Enhanced Combined Cycle Modeling

– from bid to bill

2018.06.26

Congcong Wang, Gary Rosenwald, Kevin Vannoy, Chuck Hanson, Yonghong Chen and Jason Howard

Purpose

- Discuss Conceptual Design of MISO Enhanced Combined Cycle (ECC) Model

Key Takeaways

- Recent market system performance improvement enabled enhanced modeling with estimated benefits of $14~$34 million
- The ECC model allows market participants to offer more accurately and MISO to access greater flexibility of the resources
- Revamped pricing and Make Whole Payments align with market clearing to incentivize effective dispatch following

Participant interests in ECC model since 2011 were enabled by recent computation advancements

Increasing needs of ECC

- MISO currently hosts 44 Combined Cycle Gas Turbine (CCGT or Combined Cycle) resources with more under development
- Simplified modeling options either as a single aggregate resource or as individual units have been used since market inception

Recent computation enabler

- Market participants have shown great interests but unit commitment (SCUC) problem could not be solved within acceptable time
- Recent advances in SCUC problem formulation and solver performance show acceptable solve time and multi-million $ annual benefits

ECC model represents one of the most complex participation models in MISO energy & AS markets

- Following the foundational work set forth by R&D, ECC Conceptual Design covers bid to bill including market clearing and settlement

Registration and Modeling	• Commercial modeling • Hybrid Offer Structure
Measurement and Verification	• Telemetry and Communication • Measurement • Outage management
Market Clearing	• Unit Commitment (DA/RT) • Economic Dispatch (Energy and Reserves) • Operation of Duct Burner and others
Settlement	• Make Whole Payments • Self-Commit and Others
Pricing	• Startup/Transition cost; operating limits

- Collaboration with stakeholders through ECC task team allowed the design to effectively capture the operating characteristics of CCGTs

Participants can register multiple configurations and specify offers based on actual costs/limits

- Three levels of offer parameters modelled under ECC
  - Resource level
  - Configuration level
  - Component level

Initially allow up to seven (7) configurations

Valid Configurations	Physical Units Usable Capacity			
	CT1	CT2	DB	ST
AllOff				
1Bx0		100		
0x1				50
1x1A	100			80
1x1A-DB	100		On	120
2x1	100	100		200
2x1-DB	100	100	On	250

	AllOff	1X1-A	1X1-B	2X1	2X1-DB	3X1	3X1-DB
AllOff	1	valid	valid	valid	invalid		
1X1-A	10min/0min/$0	1	invalid	30min/10min/$900	invalid		
1X1-B	10min/0min/$0	invalid	1	30min/10min/$900	invalid	⋮	
2X1	10min/0min/$0	10min/10min/$0	10min/10min/$0	1	10min/0min/$50		
2X1-DB	invalid	invalid	invalid	10min/10min/$0	1		
3X1							
3X1-DB							

Configuration name	when start from alloff				
	COLDSTARTUPCOST	INTERSTARTUPCOST	HOTSTARTUPCOST	HOTTOCOLDTIME(h)	HOTTOINTERTIME(h)
1x1-A	1500	1000	500	10	4
1x1-B	1500	1000	500	10	4
2x1	2500	2000	700	12	6
2x1-DB	N/A (invalid to start from Alloff)				
3x1	3500	3000	900	12	6
3x1-DB	N/A (invalid to start from Alloff)				
Alloff					

INDIVIDUAL UNIT NAME	MINDOWNTIME(h)	MINUPTIME(h)	MAXRUNTIME(h)
CT1	8	5	N/A
CT2	8	5	N/A
CT3	8	5	N/A
ST	12	10	N/A
DB	2	2	N/A

MISO will optimize the commitment among multiple configurations instead of on/off of the whole plant

Today's simplified model	Enhanced Combined Cycle
• MISO makes on/off commitment decision of the whole resource with no visibility of underlying components • MISO determines dispatch MW based on as offered min/max output limits, ramp rates, etc. (can be inaccurate since limits/rates vary by configuration) • Participants receive MISO instructions and determine which components to commit in order to produce the instructed MW	• MISO makes commitment among up to seven as registered configurations • MISO dispatches under more accurate configuration-level offers and can also account for operating limitations during transition • Participants receive MISO instructions of which configuration to operate and can better follow dispatch with their operating characteristics more accurately considered

RT SCUC will allow configuration committed in Day-Ahead to change in Real-Time

Day-Ahead Market

- Performed one day head for the next operating day at hourly interval

Forward and Intra-day RAC

- Performed after DA market till the end of operating day at hourly interval

Look-Ahead Commitment

- Performed every 15 minutes typically looking ahead 3 hours at 15/30min interval

- Access resource flexibility when Real-Time conditions are different than expected previously
  - Allow transition up to obtain the needed online capacity
  - Allow transition down to avoid being stranded in an inflexible configuration
- Maintain feasibility with preceding commitments by DA/RAC/LAC and respect resource operating parameters
  - SCUC constraints to ensure sufficient transition/notification time and satisfy min up/down time when returning to existing commitment plan
  - Establish eligibility criteria to maintain consistency between DA and RT and moderate financial exposure to buy-back DA position

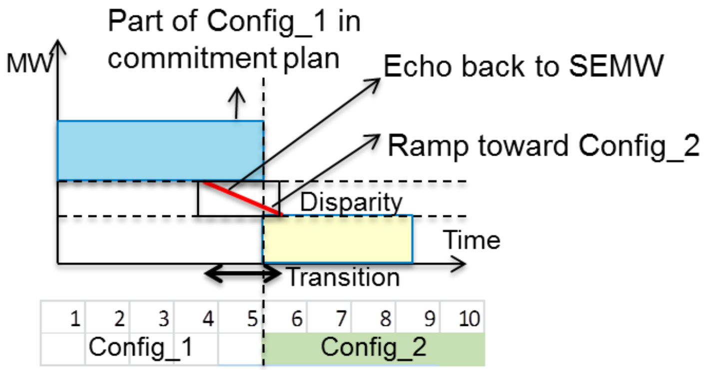
Note: SCUC – Security Constrained Unit Commitment; SCED – Security Constrained Economic Dispatch; RAC – Reliability Assessment Commitment; LAC – Look-Ahead Commitment

SCED will account for resource operating needs especially during transition

Day-Ahead market
- One day ahead
- hourly interval

Real-Time dispatch (UDS)
- ~10min ahead
- 5min interval

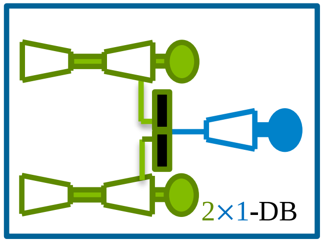
Automatic Generation Control (AGC)
- Instantaneous
- Every 4 seconds



- Dispatch energy if the resource State Estimator (SE) MW is within dispatch range and "current configuration" is consistent with commitment plan
- Echo back to SE MW if out of dispatch range or current configuration is inconsistent with commitment plan
- Do not clear reserves during scheduled "Transition Time" or when resource status is "in Transition"

Note: Participants can continue to send Off Control mode in AGC like today during start-up. Unlike start-up which is outside the commitment plan, ECC transitions occur within the plan and MISO needs to consider the resource in its dispatch

Example: ECC model better addresses today's operation challenges of Duct Burner



- Usually can transit in/out DB quickly (~10min)
- Limited dispatch range and ramping
- Some have min run time (~ 2h) once into DB

- **Offer**: DB mode can be offered as a separate configuration with its own min/max output limits, ramp rates, min run times (at component level)
- **SCUC**: evaluates future system conditions and commits DB only when warranted by anticipated conditions for at least min run time (made-whole)
  - If system conditions change, LAC can transition out of DB to access the high ramp and large dispatch ranges of non-DB modes instead of being stranded in DB mode
- **SCED**: respects DB mode min/max output limits, ramp rates, etc. and resource can better follow the resulting dispatch instructions

Offer structure and market clearing changes impact cost causation in Make Whole Payments

Today's aggregate model	Enhanced Combined Cycle

• Settlement is at whole resource level, and price-based revenues are calculated like other resources
• With resource offer similar to conventional units, Make Whole Payments are evaluated similarly
  • Startup and No-load costs, energy and reserve costs
  • DA/RT *RSG* make-whole for DA/RT committed resources
  • RTO*RSG*P/DAMAP make-whole for resource committed in DA but dispatched differently in RT
	• Settlement is at resource level and revenues are calculated similarly
	• With the change of offer structure and market clearing, MWPs change
	  • Offer structure and transition cost
	  • DA/RT overlapping commitment (e.g., 1x1 DA committed configuration is changed to 2x1 in RT)
	    ○ Netting approach to determine which costs are to be covered by DA RSG or RT RSG
	    ○ "***Roll DAMAP into RT RSG" for resources committed and dispatched differently in RT***

Note: DA RSG – Day-Ahead Revenue Sufficiency Guarantee; RT RSG –Real-Time Revenue Sufficiency Guarantee; RTORSGP: Real-Time Offer Revenue Sufficiency Guarantee Payment; DAMAP – Day-Ahead Marginal Assurance Payment

Make Whole Payments are designed to be consistent with MISO Settlement construct

- Principles: compensation based on underlying cost causation
  - Make whole to costs resulting from RTO/ISO commit/dispatch (*RSG*)
  - Preserve DA margin eroded by following RT schedule (DAMAP)
- DAMAP ensures resources do not lose DA profit by following RT dispatch; otherwise they may reduce flexibility to lock DA position
  - Under DA/RT two-market settlement, RT price volatility may cause resources to be dispatched differently and lose DA profit
  - Resources could set limits at DA position or set ramp close to 0 to reduce the risk from RT volatility, resulting in less operation flexibility

DA Profit – RT profit

Make up the difference between DA profit and RT profit

$$\text{Min}\ \{0,\ \text{RT Price} \times (\text{RT MW} - \text{DA MW}) - (\int_0^{\text{RTMW}} \text{Cost} - \int_0^{\text{DAMW}} \text{Cost})\}$$

Example: RT RSG to ensure cost recovery

Cost recovery for Energy, similar for reserves

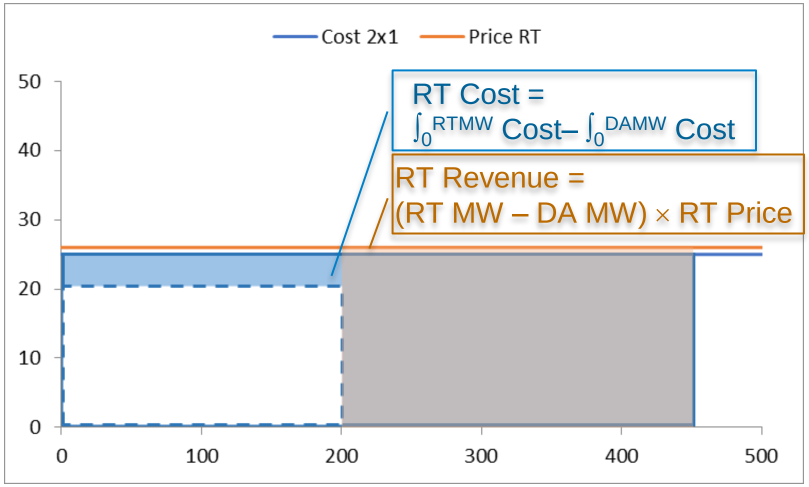
Min {0, RT revenue – RT cost}

$ goes out of MP

$ goes to MP

DA 1x1	MW	Cost 1x1	Price DA
200MW	0	20	40
	160	20	40
	245	20	40

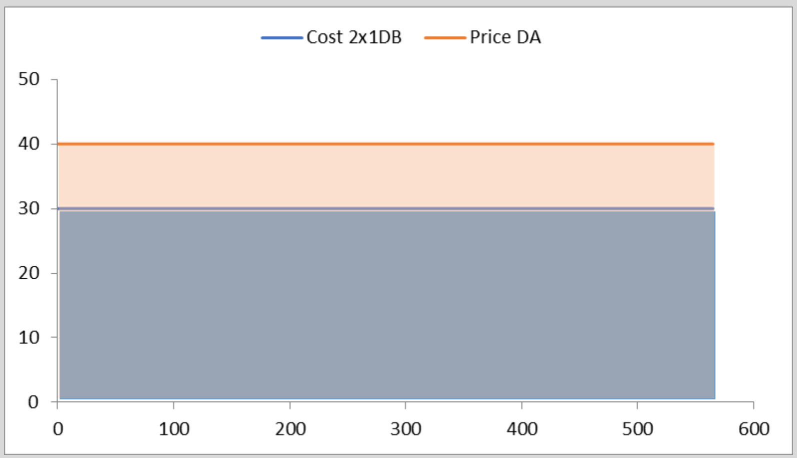
RT 2x1	MW	Cost 2x1	Price RT
450MW	0	25	26
	350	25	26
	525	25	26



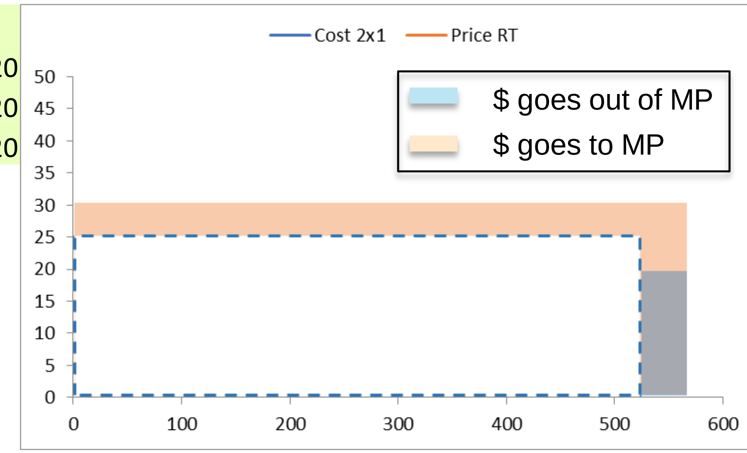
Example: DAMAP to Preserve DA margin

Energy buyback when transition down from 2x1-DB in DA to 2x1 in RT

DA 2x1-DB	MW	Cost 2x1DB	Price DA
565MW	0	30	40
	565	30	40

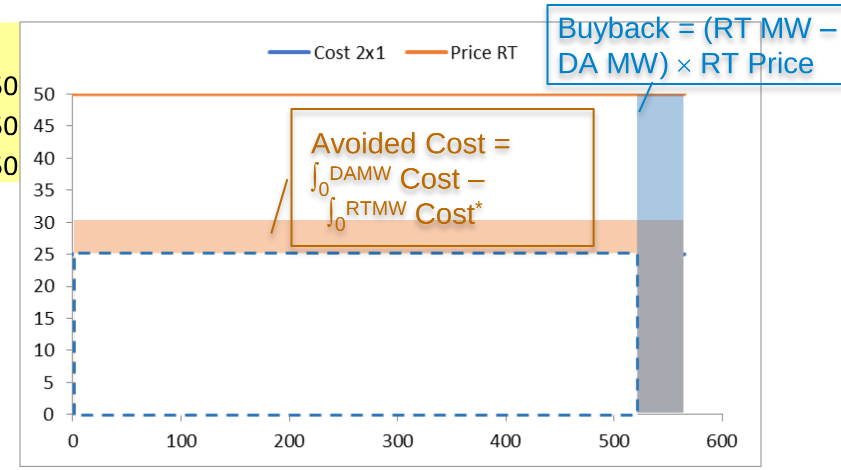


Price RT
20
20
20



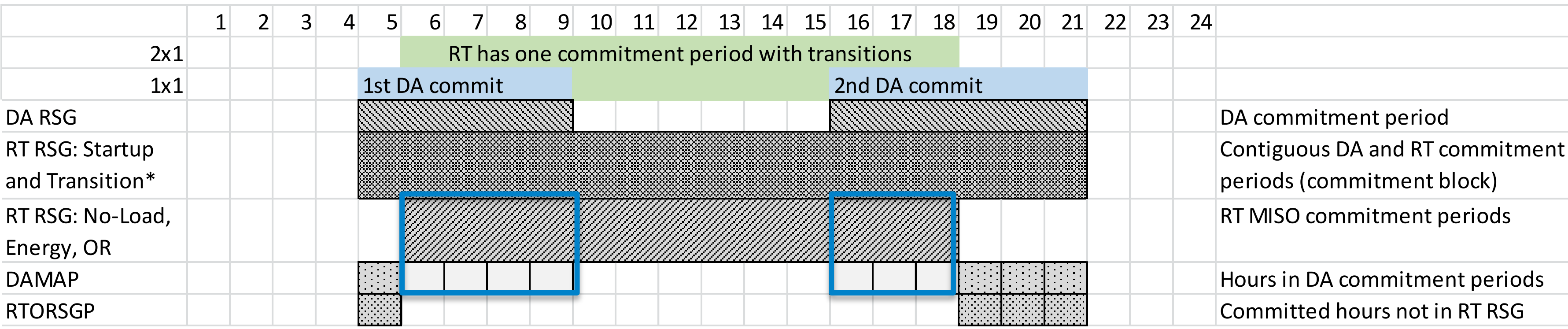
RT 2x1	MW	Cost 2x1
525MW	0	25
	350	25
	525	25

Price RT
50
50
50



Note: In the illustration assuming MP does not change DA/RT offer, cost curve of DA committed configuration is used to evaluate DA cost and cost curve of RT committed configuration is used to evaluate RT cost

“Roll DAMAP into RT RSG” approach



DA/RT overlapping commitment (RT changes 1x1 DA committed configuration to 2x1)

- DAMAP will continue to be evaluated for any hour with a DA position
- Nevertheless, the different DA/RT ECC output levels are associated with both dispatch decisions (like today’s DAMAP) and commitment changes (new for ECC) coupled across the whole commitment period
- The idea is to use RT RSG to evaluate uncovered cost if output more MW and DAMAP to evaluate eroded DA margin if output less MW
- RT MWP is obtained by summing over products across the RT commitment periods and adding back startup, transition, no-load costs

Contingent design to apply existing ELMP to ECC and continued research on transition related costs

Readily implementable solution within ECC project	**Further solution contingent on ELMP enhancement**
• Continue to use existing ELMP Online Fast Start Pricing logic • Eligibility rule: a configuration is ***started*** (from ALLOFF) within 60min and has min run time of 1hr • Most CCGTs are not qualified and will be setting prices like other non-Fast Start Resources	• Expand ELMP logic to include transition related costs in prices • Eligibility rule: a configuration that is transitioned (NOT from ALLOFF) within 60min and has min run time of one hour • Duct Burner more likely qualifies to set prices like a Fast Start Resource

Add to ECC if ELMP enhancement is completed in time, but would not affect ECC implementation otherwise

Conclusion

Computation advancement enabled market enhancement

Market design to transform concepts to solutions for operation realities and ensure adequate incentives

… Implementation to create value in production