge for load flow developers
  - Load Flow solution engine needs to be adjusted to diagnose and correct the problem on the fly

B. VB Impact on Unit Commitment

- In general, there are typically 3 SCUC runs for one market day
  - DA – financial, ~90% of the market, VB exists in DA only
  - RUC – assure sufficient resource available
  - RT
- Can excessive VB cause inefficiencies in UC, and can DA UC inefficiencies be corrected in RT?
  - RT as a balancing market will adjust DA dispatch without any problems…
  - …but DA commitment (over- and under-commitment) usually cannot be "undone" by RT
  - If a steam (longer start up) unit was started in DA, it likely will run, even if it is not needed in RT
  - Competitive unit not committed in DA/RUC may not be able to run in RT
- In the long run market will settle - thanks to VB, but short term impact is worth further analysis

2. What Load Flow Models Should Be Used for DA SCUC?

- What do we mean by DC or AC load flow solution?
  - AC or DC may have different meaning for people with different backgrounds
- What LF models are used now for DA and RT?

LF models/solution methods

- Full AC LF – with MW and MVAr
  - Classic RT EMS model
  - The only model that computes voltage magnitudes and MVAr flows
- Linear DC load flow
  - Too simplified for production, not the best for marginal losses
  - Fine for market design testing and simplified analysis
- Iterative non-linear MW-only load flow solution
  - Should be called Hybrid AC/DC

There are many implementation variations of each method

Hybrid AC/DC MW only

- What is Iterative MW only LF?
  - The same load flow equations as classical AC LF, but
  - Solve for voltage angles, but assumes that voltage magnitudes do not change during solution
  - Commonly used method for DA now, used for many years
  - Some may call AC, some DC
- In most cases provides a very close estimate of MW flows and MW losses as compared to true AC
  - Allow consistent marginal losses implementation
- Voltage magnitudes do not need to be exactly 1.00
  - Voltage magnitudes can be based on RT historical values
  - Rating can be adjusted for prevailing RT MVAr flows or DA/RT uncertainties

What is a redispatch model?

- Even if initial solution is non-linear AC, incremental redispatch model is often linear
  - DFAX (PTDF, Sensitivity factors) are mostly from DC solution (can be AC based)
  - RT starts from true AC, but then use linear redispatch

- "True" non-linear models require successive linearization and assumes iterative resolving of non-linear LF until convergence is reached
  - Discrete non-convex nature of SCUC impacts convergence

AC LF Challenges for DA

- DA bid-in load represents ~90% of load
  - Is it possible to define voltage profiles and schedules for the whole day based on incomplete load?
- As there is No “DA MVAr market”, there will be always some simplifications if using “classical” AC LF models - “Free MVAr”
- Impact of virtual bids
  - If there is 100 MW virtual load bid, should there be ~50 MVArs of virtual load to keep power factor? (No)
- Coordination between ISOs
  - Flows on commercial flowgates play essential role for some ISOs, flows are computed via custom linear methods, not via load flow
  - How to model external areas? Modeling of loop flows is a critical issue for larger ISOs.

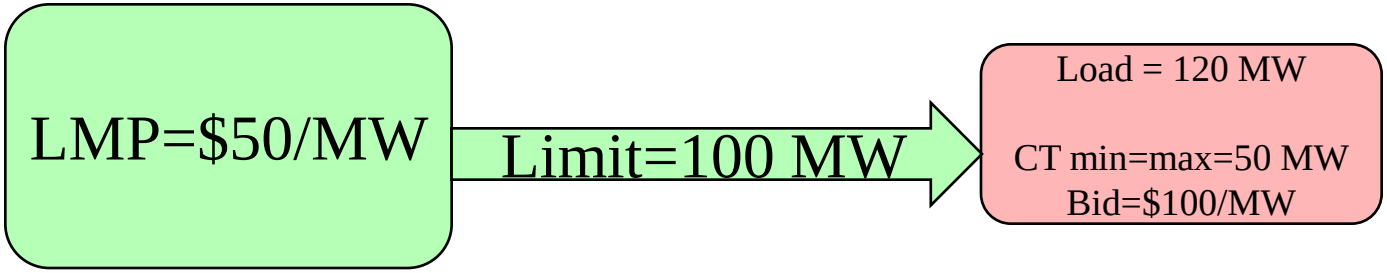
AC vs. Iterative AC/DC model

- Using iterative method with good MW losses estimates is critical
  - “MWs travel far” - MW errors accumulate and propagate
- AC LF model may give better results for areas impacted by voltage issues and reactive flows, but benefits may be marginal
  - “MVArs do not travel far” – may have little impact on the “top ten” binding constraints
- Contingencies can be modeled via less sophisticated methods
  - Modeling of all contingencies via full AC may impact performance

Conclusion on AC vs. DC

- There is no conceptual leap to implement AC LF for DA market and AC LF solution engines are well known/tested
- It is each ISO's decision regarding the model and the appropriate level of detail/options within the chosen DA SCUC model
- It would be great to agree on the terminology to avoid future confusion

3. Should Non-Dispatchable Units be Allowed to Set LMP?



- If CT runs, flow=70 MW < 100 MW Limit
- If CT doesn't run, flow=120 MW > Limit
- <u>Limiting branch flow can't be at the limit</u>. Is it a binding constraint?
- What should be the LMP in the load pocket?

What Are the Possible Options?

- Depending on the ISO and market type (DA or RT) you may get different answers
- In all cases, the impact on the minimized BPC is small, while the impact on LMPs is much higher
- Can we develop some standard solution?
  - Next slide demonstrates possible solutions in use now

What are the Possible Options?

Method 1 Do nothing: LMP=$50, MW=50, Pay uplift (BPCG)

Method 2 Model unit as dispatchable: LMP=$100, MW=20

- Dispatchable in DA, MP will then settle in RT or via VB

Method 3 Run in two separate passes

- Pricing and then scheduling (DA way), Pricing pass assume CT dispatchable
- Scheduling, then pricing (RT way)
- LMP=$100, MW=50
- Binding constraint flow below the limit

Conclusions

- DA SCUC implementation is complicated in itself, and there are additional challenges requiring careful implementation consideration
  - Including other implementation issues not discussed here
- Virtual Trading is an accepted LMP market feature that presents load flow solution challenges and may impact UC results
- True AC load flow for day-ahead SCUC/SCED may present more implementation challenges than hybrid MW-only AC/DC solutions and the cost-benefit for DA markets should be further evaluated
- Consideration of non-dispatchable generation impacts dispatch and LMP with no standard solution

Questions?