Extending ISO Operational Software to Long-Term Production Cost Models

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Summary

Purpose

- Demonstrate how market efficiency will benefit from extending ISO market clearing software details to long-term Production Cost Models (PCM)

Key Takeaways

- Future uncertainty requires modeling more details in PCM, not less
- Updated software design and computational approaches allow better alignment of long-term PCM with short-term markets
- Using the same solution engine for long-term analysis as for day-ahead markets is a sensible approach

Background

- PCM software is used to analyze future LMP markets, perform economic analysis of transmission projects & congestion costs, and assess other grid investments

- Traditional PCM software contains simplifications as compared to today's markets

- Many simplifications exist for good reason; certain market products and features have no place in long-term modeling
  - **However, many simplifications are legacies of older software and computational limitations**

- This results in inefficiencies as long-term modeling is increasingly disconnected from market design and function

PCM vs Markets vs Transmission Planning

Short-term Markets

- Real-time / Day-ahead / Next week
- Focus on ISO footprint, EMS based models
- Approximately 1000 contingencies
- Ancillary Services (AS) modeling
- Large share of generators are self committed – see our presentation with MISO (FERC June 2018)

Transmission Planning (reliability)

- 1-10 years out
- US wide planning Load Flow (LF) cases (EI, WECC)
- 10,000+ contingencies - more constraints than short-term
- N-1 and N-1-1, transfer analysis
- Generation Deliverability accounting for uncertainties in dispatch, cost allocation

PCM

- Few months out to 10 years
- Same LF case as in transmission planning
- Contingencies/constraints - should align with transmission planning, i.e. N-1
- More uncertainties than short-term or planning

PCM Aligned with Today's Markets has Many Benefits – The Market Efficiency Argument

- Modeling the future in accordance with actual and evolving market rules & features reduces risk of producing results disconnected from ISO markets
- New technologies such as battery storage and renewables require more modeling details, adaptable to new rules as developed by market operators and FERC
- For medium-term study (one month to one year), an accurate extension of actual market software is needed to determine economic impact of transmission outages and market design changes

PCM Aligned with Today's Markets has Many Benefits – From a Developer's perspective

- When a developer is assessing a new grid investment (generation, transmission, etc.), they require accurate projection of revenues and cost/benefit
  - Need confidence that models reasonably represent future benefits and risks
  - Developers of new technologies are interested in potential revenues from ancillary markets
  - PowerGEM consistently hears… "more detail is better"

- A frequent question renewable generation developers ask is: what is the transmission congestion and curtailment risk surrounding my project?
  - Software must be able to handle all transmission elements and contingencies that may be modeled in future day-ahead and real-time markets to answer this question

Key Elements of Market Clearing Software to Extend to PCM

Improvements for Discussion Today

- Utilize consistent software solution methodology from short-term to PCM
- Add transmission detail: N-1 contingency analysis, outage modeling
- Design and improve energy storage modeling based on day-ahead experience
- Extend more elements of short-term ancillary services modeling to PCM

Additional Considerations

- Unit commitment cycles aligned with ISO markets
- Additional bid types
- Day-ahead to real-time transition modeling

I: Basis for Enhanced PCM – Improved Software and Computational Methods

- The PowerGEM approach is to use the same solution engine to perform long-term PCM as to replicate short-term ISO markets
  - No need to “reinvent the wheel” and keep separate solvers

- Improved solution methodologies and performance implemented for day-ahead are automatically implemented in PCM – and vice versa

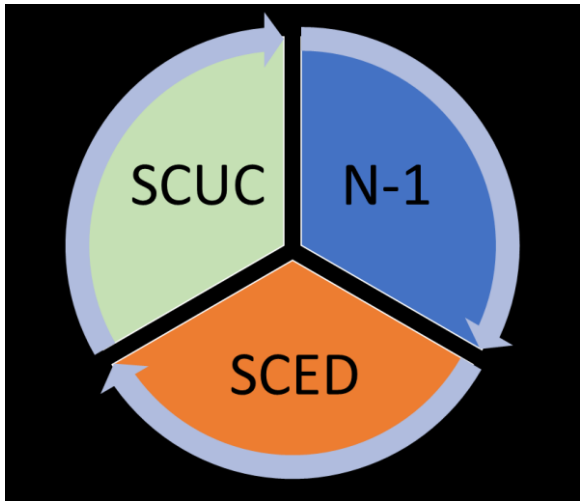
PROBE Market Simulation and PCM Software

- Implemented at five ISOs over a 15-year time frame
  - Subject of several joint ISO/PowerGEM FERC presentations over the last 8-10 years
  - Models day-ahead, real-time, supplemental commitment (RAC/RUC)
  - Mid-term (1-3 month ahead) simulation: transmission outage coordination and FTR adequacy

- Licensed to non-ISOs as a longer-term PCM software
  - Same solution engine for ISO versions and PCM; no disconnect between short and long-term

- Current performance: 1-2 minutes per day for the largest ISOs with many (10,000 or more) constraints; 6 to 10 CPU hours to run 365 days
  - **Performance quoted is for any above-average laptop**; using multi-core capabilities or more powerful computing can certainly speed this time

PROBE Implementation Overview



PowerGEM doesn't decouple SCUC, SCED and N-1
It is a single integrated application

- SCUC calls SCED and N-1 CA internally many times until converged
- Numerous heuristics and constraint relaxation during SCUC search
- Little value in refining UC solution until all N-1 constraints enforced and flows are computed via non linear load flow near final solution

- **SCED is based on dual simplex LP**
- **Allows enforcing traditional N-1 with thousands of contingencies - discussed later**
- **Same SCUC Solver for ISO versions and PROBE LT**
- **Not using third party MIP solvers, everything is coded in C/C++**

II. Enable More Constraints in PCM

- Concern: Traditional PCM software supports a limited number of transmission constraints due to performance and memory limitations

- Allowing more constraints in PCM enables:
  - More realistic study of congestion and curtailment risk
  - Study of “micro-solutions” to local constraints such as Storage As a Transmission Asset (known as ‘SATA’ at MISO and CAISO)
  - Mid-term study consistent with actual operations

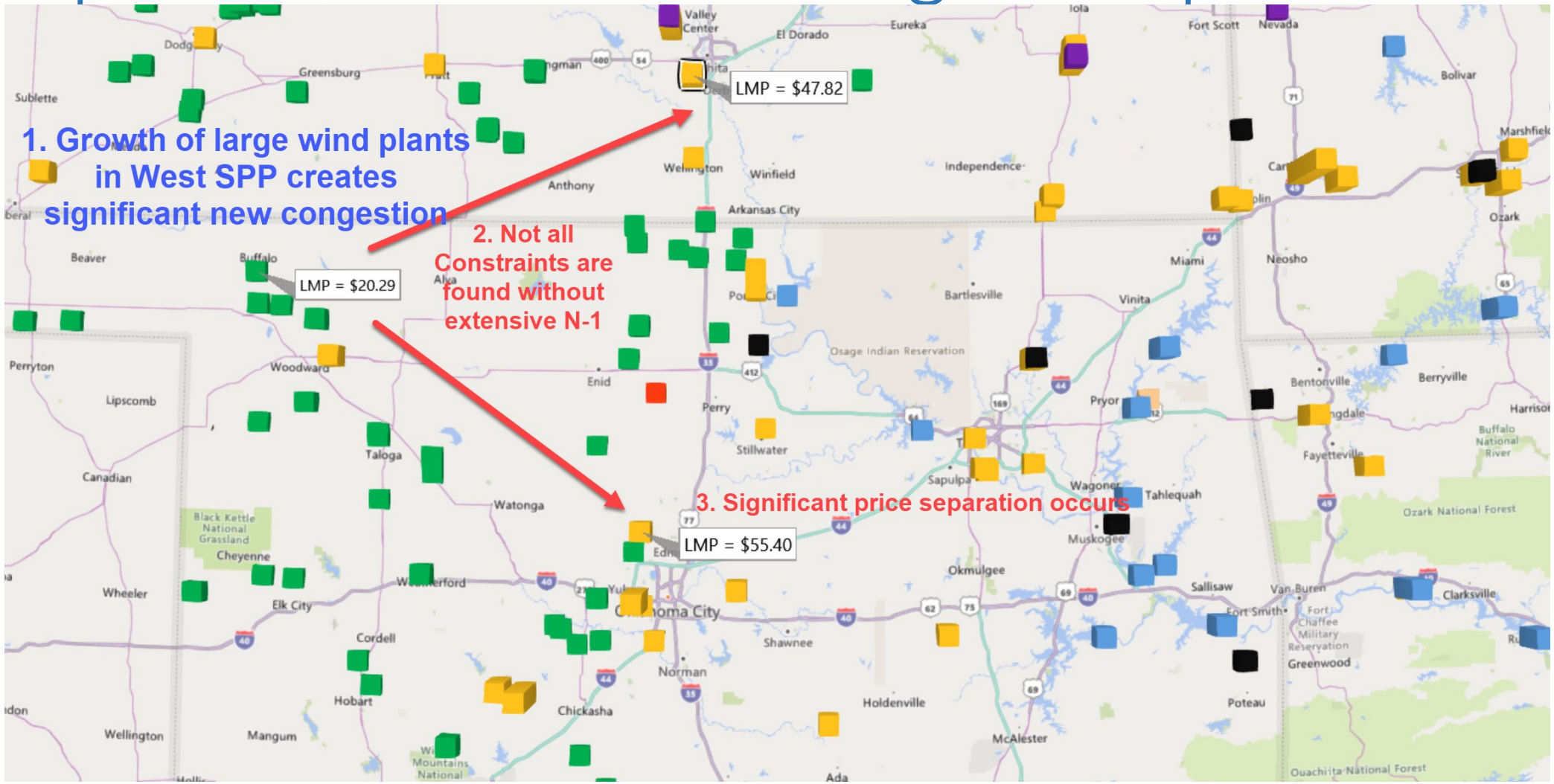
Constraint Monitoring Comparison

Traditional PCM: 500 to 1000 Monitored Flowgates, No or Limited N-1	
Results in fewer binding constraints	May under-report production cost

Short-term Markets: Several Thousand Constraints and Contingencies	
Captures daily market congestion	Continuously updated by ISOs

Advanced PCM: 18,000 Flowgates in Recent PowerGEM Long-term Simulations	
Identifies more congestion & wind curtailment	Better accounts for uncertainty; likely closer to markets

Impact of Limited Modeling: Example



Impact of Limited Modeling: Discussion

- Traditional PCM may not capture new congestion in this example
  - Developers (and their investors!) are not happy – revenues fall well short of expectations
- Traditional PCMs rely heavily on historic constraints
  - A few hundred historical constraints can't capture significant grid changes
- Inefficient for markets: PCM is overly optimistic on renewable energy delivered since it will model many fewer constraints than markets
  - Planners put markets in a bind by not accounting for and fixing this sooner

Solution: PCM with N-1 Contingency Analysis

- Solution 1 – conventional N-1
  - 1,000- 10,000+ monitored lines and 1,000- 5000+ contingencies
  - Many millions of mon/con pairs per each optimized time interval
- Solution 2 – Expanded flowgate model
  - Typically 10,000 – 20,000 mon/con pairs as a proxy for N-1 – faster than N-1
  - List is developed via proprietary flowgate screening method in PowerGEM TARA software
  - For given topology finds all flowgates that may be limiting for various dispatch scenarios
- Supplement with traditional voltage stability interfaces/nomograms as necessary

- Computational approach: Pre-computing distribution factors for all constraints for all time intervals with different topology is not efficient. Smarter, more accurate, and more efficient methods are used in PROBE.

III: Expand Transmission Outage Modeling, Details, and Methodologies to PCM

- Concern: Long-term PCM products limit transmission outage modeling
  - This may be ok for really long-term simulation, i.e. 2026 or 2028; outages are not available

- Extending advanced outage modeling to PCM “opens the door” to study the impact of proposed transmission outages on mid-term market outcomes
  - One to three-month FTR adequacy and outage analysis require details such as overlapping partial day outages

- Solution/implementation
  - Topology changes within a single SCUC solution window require recomputing distribution factors for each time horizon
  - In PROBE we assume that every time interval has different topology and different distribution factors, essential for intra-day outages

IV: Use Day-Ahead Energy Storage Resource (ESR) Modeling Experience for PCM

- Different ESRs have different characteristics, but basic approach doesn't change

	Large/long term ESR (Pump/Hydro)	Short term ESR (Battery)
Capacity	As large as 3000 MW	Mostly less than 100 MW
Operation cycle	Weekly or daily cycle	Multiple cycles in a day
Efficiency factor	Moderate 60% - 75%	Very high (>95%)
UC characteristics	More (such as EcoMin)	Less/none

- Enhanced ESR models will benefit PCM
  - ESRs may impact surrounding congestion (the "SATA" example)
  - Expected rapid growth of battery and other forms of ESRs following FERC order 841
  - Consistent with day-ahead approaches, and based on day-ahead market experience

ESR Approach: Adapt Day-ahead Pumped Storage Models

- ESR with capability to manage state of charge (SOC) can best utilize ESR's ability to improve market efficiency, but is more complicated to implement

- PowerGEM developed a proven, custom SOC model, used to optimize the world's largest pumped storage (Bath County in PJM) for 10+ years
  - **PowerGEM is implementing this model for PCM**

- Should ESR model be optimized via single day or longer solution window?
  - ISOs optimize storage via day-ahead market
  - Longer (weekly) solution window may misrepresent/overestimate ESR benefits

PROBE ESR Modeling Example

HH:MM	BidName	unTp/V	LMP	Dispat	Rever	SOC	ChargM	ChargM	GenM	GenM
00:00	Storage Proj 1	Battery	23.18	0	0	5	-20	0	0	20
01:00	Storage Proj 1	Battery	22.39	-5.5	-122.1	10.4	-20	0	0	20
02:00	Storage Proj 1	Battery	22.22	-20	-444.3	30.2	-20	0	0	20
03:00	Storage Proj 1	Battery	22.38	0	0	30.2	-20	0	0	20
04:00	Storage Proj 1	Battery	22.21	-20	-444.3	50	-20	0	0	20
05:00	Storage Proj 1	Battery	22.67	0	0	50	0	0	0	0
06:00	Storage Proj 1	Battery	29.4	0	0	50	0	0	0	0
07:00	Storage Proj 1	Battery	32.8	25	819.9	25	-25	0	0	25
08:00	Storage Proj 1	Battery	26.73	25	668.2	0	-25	0	0	25
09:00	Storage Proj 1	Battery	24.76	0	0	0	-25	0	0	25
10:00	Storage Proj 1	Battery	24.22	0	0	0	-25	0	0	25
11:00	Storage Proj 1	Battery	23	0	0	0	-25	0	0	25
12:00	Storage Proj 1	Battery	22.43	0	0	0	-25	0	0	25
13:00	Storage Proj 1	Battery	21.96	-0.5	-11.1	0.5	-25			
14:00	Storage Proj 1	Battery	21.69	-25	-542.2	25.3	-25			
15:00	Storage Proj 1	Battery	21.04	-25	-525.9	50	-25			
16:00	Storage Proj 1	Battery	21.66	0	0	50	-25			
17:00	Storage Proj 1	Battery	22.83	0	0	50	-25			
18:00	Storage Proj 1	Battery	23.09	0	0	50	-25			
19:00	Storage Proj 1	Battery	31.38	25	784.4	25	-25			
20:00	Storage Proj 1	Battery	27.92	25	698	0	-25			
21:00	Storage Proj 1	Battery	24.07	0	0	0	-25			
22:00	Storage Proj 1	Battery	23.06	0	0	0	-25			
23:00	Storage Proj 1	Battery	22.8	0	0	0	-25	0	0	25

Unit Name	Storage Proj 1
Efficiency Factor	0.97
Minimum State of Charge	0 Mwh
Maximum State of Charge	50 Mwh
Initial State of Charge	5 Mwh
Final State of Charge	0 Mwh
GenMax	25 Mw
ChargMax	-25 Mw

V. Implement DA Ancillary Services Modeling

- Ancillary services (AS) are a small part of short-term markets and overall market revenues – ***but don't tell that to market participants!***

- Concern: Co-optimization of AS consistent with ISO market approaches has largely been ignored by long-term PCM tools
  - Renewable capacity is now greater than coal (per FERC monthly energy update)
  - Growth of renewables & storage has required operators to study reserve requirements
  - New technology may rely on AS markets for revenues and seek accurate projections from production cost modeling

How do we Implement? Co-optimize Reserves Consistent with Markets – Example

HH:MM	AncilZoneName	AncilReqType	in_CombReqM	Min_ReqMW	AncilDispMW	AncilPrice
09:00	NYISO_AS_TOTAL	RegulDn	140	140	140	4.99
09:00	NYISO_AS_TOTAL	RegulUp	140	140	140	4.56
09:00	NYISO_AS_TOTAL	Spin	705	565	705	4.61
09:00	NYISO_AS_LongIsland	Spin	300	300	300	4.34
09:00	NYISO_AS_East	Spin	530	530	605	0
09:00	NYISO_AS_TOTAL	NonSpin	2670	1965	2670	2
09:00	NYISO_AS_LongIsland	NonSpin	900	600	900	2
09:00	NYISO_AS_SENY	NonSpin	1300	1300	2059.8	0
09:00	NYISO_AS_East	NonSpin	1400	870	2074.8	0
	Allows zonal "nesting"	**Four most common service types**	**Enforces "substitution" rules - higher quality reserves can substitute for lower**			**Detailed pricing**

In a recent 2026 PCM study, a generator in the NYISO queue in the Long Island zone was able to identify hundreds of thousands of dollars additional revenue on Long Island due to AS, and helped meet NYISO's expanded reserve requirements

- Enables study of reserve requirements and vast market changes to meet renewables goals such as NY state target of 9,000 MW offshore wind
- Provides better revenue projections to developers
- Fosters proper investment and sends appropriate market signals

Summary

- Software advancements leave no reason to use simplified PCMs
- Better transmission, ESR, and AS modeling are key areas where short-term market details can be extended to long-term PCM
- Advancing short-term market elements in PCM enables mid-term study in detail comparable to ISO day-ahead markets
- Market efficiency will benefit from improved production cost models and developers will have better software to assess market risks