Implementation of Fuel, Generator Contingency, and Remedial Action Scheme Constraints for Electric System Resilience

Guillermo Bautista, Ph.D.
Director, Market Analysis & Forecasting
California ISO Corporation

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Resiliency Under a Decarbonized Grid

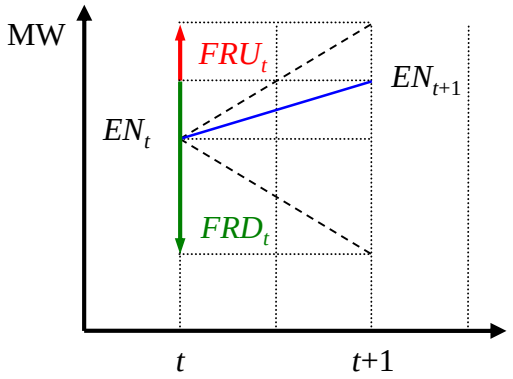
- Reliable operation with a change in generation mix
- Increased levels of operational uncertainty
- Oversupply conditions is a new reality
- Steep ramp requirements ~15,000MW and growing
- Incentives for resources to follow dispatch instructions
- Compensation for resources for the capabilities and services they can provide
- Optimization of the use of the grid

Software capabilities of the CAISO's markets

- Linearized AC power flows
- Dynamic ramp rates
- Multi-Stage generator model for combined cycle units
- MIP techniques to solve the optimization problem
- Multi-interval formulation (72 hours DAM, 4.5 hours RTM)
- Two internal runs to account for priorities and constraint relaxations
- Quadratic optimization to handle price degeneracy

Flexible ramping product in place to handle uncertainty

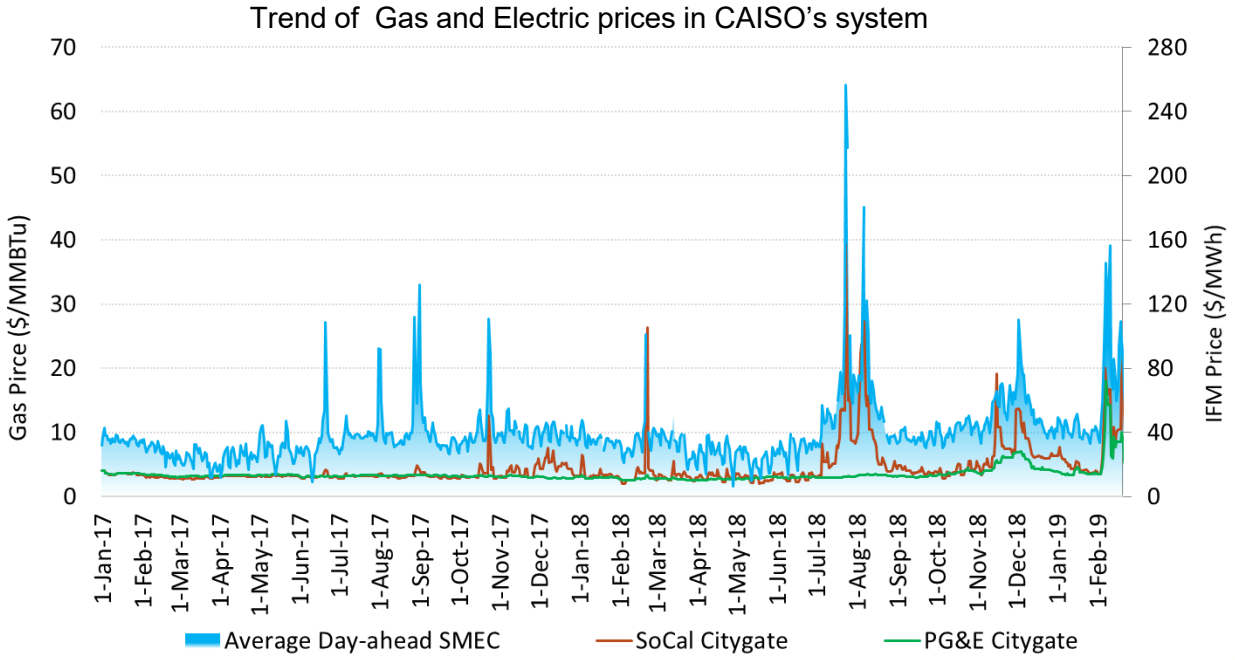
- Flexible Ramping Up/Down Uncertainty Awards
  - No bids, priced at opportunity cost
  - Paid FRU/FRD marginal price (shadow price of requirement constraint)
  - Allocated to those that cause uncertainty



- Forecasted Movement Up/Down
  - From binding to advisory dispatch
  - Paid FRU/FRD marginal price
  - Charged FRD/FRU marginal price
  - FMU/FMD settlement supplements energy settlement
  - Addresses price formation issue of opportunity cost for out-of-merit dispatch in t being reflected in advisory LMP of t+1

Gas-Electric coordination becoming more critical

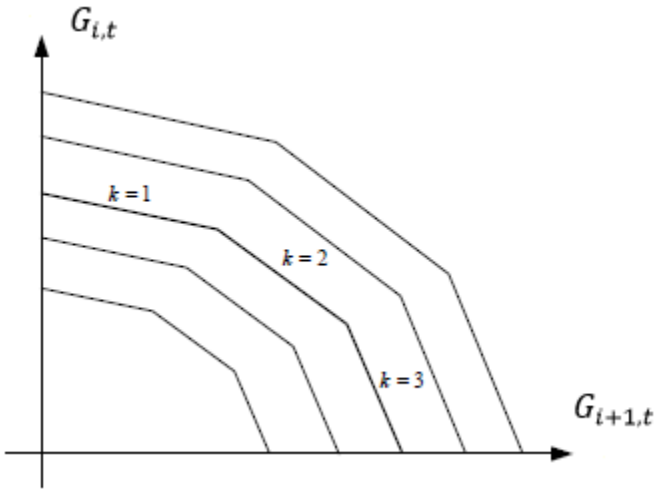
- Gas-based generation fleet is still a fair share of the CAISO's supply mix
- Recent Aliso Canyon leakage imposed gas limitation on the electric system
- Gas volatility has increased in recent years
- Use of outdated gas prices in the electric system may lead to inefficient unit commitment



Gas limitations modelled as generation nomograms

$$\sum_{i \in S} \propto_i (G_{i,t}) \leq \gamma_t R \quad \forall t \in T$$

$$\sum_{1}^{T} \gamma_t = 1$$

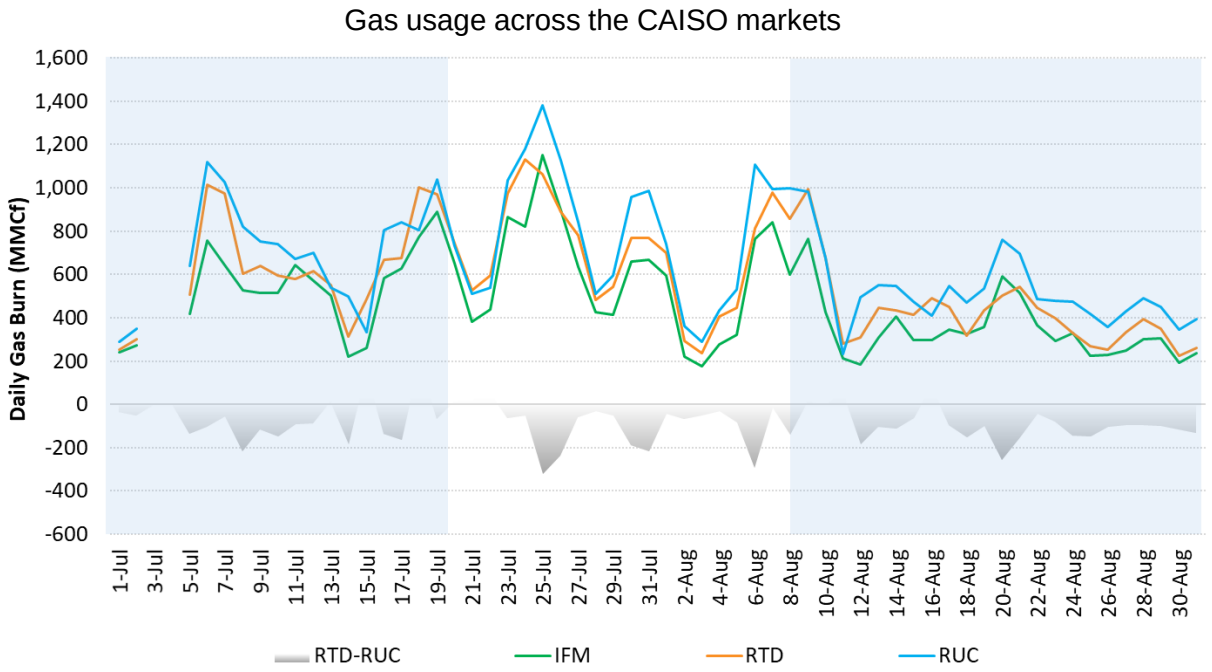


- $G_{i,t}$: Generation dispatch
- $\propto_i$: Gas conversion factor
- R: Gas limitation
- γ_t: Distribution factors

- Nomogram constraint optimally allocates gas reductions
- Creates a price signal for resources
- Reduces manual adjustments from Operators

Improvements to reflect gas conditions in the electric system

- Use of most recent gas indices for day-ahead market
- Close coordination between gas and electric operators
- Manage some gas limitations through the electric system optimization



Generation Contingency constraints more efficiently dispatches resources around known constraints

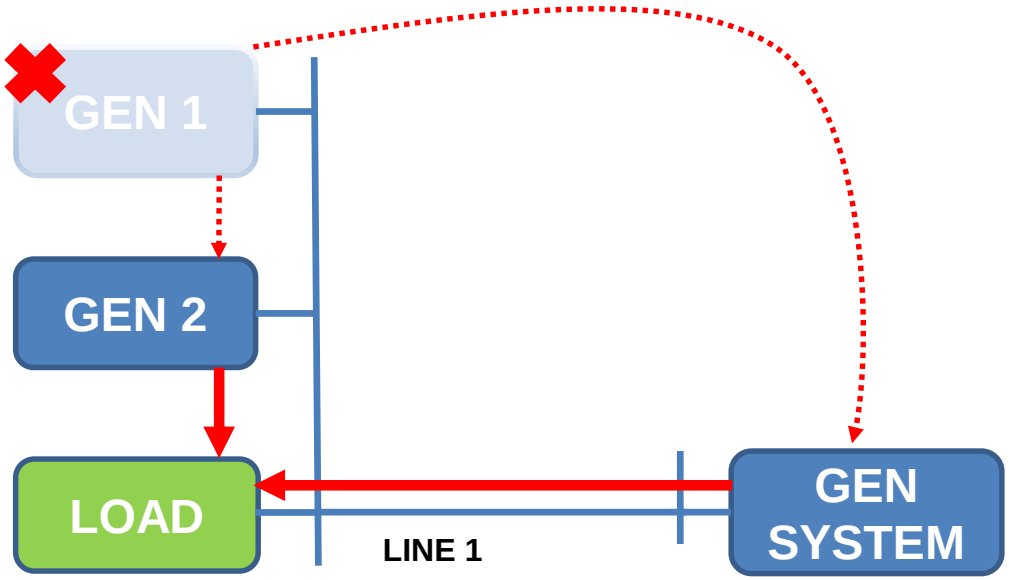
- Enhances the SCED to be immediately secure if generator contingency or remedial action scheme activated
  - Currently, market just considers transmission loss
- Transmission system relies on an already large and increasing amount of arm-able remedial action scheme generation
  - Over 20,000 MW of remedial action scheme arm-able generation
  - Operations team must manually manage related constraints
- Generators associated with remedial action schemes cannot be optimally dispatched in market until now
  - Operators currently disable contingencies, manually monitor flows, and engage in out of market action to manage around these constraints

Generation contingency proposal

Generator Contingency

Model the "pick-up" effect of the system for a generator loss

- Consistent with reliability studies for generator loss
- Consistent with operator's real-time contingency analysis tool
- Incorporate the potential change in electrical flows into locational marginal prices



Loss of generation spread to other online resources to model transmission line flows.

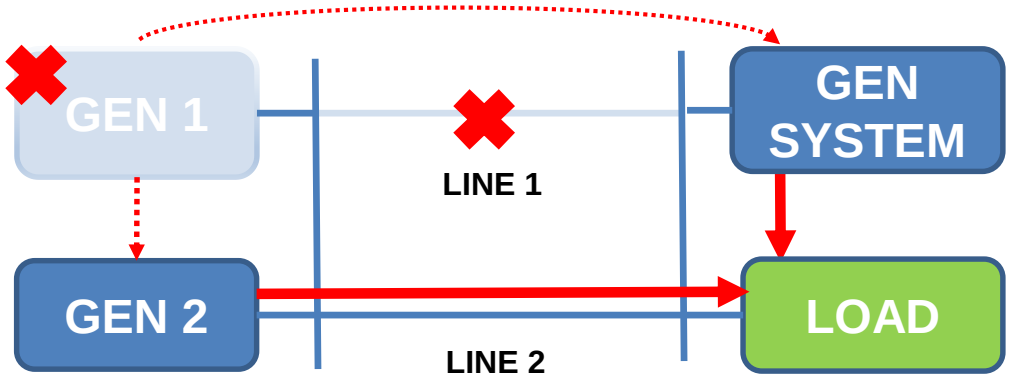
Most **GEN 1 output** picked up by **GEN SYSTEM**.

GEN 1 locational marginal price considers flows on **LINE 1** due to pick-up by **GEN SYSTEM**.

Generation contingency proposal

Remedial Action Scheme Contingency

Taking into account the loss of generation, only one generator contributes to congestion



GEN 1 is part of remedial action scheme and trips off if **LINE 1** or **LINE 2** go out

GEN 2 is not on remedial action scheme

GEN 1 locational marginal price considers **that GEN 1** will not overload **LINE 1** or **LINE 2** if they go out.

GEN 1's locational marginal price has a lower congestion component than **GEN 2**