Assessing Flexibility on Future Power Systems

Case Studies for CAISO

Erik Ela, Qin Wang, Clyde Loutan
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Three Pillars of an Adequate Supply Fleet

Efficient Markets

Capacity

Energy

Flexibility

Energy Storage

Central Station

Delivery Infrastructure

Variable Generation

Demand Response

What is flexibility?

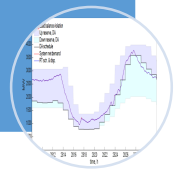
The ability to adjust output to meet and adapt to the expected and unexpected changes of the system over different time horizons

- Ramp Rate (MW/min) ↑
- Power Range (MW) ↑ and Min Gen ↓ and forbidden zones ↓
- Start-up time (Hours) ↓
- Minimum run/down times (Hours) ↓
- Ability to sustain output (MWh)↑
- Frequency to be called (Calls per year) ↑
- Capability to provide additional services ↑ (Ex. D-Curve range, droop setting)
- Ability to change fuel/source ↑
- Ability to deliver energy to where it is needed ↑

Mechanisms to Ensure Flexibility Provided Reliably and Cost-Effectively

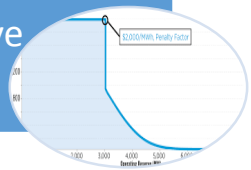
- Address uncertainty and ramp with commitment and dispatch

Uncertainty and ramp reserve product



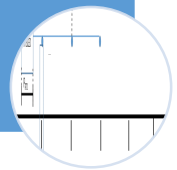
- Value reserve above minimum requirements

Operating Reserve Demand Curve



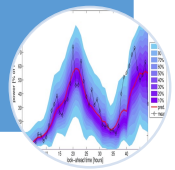
- Price opportunity costs of ramp

Multi-interval settlement



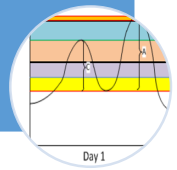
- Represent uncertainty explicitly

Stochastic multi-scenario market scheduling



- Make sure flexibility is built

Forward Flexible Capacity Attribute Procurement



- Let demand provide flexibility inherently

Real-time demand pricing

- Flatten the curve with correct incentives

Energy Storage

- Reduce uncertainty directly

Enhanced Forecasting

The Flexibility Challenge

Problem 1: The system fleet is flexible, but resources do not have the incentive to hold back energy to provide flexibility

Solution1

Solution for all

Solution 3

Problem 2: The system fleet is flexible, but operational procedures are not extracting this flexible

Problem 3: The system fleet is not sufficiently flexible, or not anticipated to be in the future

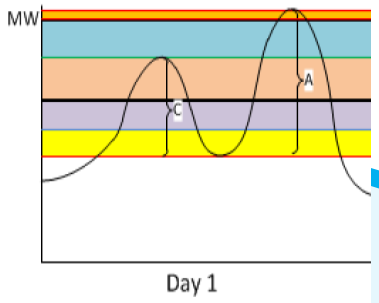
Solution 2

Flexibility Assessment Study: Installed Flexibility on the CAISO

Disclaimers: 1. Not speaking on behalf of CAISO. 2. Study and descriptions based on previous FRAC-MOO process, CAISO has since proposed changes to process that may not be captured

CAISO Flexible Resource Adequacy Criteria & Must Offer Obligation (FRAC MOO)

Gather data associated with future year



Determine flexible capacity needs

Determine Effective Flexible Capacity (EFC) of existing fleet

If LSEs are short of needs, they must procure additional flexible capacity

All resources that contribute to the EFC, must offer flexibly (i.e., not self-schedule) in the energy market.

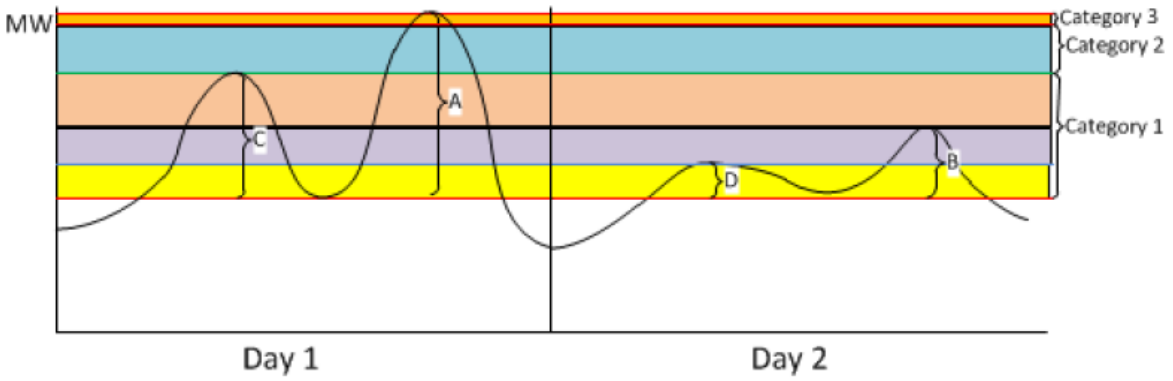
Process would be analogous to Northeastern ISOs including a flexible capacity "constraint" in the capacity market to ensure sufficient flexible capacity is built for each seasonal auction.

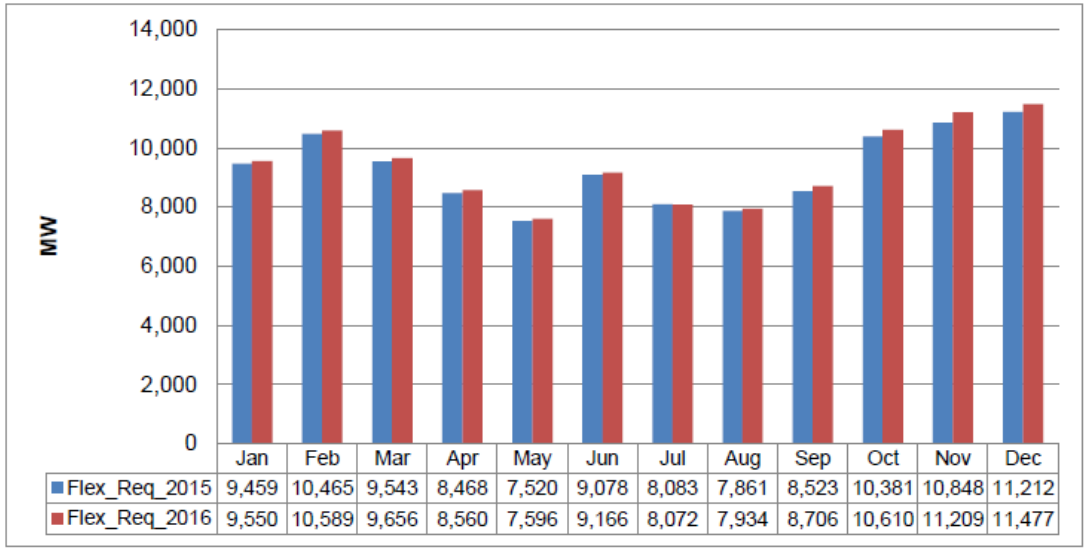
California Flexible Capacity Procurement

- Flexible capacity need : Max 3-hour ramp rate per month + contingency reserve
- Three types:
  - Base flexibility
  - Peak flexibility
  - Super-peak flexibility
- Allocation to system flexibility capacity needs allocated to LSEs based on contribution to 3-hour net load ramp
- **Effective Flexible Capacity** Calculation:

Sum of each resources

Min { 3 hour ramp, output range, output after starting within hour and half}





	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flex_Req_2015	9,459	10,465	9,543	8,468	7,520	9,078	8,083	7,861	8,523	10,381	10,848	11,212
Flex_Req_2016	9,550	10,589	9,656	8,560	7,596	9,166	8,072	7,934	8,706	10,610	11,209	11,477

Project Goals

- Provide additional analytics and tools for FRAC-MOO process
- Understand what discrepancies exist and why
- Phase 1: Flexible capacity needs
  - Benchmarking results with software tool InFLEXion
  - Percentile analysis and additional horizons
- Phase 2: Flexibility assessment
  - Why does the CAISO have less flexibility in operations than planned?
  - Utilize EPRI Installed Flexibility (IFLEX) calculation method
  - Sensitivities for greater understanding

Flexible capacity, why it may not be available?

What are the differences between effective flexible capacity (EFC) determined by the ISO and flexibility available in real-time?

- **Meeting net load**
  - EFC does not consider whether it is feasible for all EFC to be provided during every interval
  - Example: units online to provide EFC may cause over-generation during min net load periods
- **Horizon focus**
  - 3 hour horizon may not guarantee CPS1

Study Focus

- **Forecast error and commitment constraints**
  - Some EFC units with flexibility do not get committed day-ahead and are not available to provide flexibility in real-time
- **Transmission constraints**
  - EFC does not consider whether flexibility can be delivered across the network during constrained periods
- **Forced outages or maintenance periods**
  - EFC does not consider forced outage rates of resources like ELCC does

Sensitivity

- Other issues
  - Data input issues
  - Technology specific calculations

Developing Flexibility Assessment Paradigm

Available Flexibility

- **Goal:** What is the **likely flexibility** that a system **can provide** while meeting net load?
- **A**FLEX can be calculated with Inflexion and Production Cost Models
- **Outcome:** Identifies flexibility available if systems operated as is

Deliverable Flexibility

- **Goal: How much** of the available **flexibility** can be **delivered** to where it is needed?
- **D**FLEX can be calculated with an Optimal Power Flow
- **Outcome:** Identifies usable flexibility

Installed Flexibility

- **Goal:** What is the **maximum flexibility** that a system can provide while meeting net load?
- **I**FLEX can be calculated with production cost models
- **Outcome:** Identifies hard limitations to system technical flexibility capability

Key Features of EPRI IFLEX Method

- These results show the absolute maximum *feasible* flexibility, **IFLEX**, of the fleet
  - ***Analogous*** to ICAP. ***Dependent*** on system conditions, ***independent*** on operational decisions
  - Primary difference with EFC calculation, IFLEX is feasible (through simulation model)
- At noon, a certain amount of units must be off to accommodate solar, many of these resources cannot contribute to the sunset evening ramp
  - Min down time, start-up times, etc.
- Some very uneconomic commitment and dispatch solutions may be present – feasible but maybe not likely?
- Only new builds, retrofits to existing plants, or change to how much interchange is allowed can increase flexibility – no operational decisions (e.g., reserve requirements) will increase amount of installed flexibility

Modify the production cost model in the commercial tools to calculate IFLEX

Set the generation cost *c* and reserve cost *r* to 0.

Flex penalty is smaller than the Load Violation Penalty.

- $Minimize\{\sum_i c_i P_i + r_i Flexibility_i + 10 * Penalty^{Flex} + 5000 * Penalty^{Load}\}$

$s.t.$

$$\sum_i P_i + Penalty^{Load\ violation} = \text{Load}$$

Load balance should be satisfied

$$\lambda P_i^{Forecast} \le P_i \le P_i^{Forecast} \quad for\ all\ VERs$$

No curtailment in base case λ=1

$$\sum_i Flexibility_i + Penalty^{FLEX} \ge \text{Reserve Requirement}$$

Reserve requirement is a relative large number, e.g. the maximum load of the simulation horizon

$$P_i + Flexibility_i \le P_i^{\max},\ for\ all\ generator\ i$$

$$P_i = P_i^{\max}\ \ for\ nondispatchable\ units$$

$$0 \le Flexibility_i \le Ramp_i \times Horizon,\ for\ dispatchable\ unit\ i$$

All other constraints such as minimum on/off time; hot/cold start up time; etc.

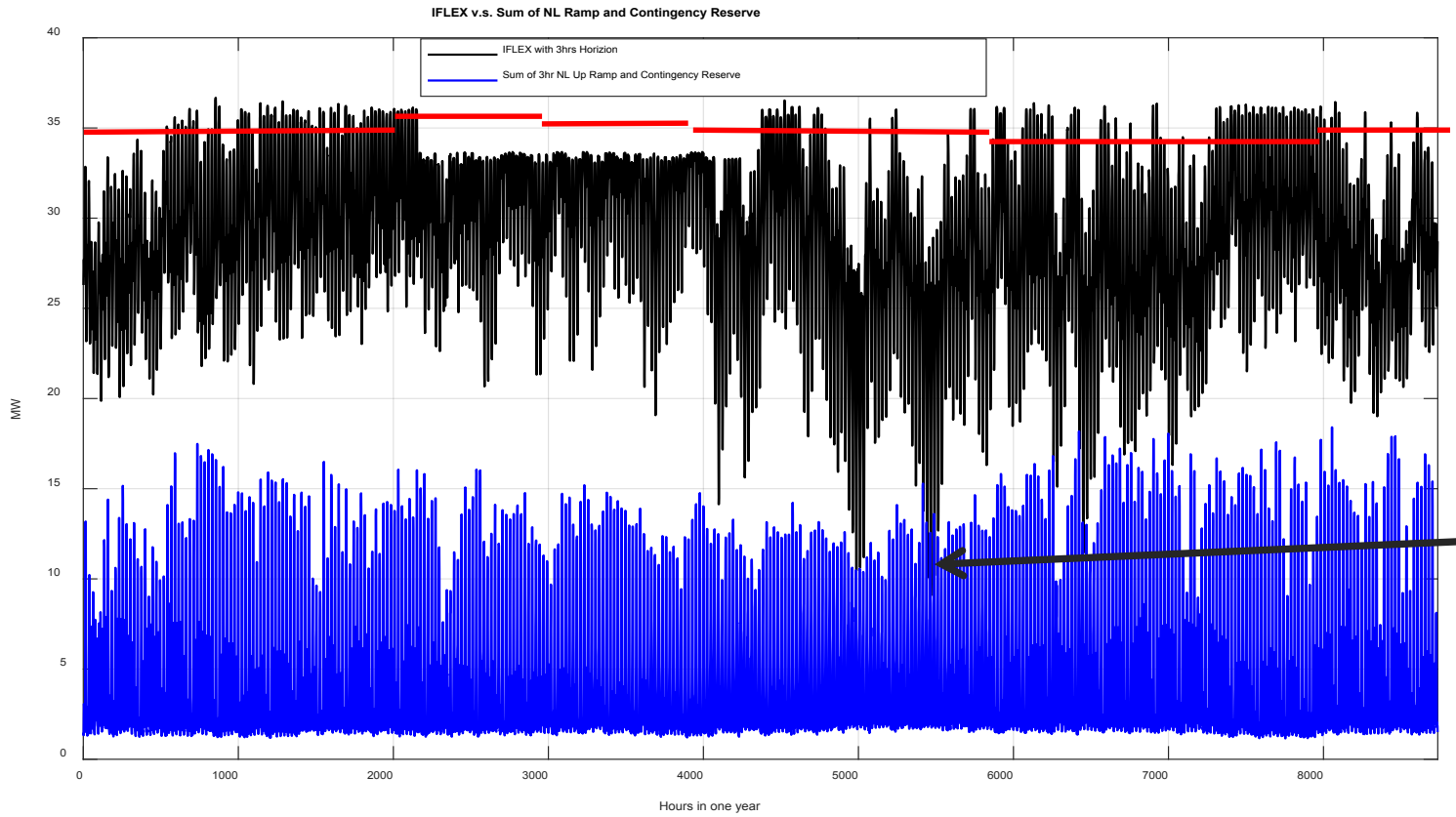
Phase 2 Study Scenarios

- **2016 Base Case**: How much feasible flexibility within the CAISO fleet compared to EFC and compared to 3-hour ramps
- **2020 Base Case**: Analysis of future flexibility from fleet using CAISO scaling methods
- **Sensitivity 1**: Evaluate flexibility at different horizons to see whether horizons other than 3-hour have challenges
- **Sensitivity 2**: Evaluate how much curtailment of VER can increase the amount of feasible flexibility
- **Sensitivity 3**: Evaluate how much provision of flexibility if only RA resources provide at RA capacity contributions

Simulation results

2020 3-hr ramp + CR v.s. 3-hr IFLEX

$$\text{Flexible Req}_{\text{MTHy}} = Max\left\{(3\text{RR}_{\text{HRx}})_{\text{MTHy}}\right\} + Max\left\{MSSC, 3.5\% \times \text{E(PL)}_{\text{MTHy}}\right\} + \varepsilon$$

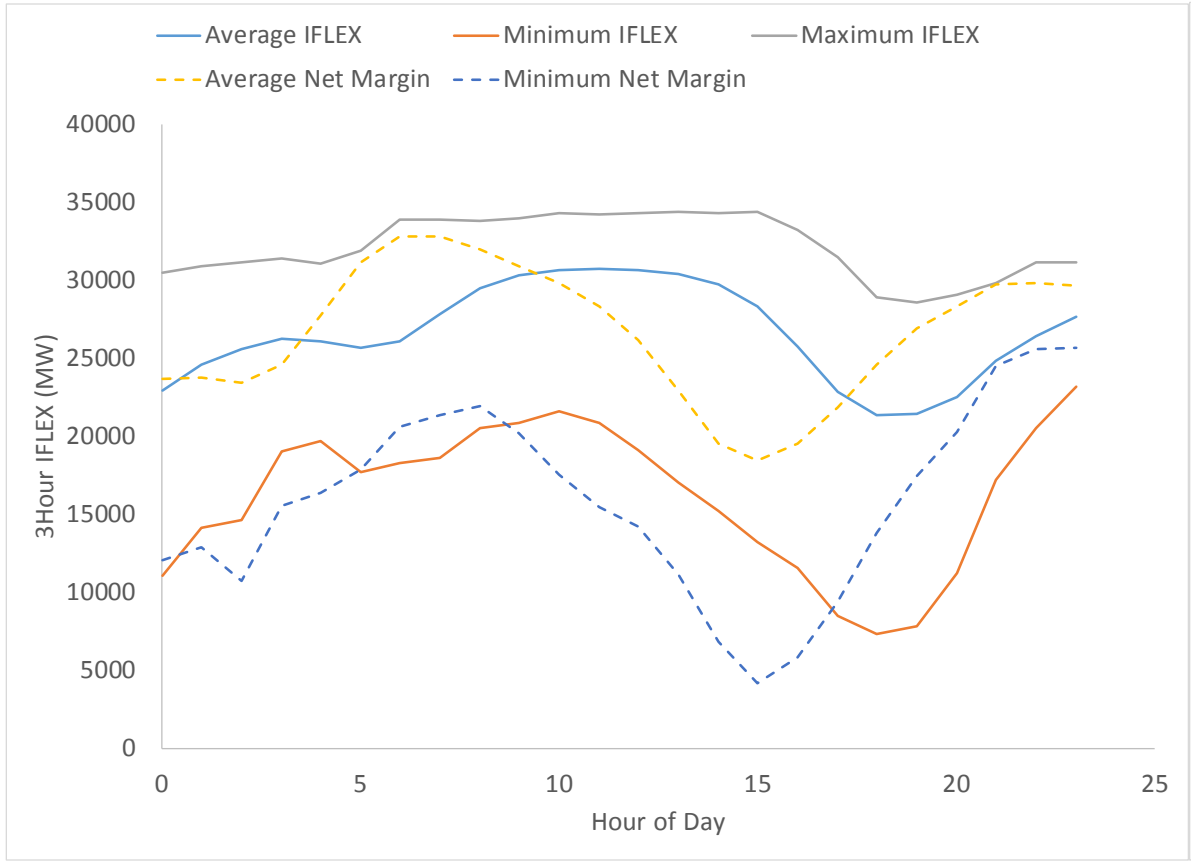


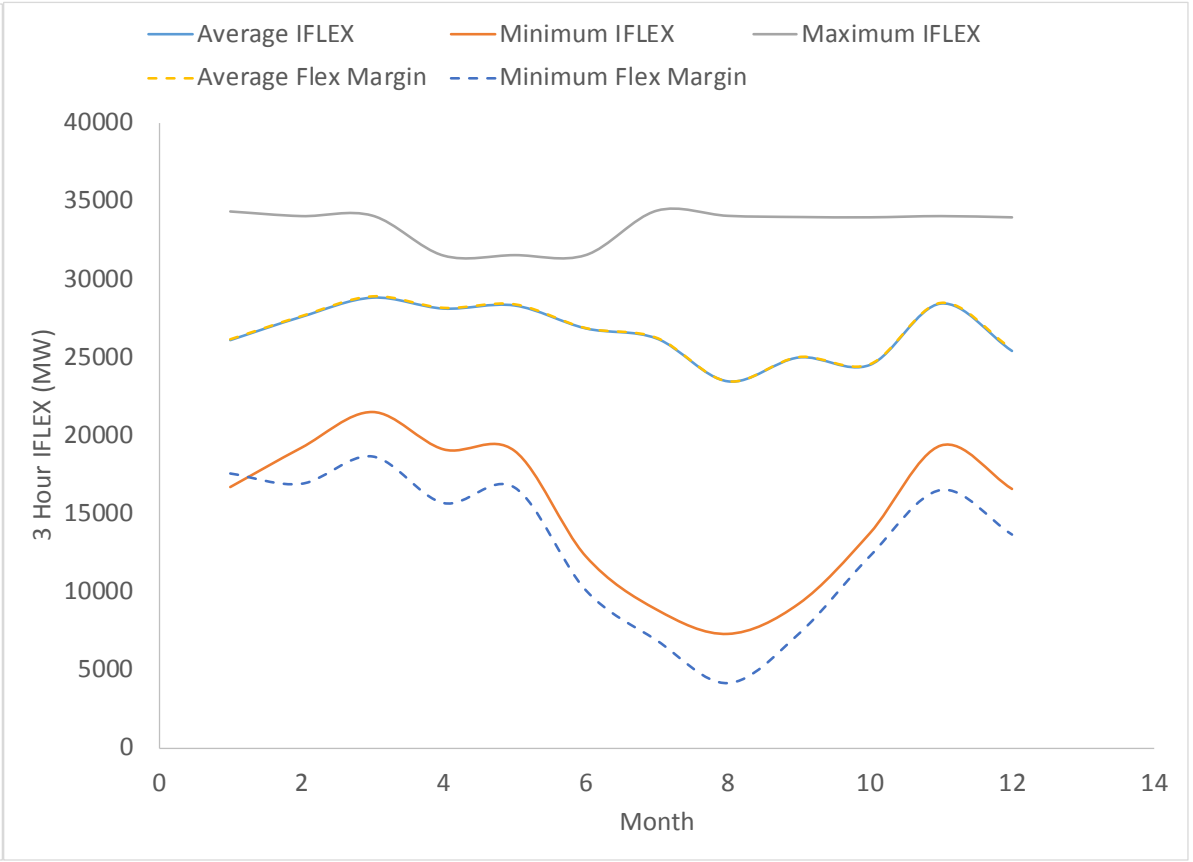
EFC

IFLEX <25% EFC

Feasible maximum flexibility is often much less than ISO-calculated EFC
Still greater than 3 hour ramp needs.

When are the greatest flexibility challenges

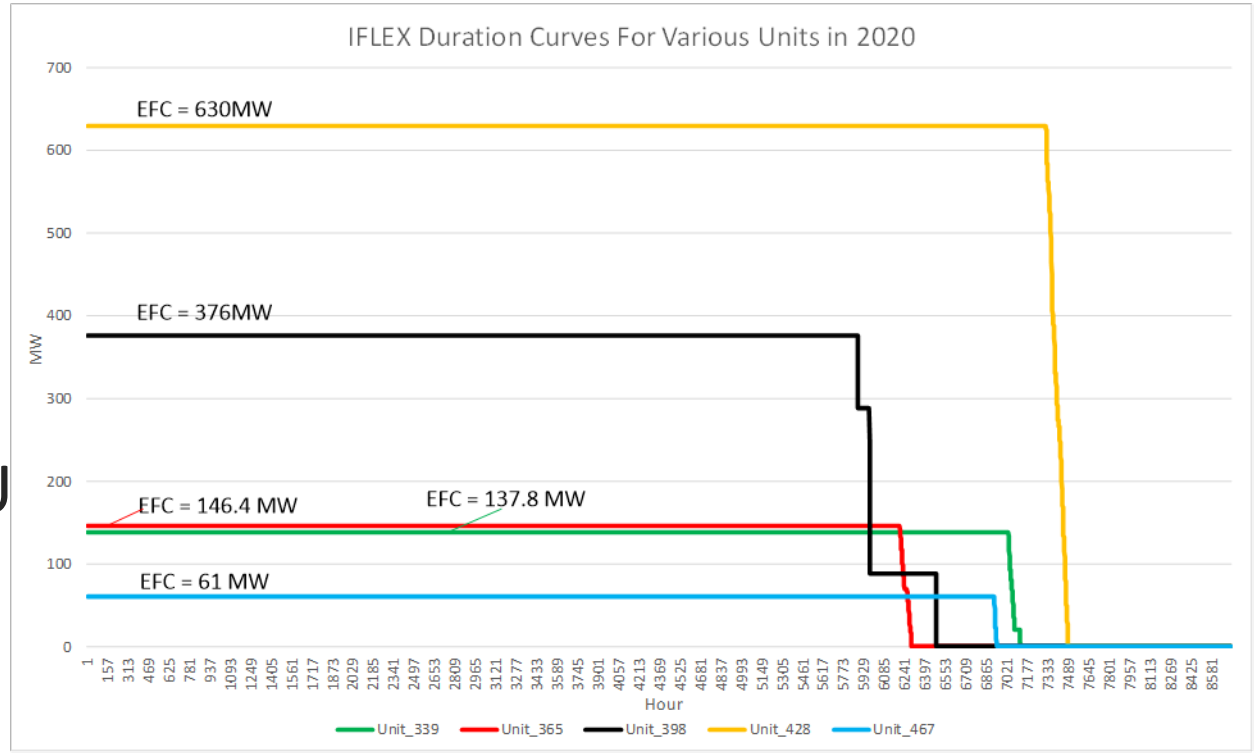




IFLEX significantly reduced in summer afternoon, after being consumed by ramps.
However, greatest risk is earlier when the ramps are occurring

Flexibility Contribution

- Most resources provide either maximum flexibility (EFC) or no flexibility
  - Providing no flexibility means supplying maximum power or offline and not able to startup (SU time or min down time)
- The software may choose what units do at random
  - Method should not be used for individual flexibility contribution



Summary and Conclusions

- Flexible capacity can be calculated with a utility/ISO's **existing production cost simulation tool** using simple modifications
- Recommend using IFLEX method for future system-wide flexible capacity planning assessments
  - Units typically provide maximum flexibility or no flexibility depending on hour and constraints
  - **Note**: It should **not be used for individual resource** flexible capacity contributions (without enhancements)
- Calculated flexible capacity on average **about 20% lower**, but **up to 80% lower** than EFC currently calculated by CAISO
  - Still generally higher than ramp needs for 2020
- Flexibility is significantly reduced in order to **meet net load conditions at beginning** of ramps
- Lowest IFLEX not the same as highest flex risk (Hour 18 vs Hour 15)
  - Spring time challenges not observed as much – Maximum flexibility vs. economic flexibility
- 1hr and 3hr horizon flexibility are almost **identical** using this method
  - Because 3hr ramps are larger, **the choice of 3-hour horizon seems to be good choice for critical horizon**
  - Recommend the ISO continue to look at other horizons – deficiencies mean different things in different horizons
- Curtailment **does not provide significant increase** to average flexibility across the year but may provide **significant increase in select time periods**
  - **Limited study** on curtailment – curtailment to provide flexibility from VER can be much greater
- If **only RA resources** providing flexibility, true deficiencies may be seen in 2020

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