



QUANTA
TECHNOLOGY

External

Economic Impacts of Behind the Meter Distributed Energy Resources on Transmission Operations

11/4/2019
CIGRE **Grid of the Future (GOTF)**
Conference

Rahul Anilkumar
Ali Daneshpooy
Abhishek Thurumalla

Contents

- Objectives
- Methodology and Study Assumptions
- Impact on Interface flows and Import/Export Trends
- Grid Operational Trends
- Locational Marginal Price (LMP) Trends and Congestion
- Energy Market and Reserves
- Sensitivity Analysis
- Conclusions

Study Objectives

- Evaluate the performance of ISO market operations under forecasted levels of self-generation (BTM-DER).
- Evaluate impacts associated with
 - Interface power transfers + BA Import/Export trends
 - Grid operational trends, including duck-curve
 - LMP and Congestion trends
 - Spot energy market, cost to energy and reserve market operations
 - Impact on system operating reserves
- Sensitivity Analysis
 - Impact of Forecasting errors

Methodology and Assumptions

- CAISO system is considered for analysis.
 - California Energy Commission (CEC) forecasted levels of self-generation for year 2024.
 - Evaluated at 100% CEC forecasted generation and 200% CEC forecasted generation (adoption in excess of forecast).

- Adding the CEC forecasted self-generation to CAISO 2024 economic study model
 - Production Cost Modeling: ABB Grid View
 - Model includes 33% RPS portfolio for California system, on way to 60% target by 2030.

Methodology and Assumptions

- Production simulations utilized to evaluate the impact of BTM DER on CAISO system economics.
- Evaluate DER Participation model where DERs are non curtailable i.e. outside of ISO visibility and control.
- Evaluate system conditions that warrant detailed reliability analysis (snapshots of the system)
- Three days considered for detailed hourly analysis that typically cover seasonal trends:
 - Spring Off Peak, Summer Peak and Winter Peak
- Evaluation of the entire year:
 - Internal and External ties and Import/Export trends

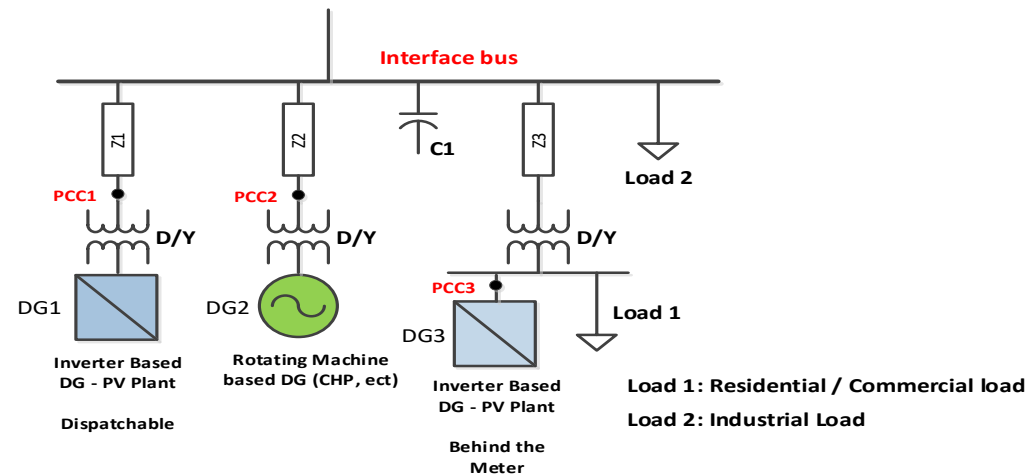
Methodology and Assumptions

- Forecast for three utilities: PG&E, SCE, SDG&E
 - 973 buses, 4.7 kV to 230 kV
 - PV and non-PV
 - PV: Residential
 - non-PV: Commercial
 - Number of added generators: 973 PV, 973 non-PV
 - MW of added generators: 3,985 MW (100%)
 - PV: 2,097 MW, non-PV: 1,888 MW
 - MW of added generators: 7,970 MW (200%)
 - PV: 6,082 MW, non-PV: 1,888 MW
 - Number of added loads: 973 for PV, 973 for non-PV
 - MW of added load: 3,985 MW
 - Load and generation are separately modeled

Entity	CEC Forecast (100% Forecast) (MW)		200% Forecast (MW)	
	PV	non-PV	PV	non-PV
PG&E	1,114	935	3,231	935
SCE	732	800	2,123	800
SDG&E	251	153	728	153
Total	2,097	1,888	6,082	1,888

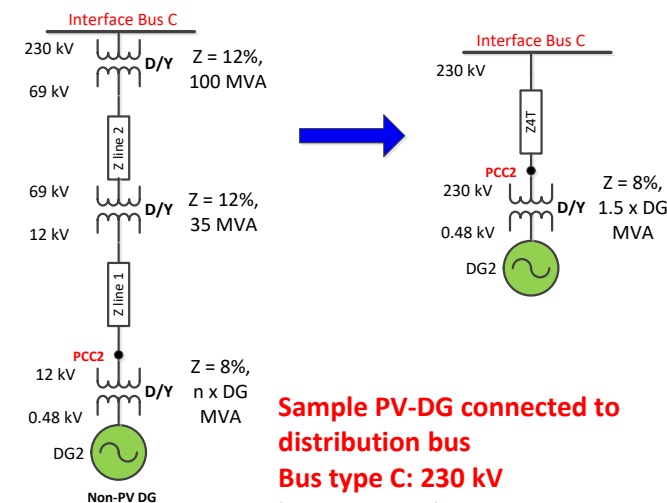
Methodology and Assumptions

- PV and non-PV generators were inter-connected at appropriate voltage level through equivalent impedances and the DG interconnection transformer.
- The equivalent impedances represent the aggregate value of distribution and/or sub-transmission lines as well as substation transformer impedances, obtained from the short circuit capacity of the system.



Proposed model for representation of Interface Bus
DG1: CAISO dispatchable DG, not part of CEC forecast
DG2: non-PV DG, part of CEC forecast
DG3: PV DG, part of CEC forecast

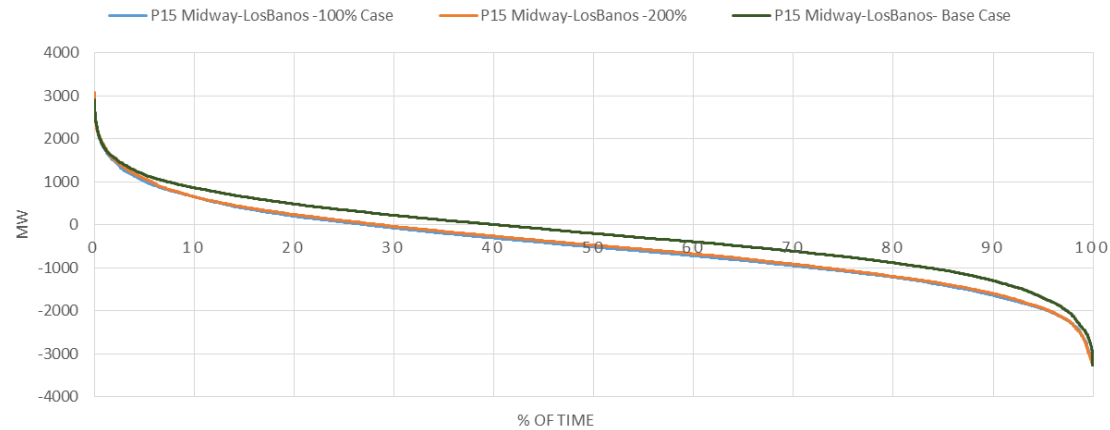
Bus Type / Definition	Bus A	Bus B	Bus C
	Distribution bus	HV bus with direct connection to Distribution	HV bus with radial connection through sub-transmission
Voltage Range	4.7 kV to 34.5 kV	55 kV to 161 kV	230 kV
Equivalent Imp	Z2D or Z3D	Z2T or Z3T	Z4
PV > 1 MW	Z3D = 0.25 pu	Z3T = 0.35 pu	Z4 = 0.8 pu
PV < 1 MW	Z3D = 0.4 pu	Z3T = 0.6 pu	Z4 = 0.8 pu
Non PV	Z2D = 0.2 pu	Z2T = 0.3 pu	Z4 = 0.8 pu



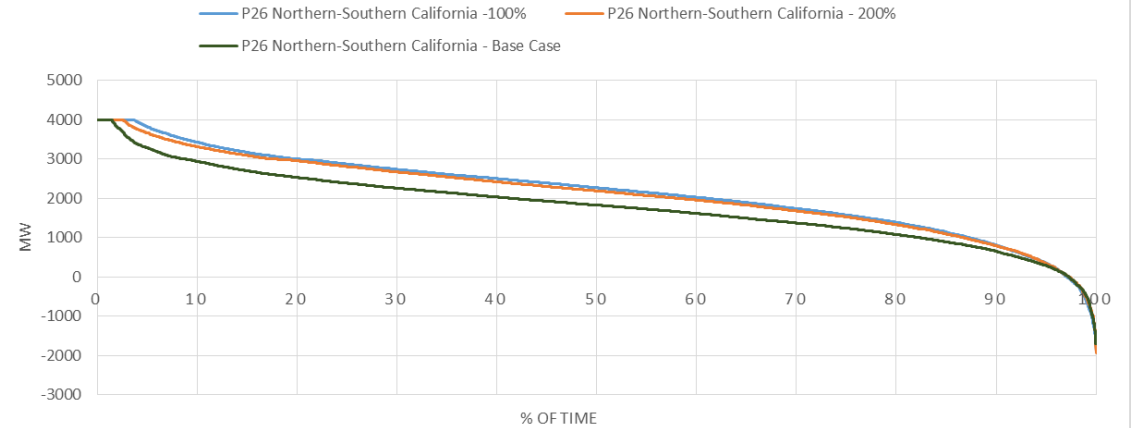
Sample PV-DG connected to distribution bus
Bus type C: 230 kV interconnection

Impacts on Interface Flows and Utilization

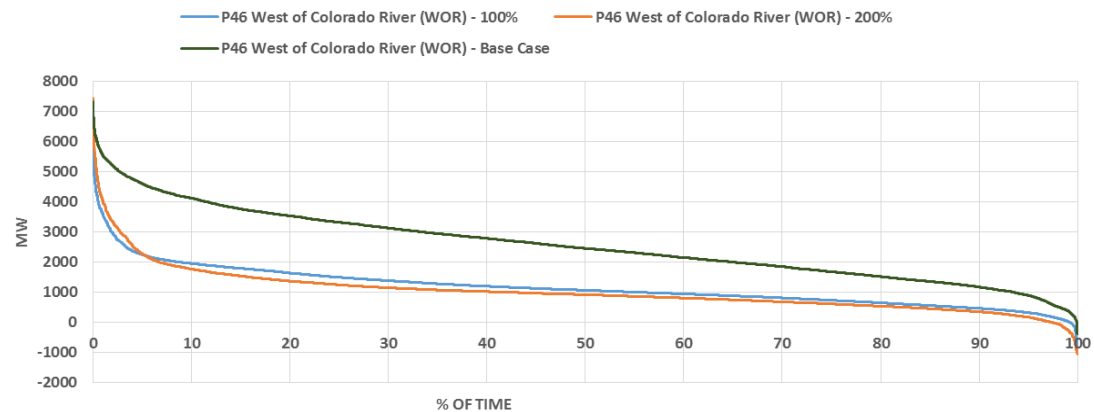
PATH 15 : MIDWAY TO LOS BANOS FLOW DURATION CHART



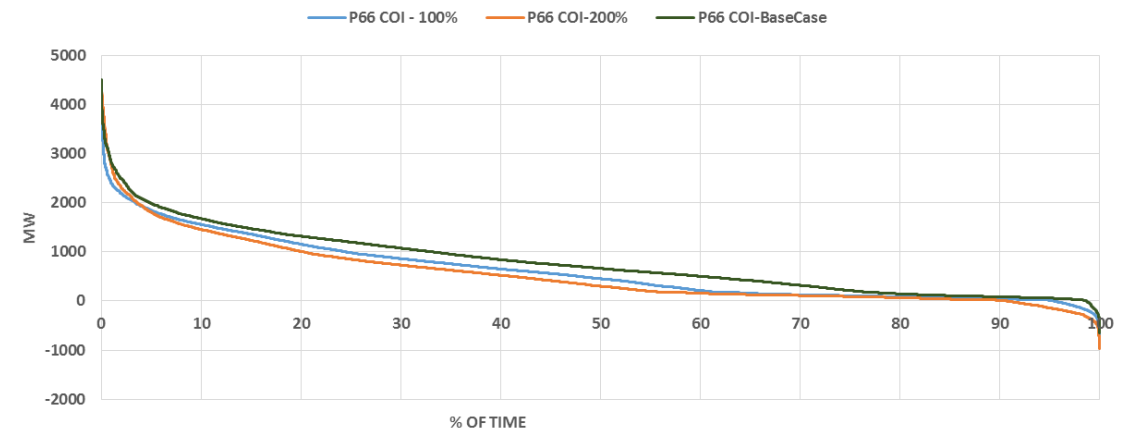
PATH 26 : NORTHERN TO SOUTHERN CALIFORNIA FLOW DURATION CHART



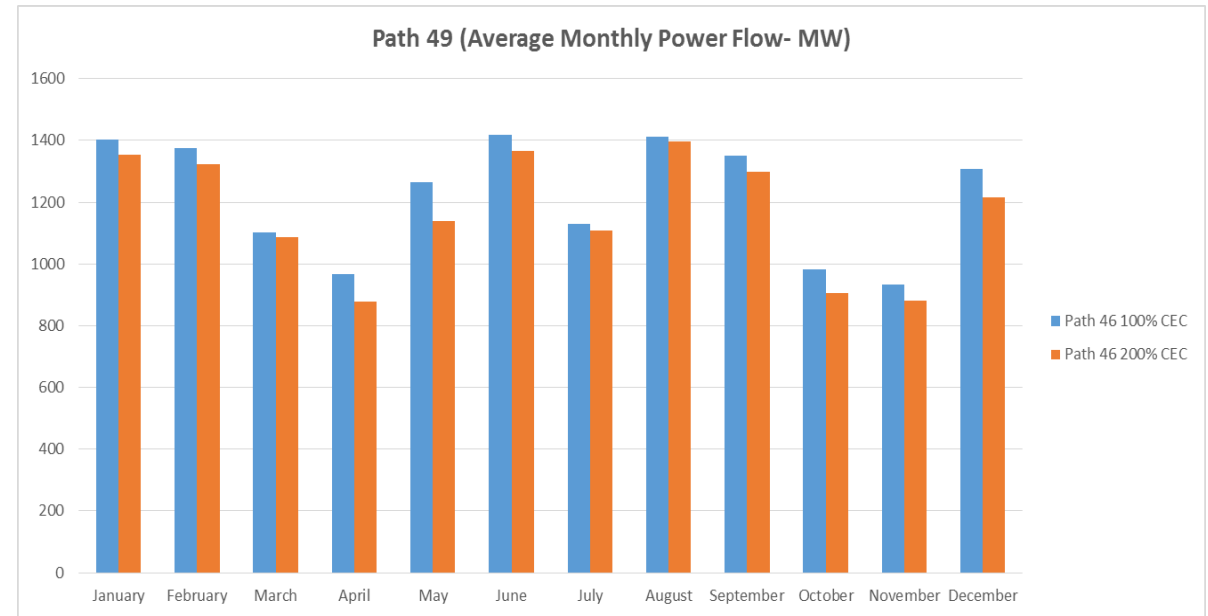
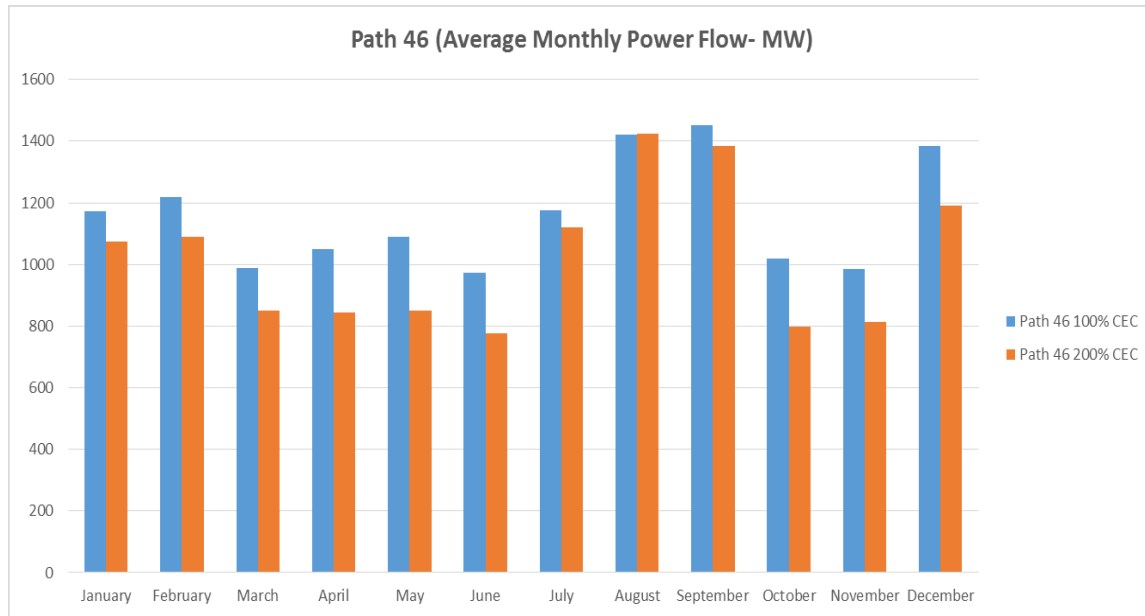
PATH 46 : WEST OF COLORADO RIVER (WOR) FLOW DURATION CHART



PATH 66 : COI FLOW DURATION CHART

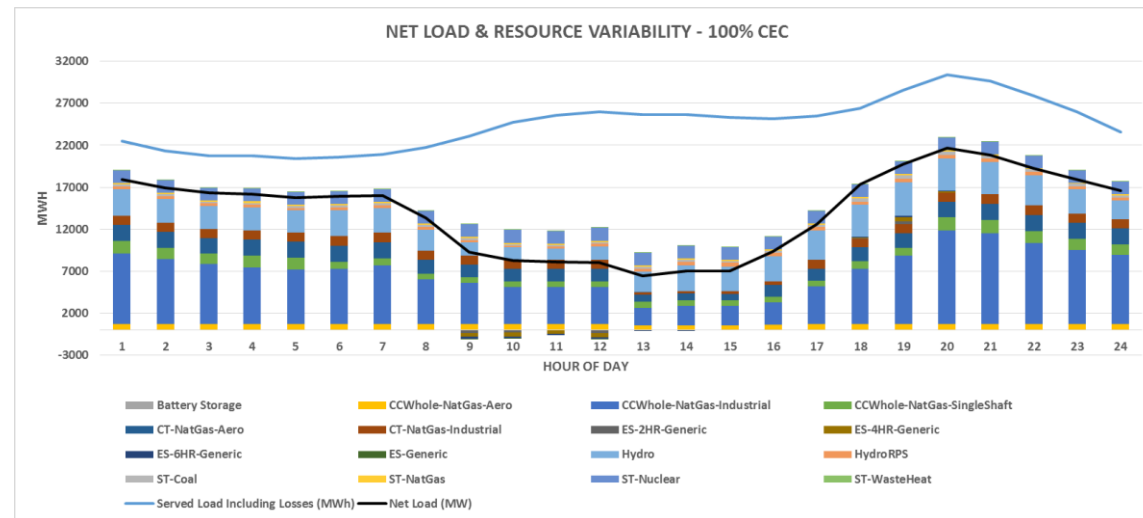
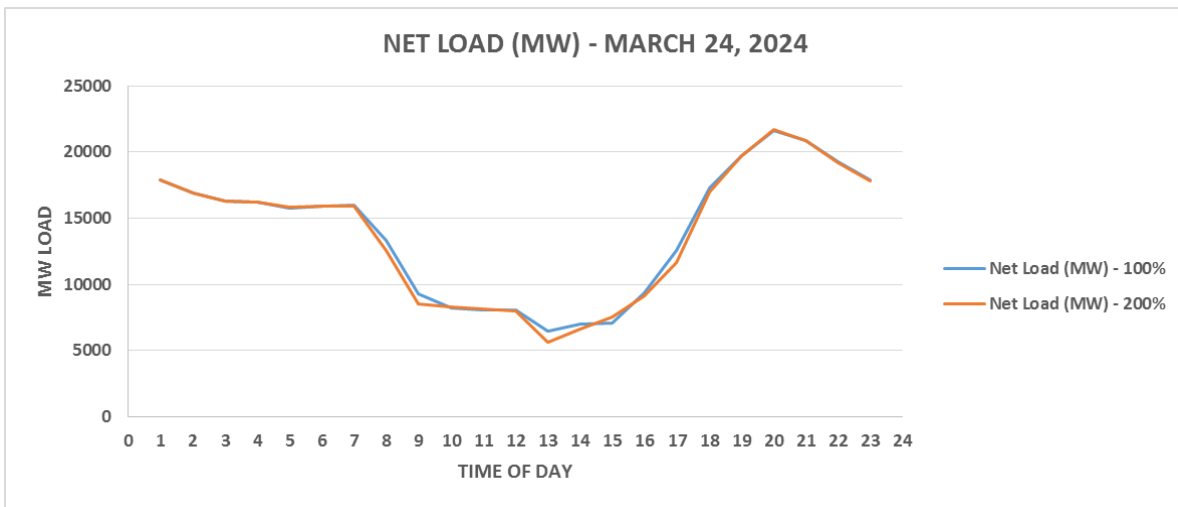


Import/Export trends

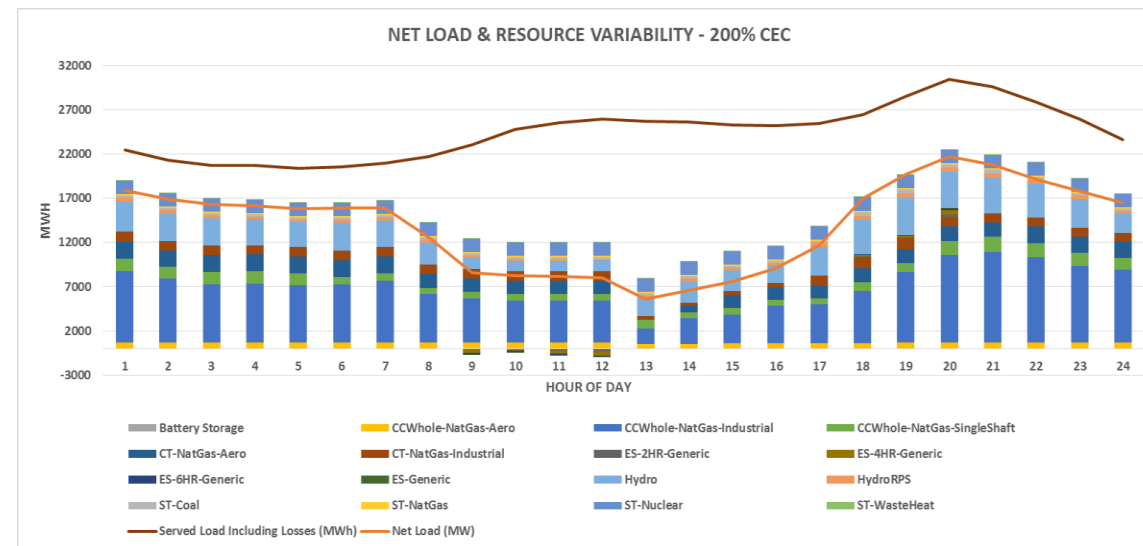


- Considerable reduction in path utilization observed between comparison of base model to other scenarios.
- No significant difference in path utilization was observed between comparison of 100% and 200% scenarios.
- Largest changes in flow duration from CAISO external interfaces observed on Paths 46 and Path 49 (compared to base case)
- During peak hours of the day, reversal in direction of power flow observed on P46, and P49.
- Hourly data shows displacement of CAISO internal thermal units to compensate larger levels of DER production, with minimal changes to internal ties.

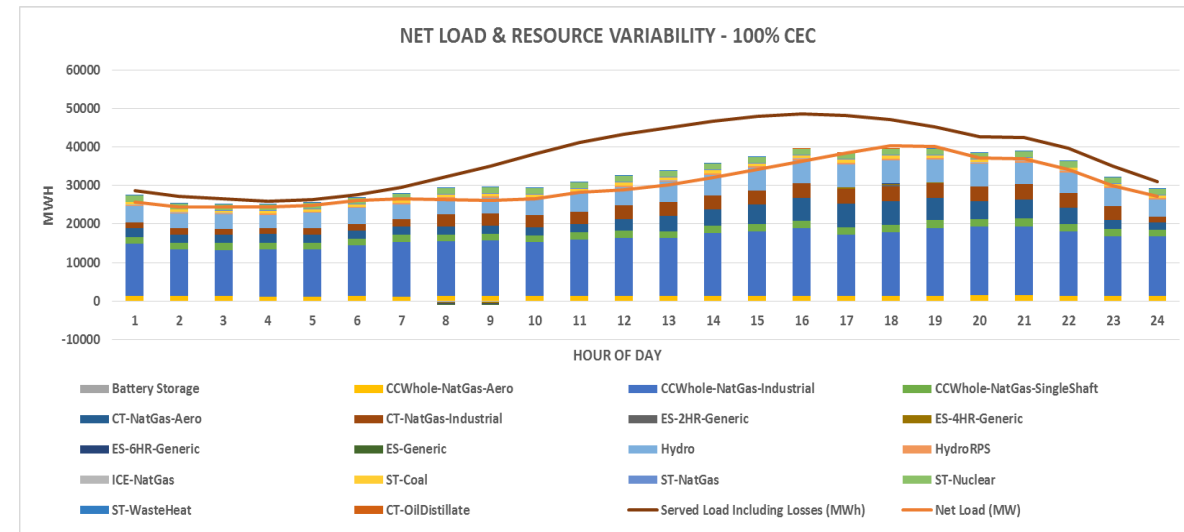
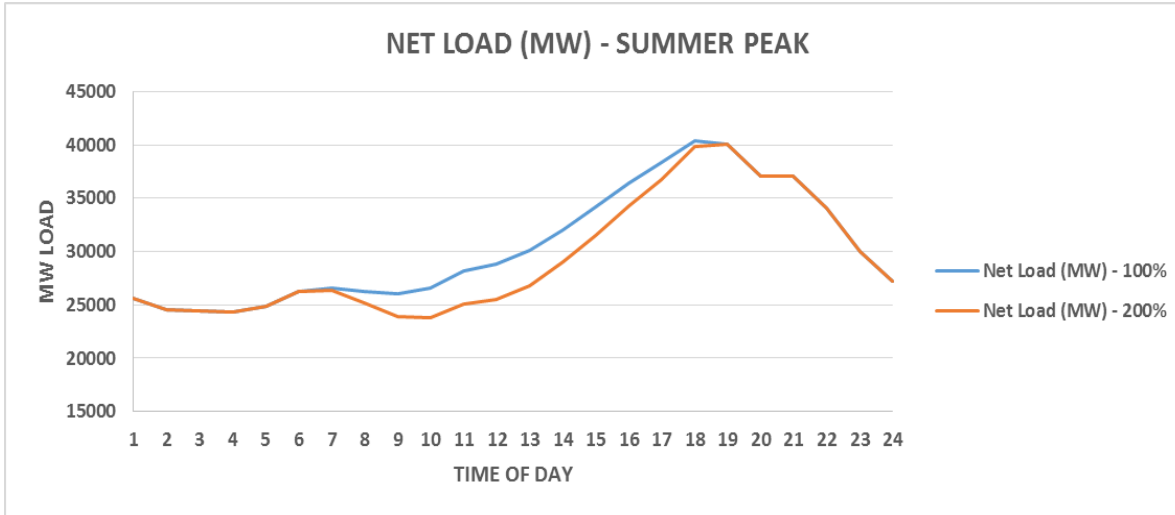
Grid Operational Trends – Spring off-peak



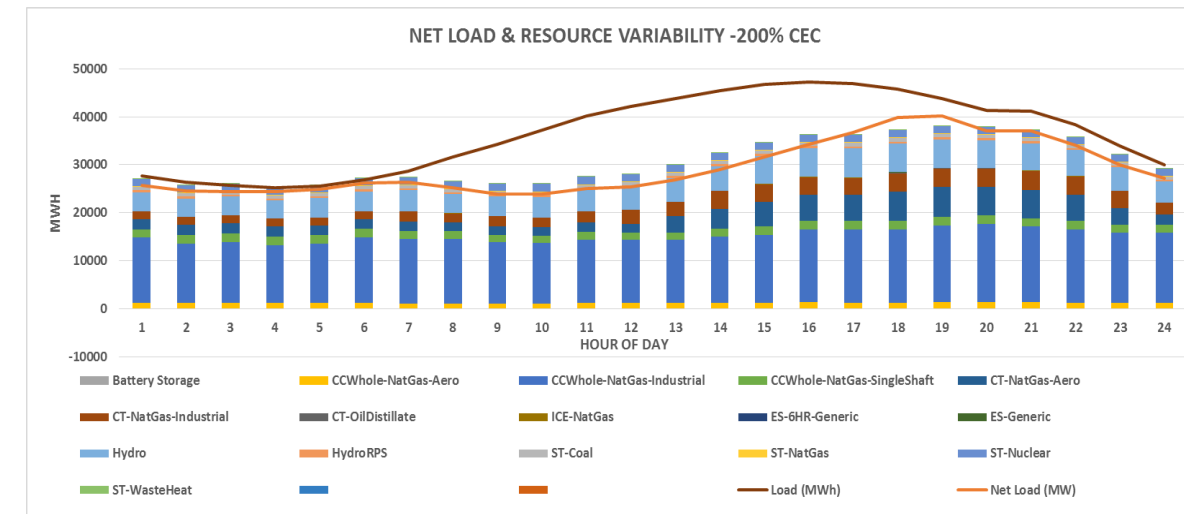
- Maximum delta change in ramp up requirement recorded between hours 16-17 of ~ 4730 MW for 200% scenario.
- Faster ramp up required for late afternoons and ramp down for mid morning with the 200% CEC forecast.
- Steeper ramps largely observed in winter and spring cases between hours 16-17 of considered days.
- Combined Cycle and Combustion Turbine are responding to variability in load.
- Pumped Storage observed to pump during daytime and generate during evening ramp.



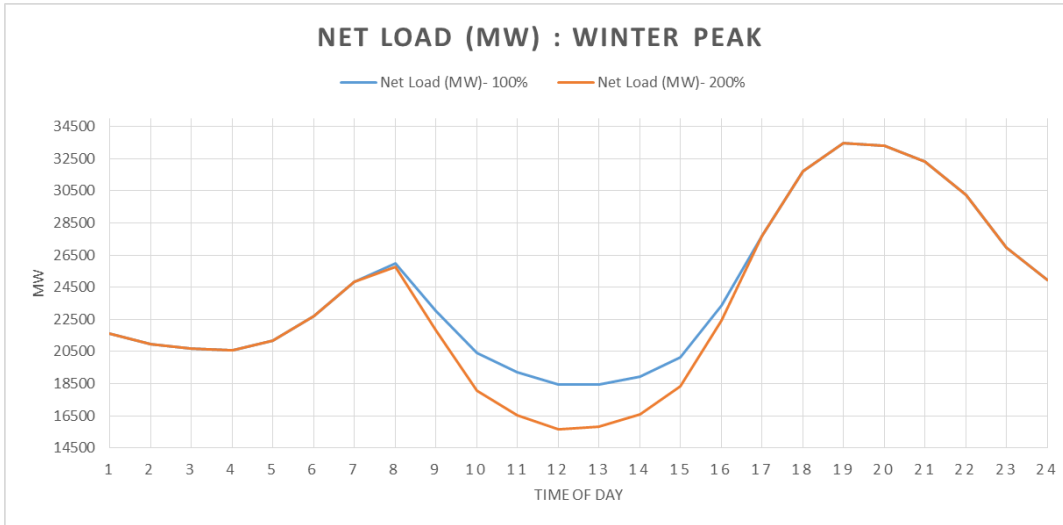
Grid Operational Trends – Summer peak



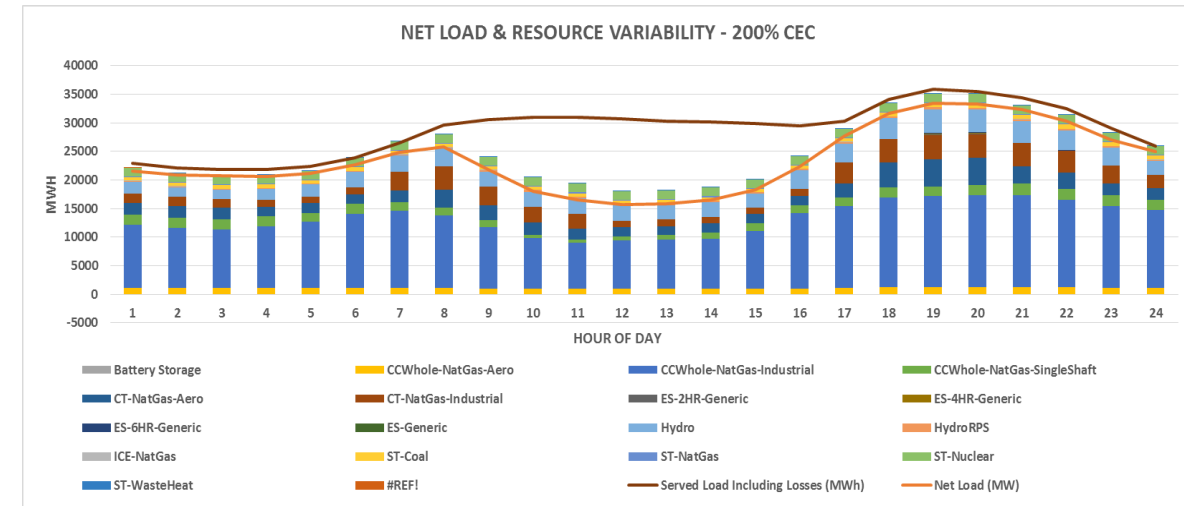
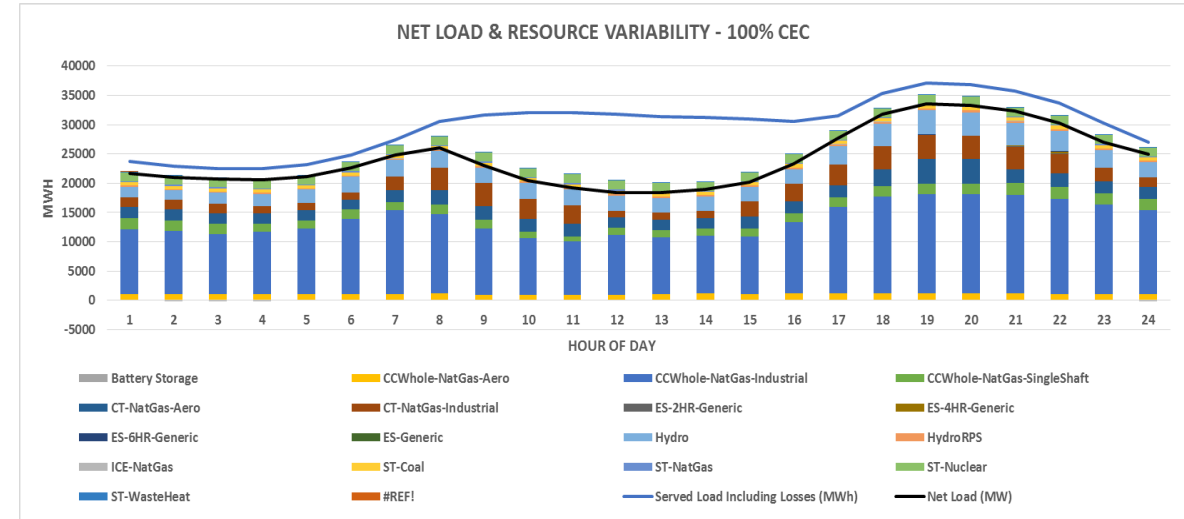
- Maximum delta change in ramp up requirement recorded between hours 16-17 of ~ 3000 MW
- Maximum delta change in ramp down requirement recorded between hours 22 to 23 of ~4000 MW
- Combined Cycle and Combustion Turbine are responding to variability in load
- Pumped Storage observed to pump during daytime and generate during evening ramp.
- Faster ramp up required during peak hours of afternoon with 200% CEC forecast.



Grid Operational Trends – Winter peak

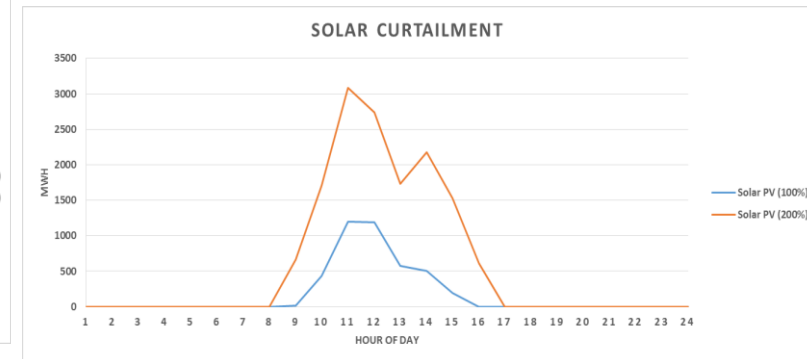
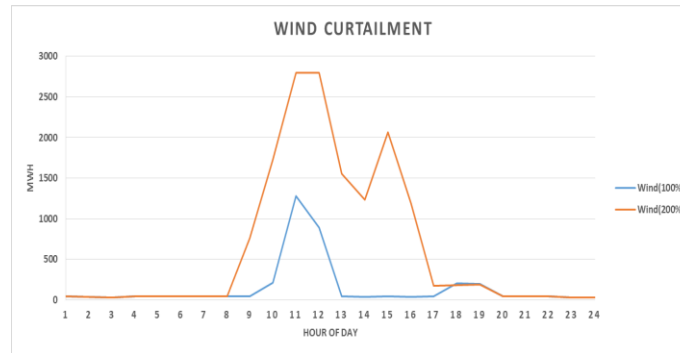
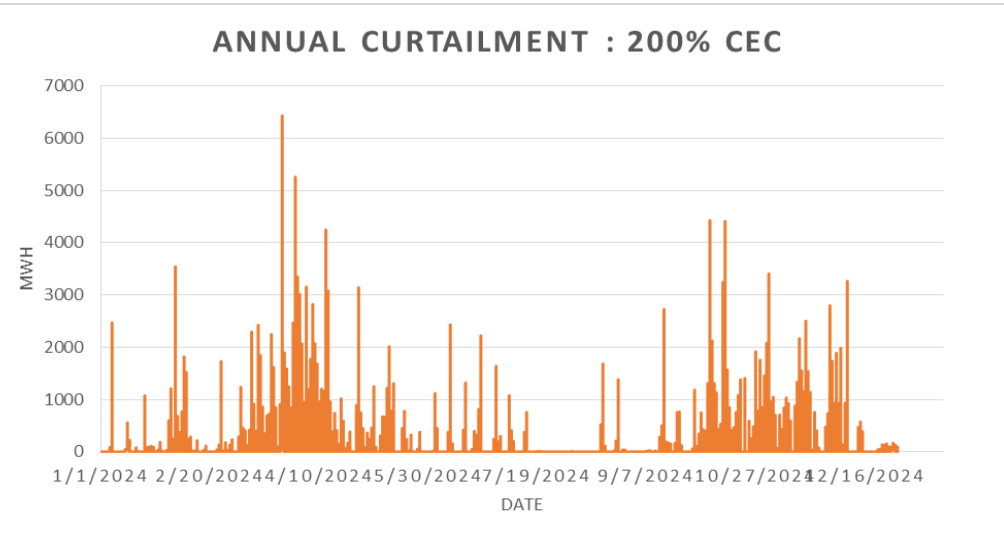
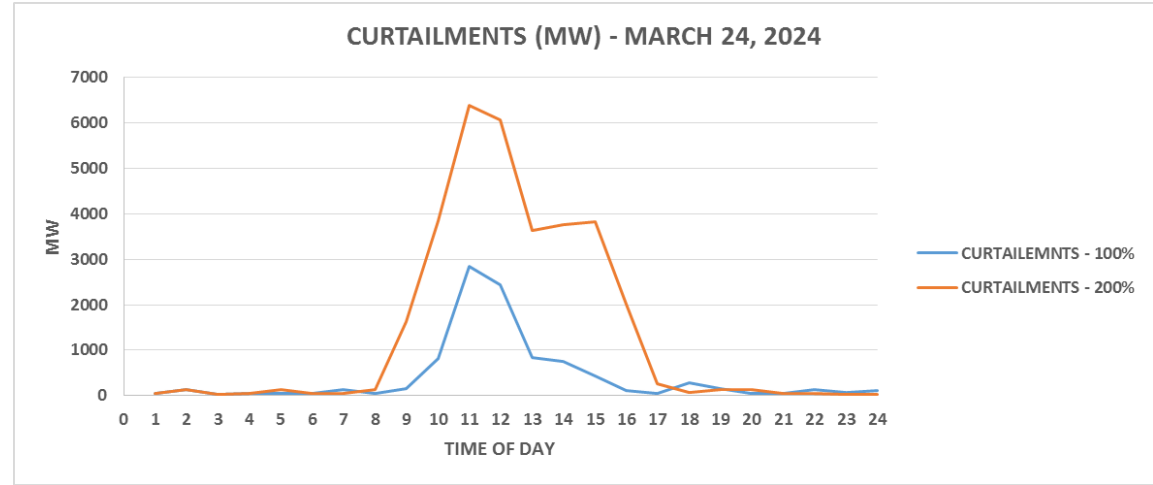
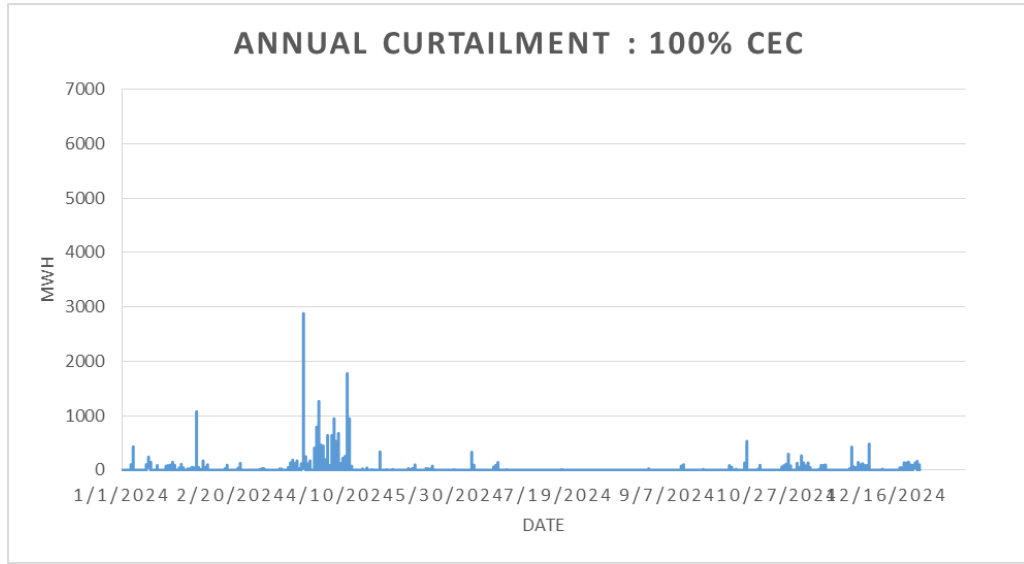


- Maximum delta change in ramp up requirement recorded between hours 16-17 of ~ 5500 MW
- Faster ramp up required for late afternoons and ramp down for mid morning with the 200% CEC forecast.
- Steeper ramps largely observed in winter and spring cases between hours 16-17 of considered days.
- Combined Cycle and Combustion Turbine are responding to variability in load
- Pumped Storage observed to pump during daytime and generate during evening ramp.

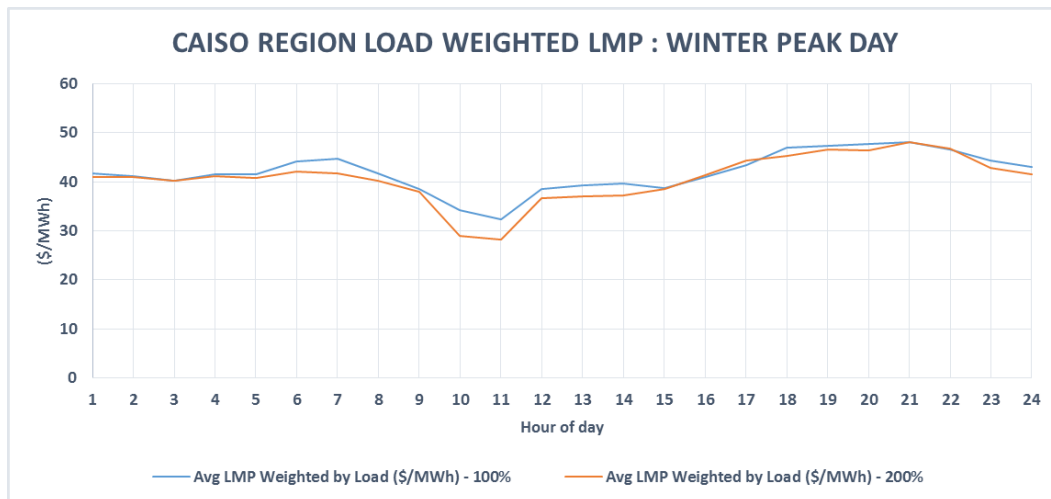
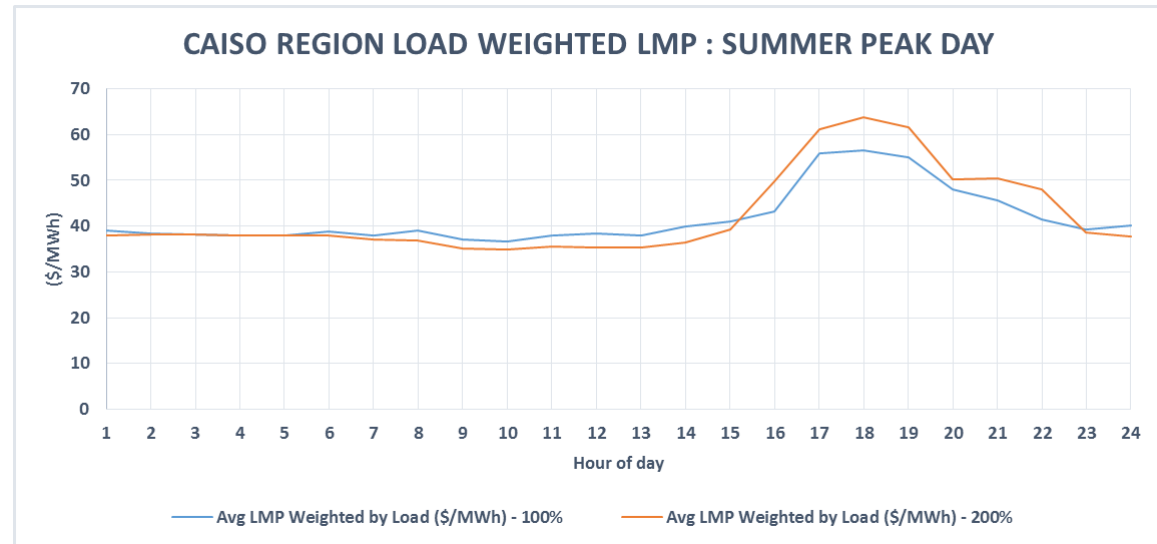
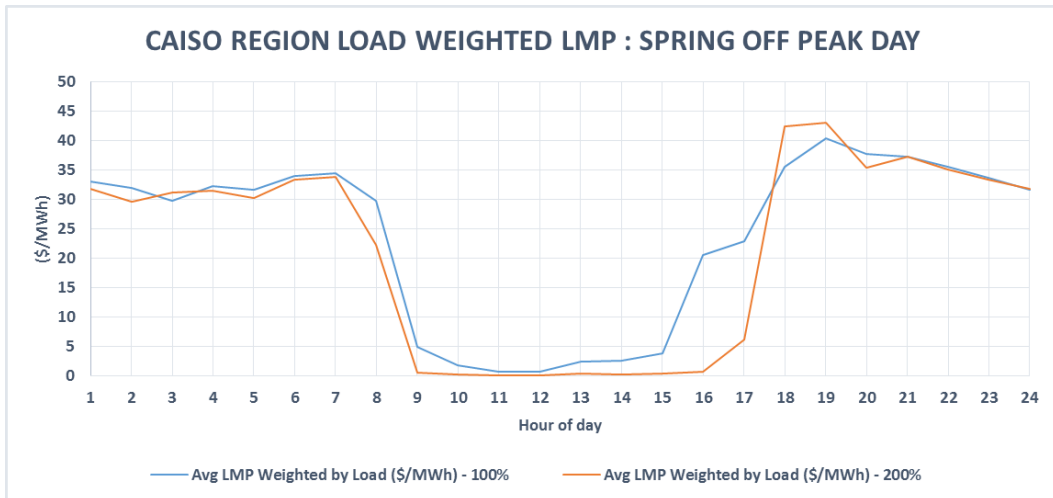


Curtailments

- Curtailment is concentrated during off peak months. Trend begins to change with increased DER integration.
- High annual total curtailment of 816GWh in 200% vs. 93GWh in 100%

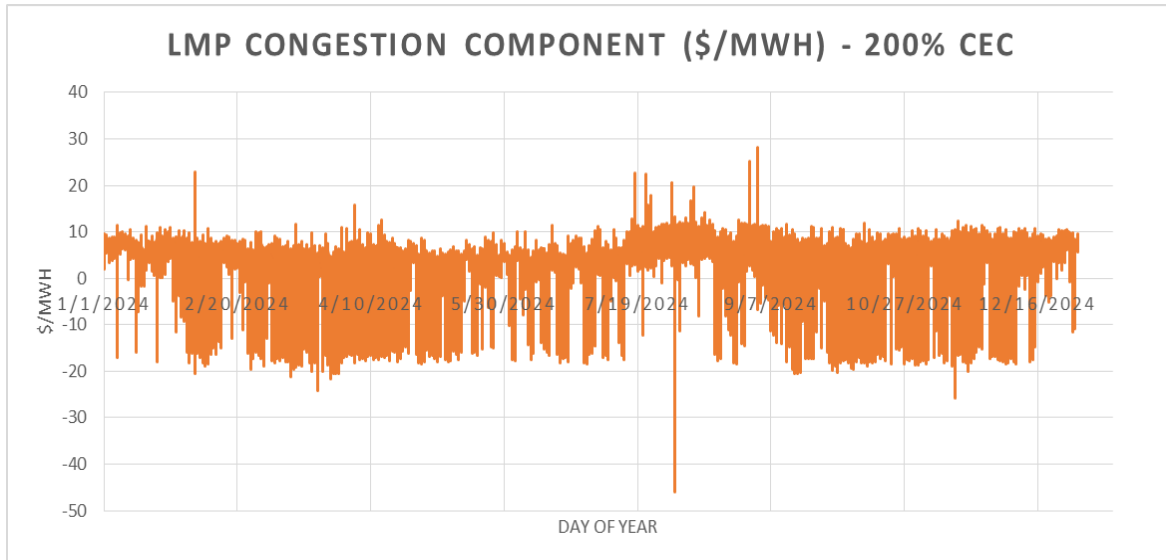
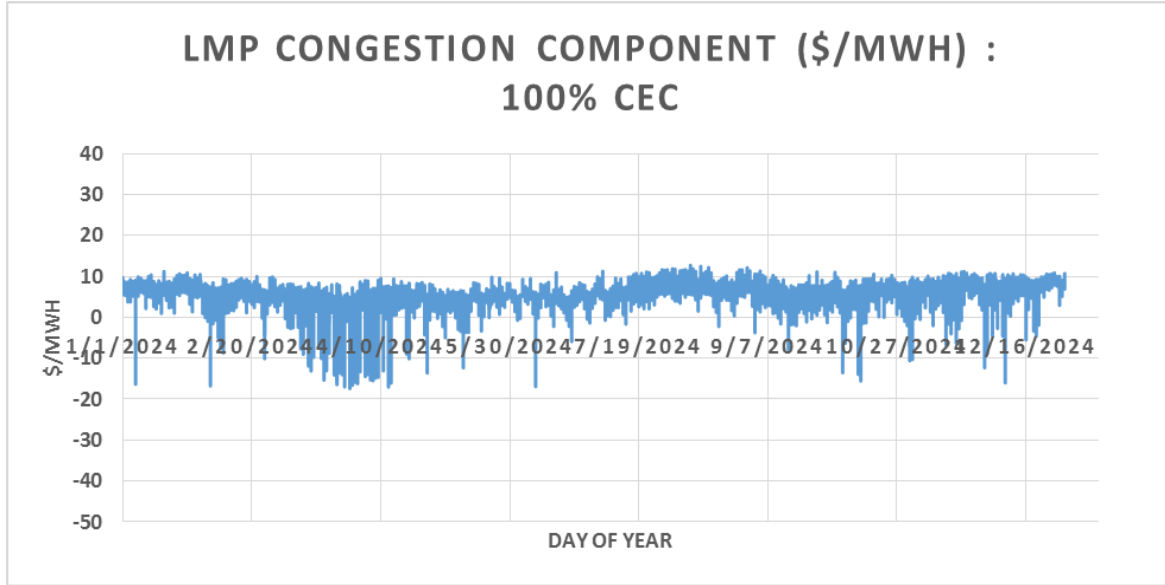


LMP Trends and Congestion



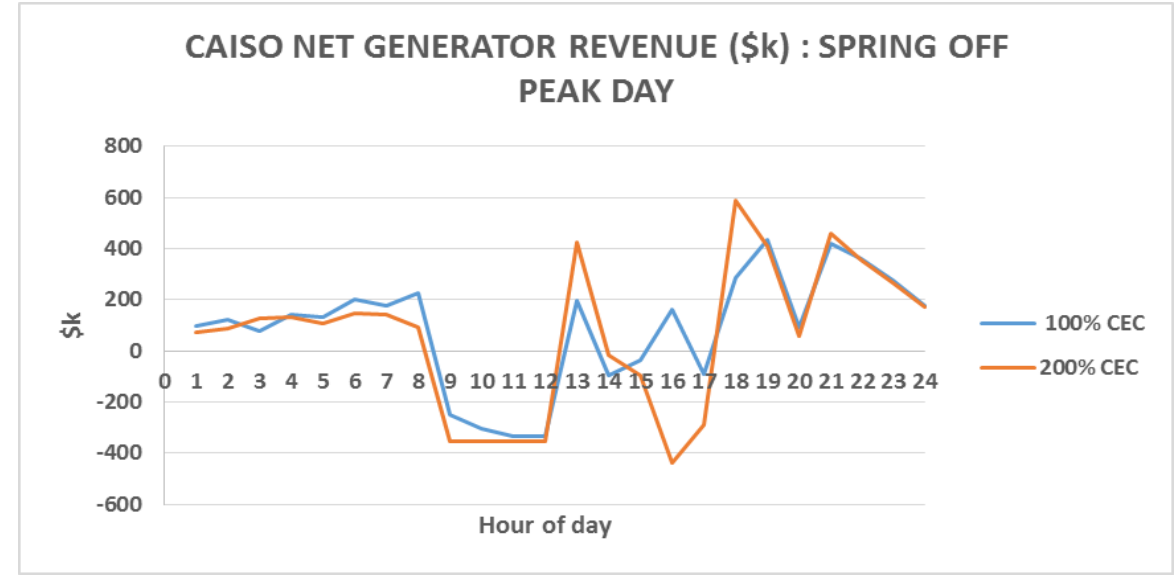
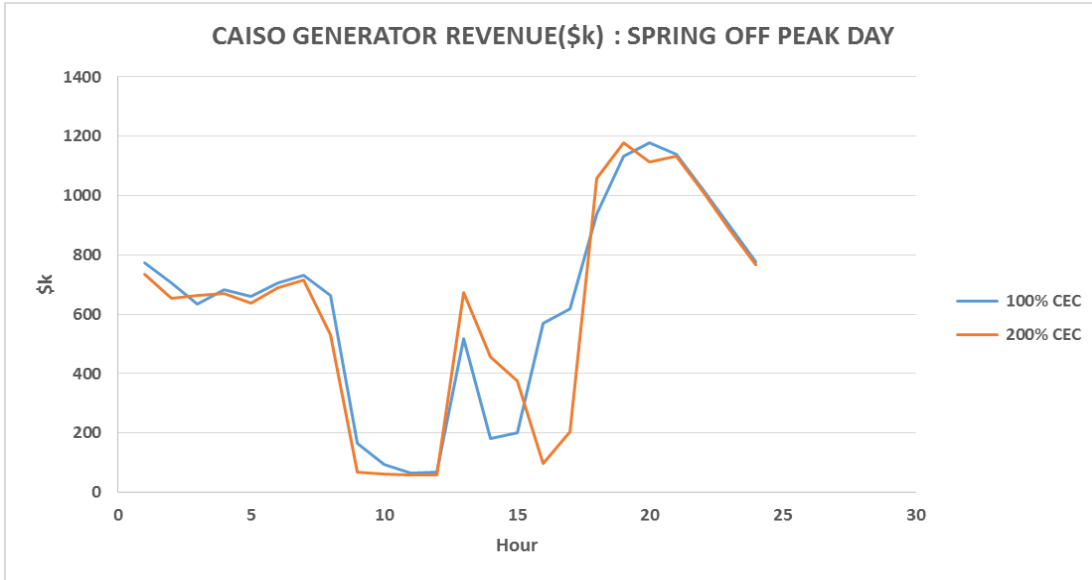
- 200% CEC show decline in CAISO region LMP's because of additional non-curtailable resources and congestion on CAISO Net 0 Export Interface
- No Wind or PV curtailment seen in either 100% or 200% cases during summer and winter periods.

Annual Average LMP congestion component

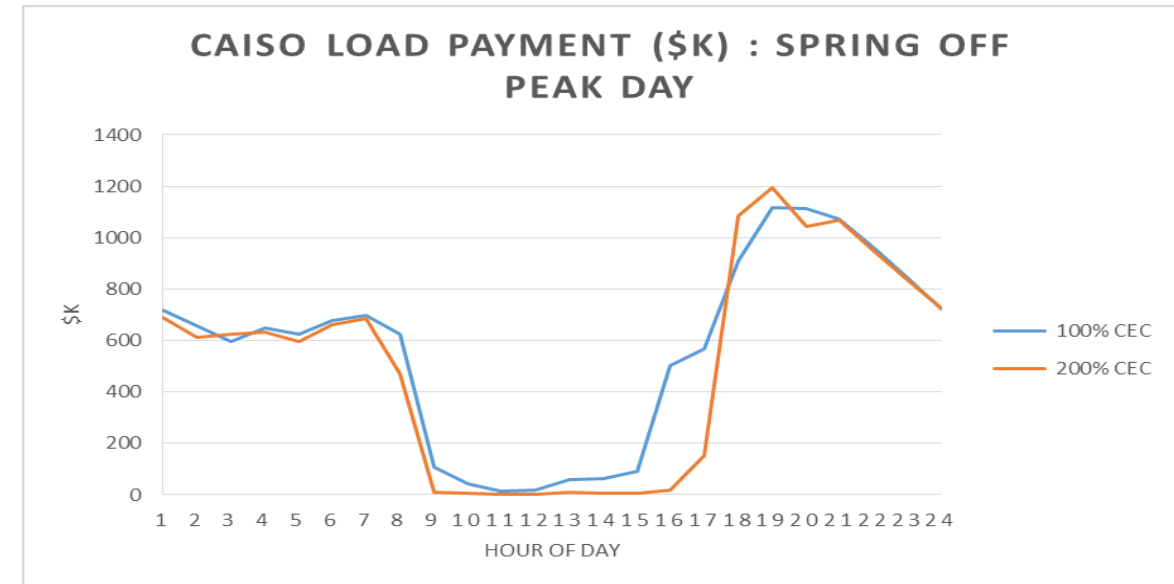


- Congestion component volatility can be seen in the charts
- 100% CEC: High volatility is seen in months of March, April
- 200% CEC: High volatility can be seen all through the year except late July through early August
- The constraints are mostly a combination of internal ties and localized congestion to accommodate increasing DER.
- CAISO net-export constraint is a binding limit in the system for majority of the hours.

Energy Market and Revenues – Load payment and Generation Revenue

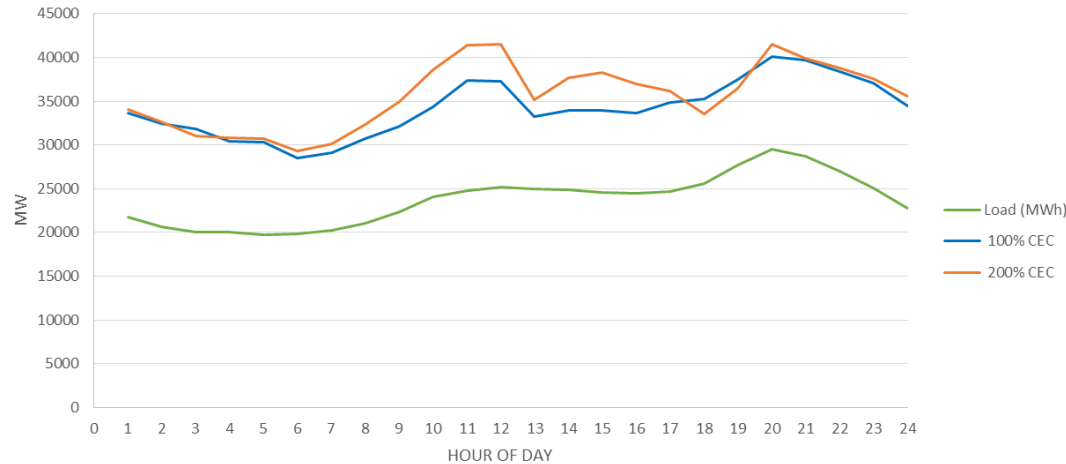


- Generator payment is higher in 200% CEC because of constraints causing higher LMP's at generators than at Load.
- Load Payment is lower in 200% CEC because of lower load LMP prices
- Net generator revenue is less than zero which could result in uplift charges



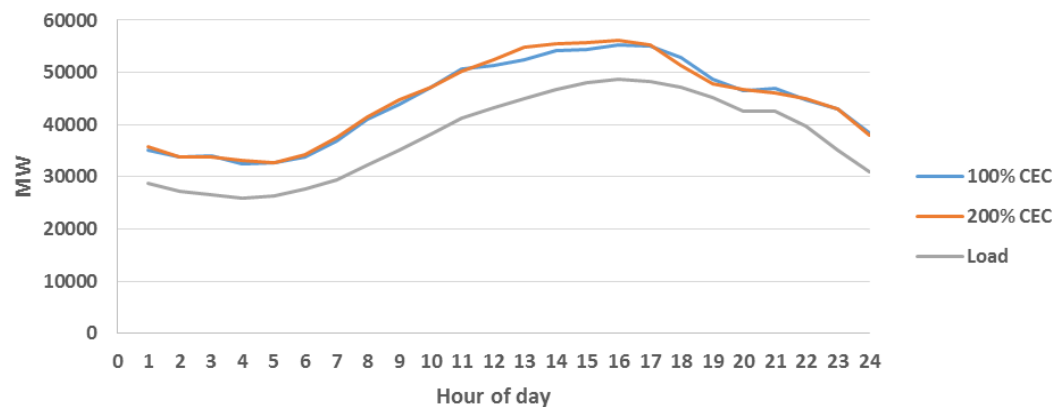
Energy Market and Revenues – CAISO load and committed resources

CAISO LOAD AND COMMITTED CAPACITY : SPRING OFF PEAK

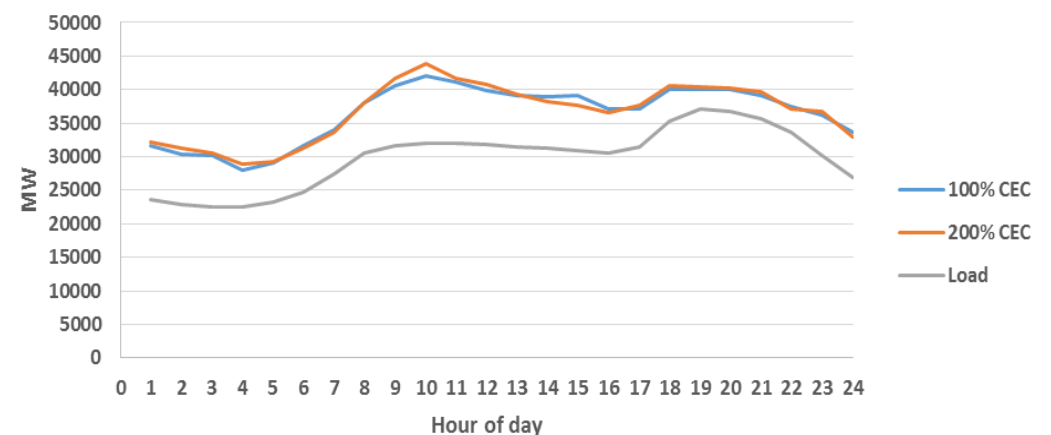


- Resource commitment shows additional resources during morning pick up in 200% CEC case
- Due to ancillary service requirement, more resources are committed for reg-up, flex-up, and spinning reserve.

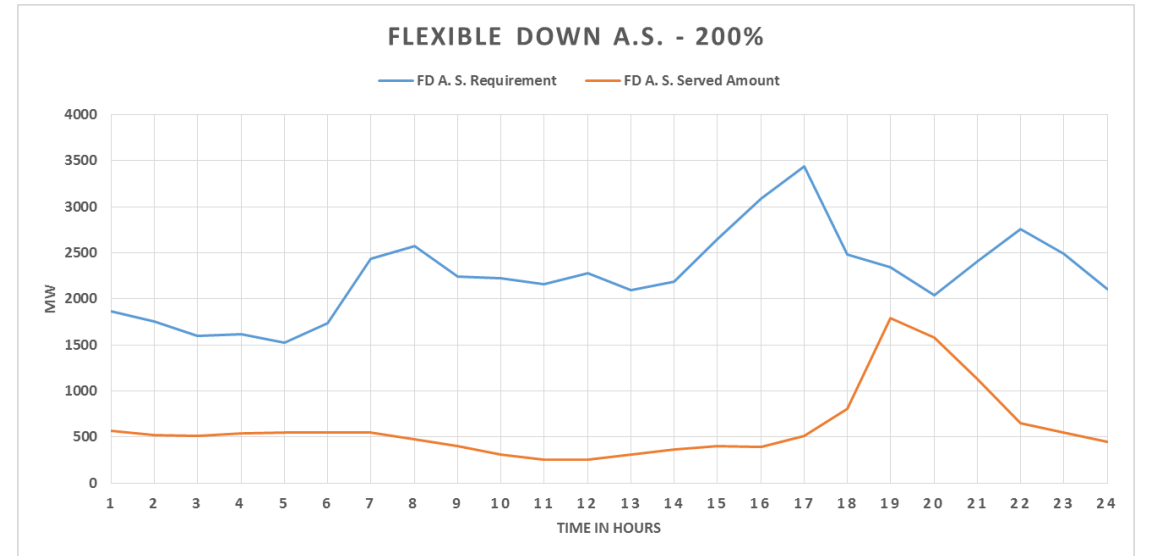
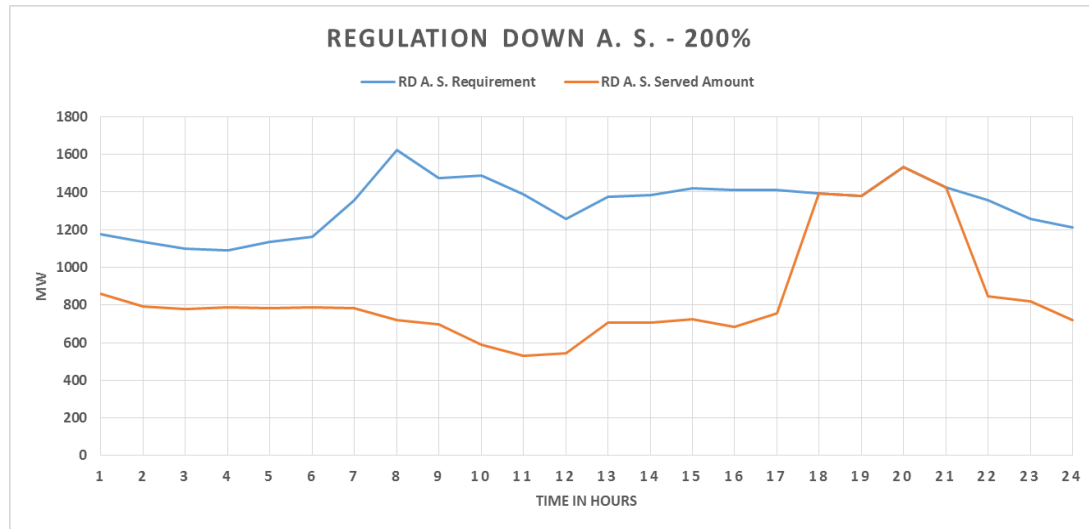
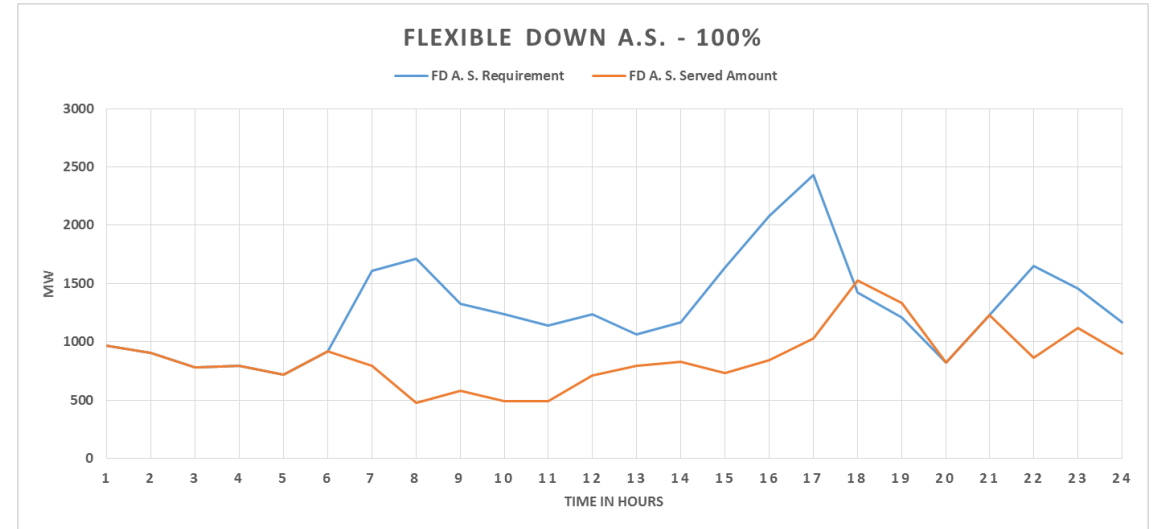
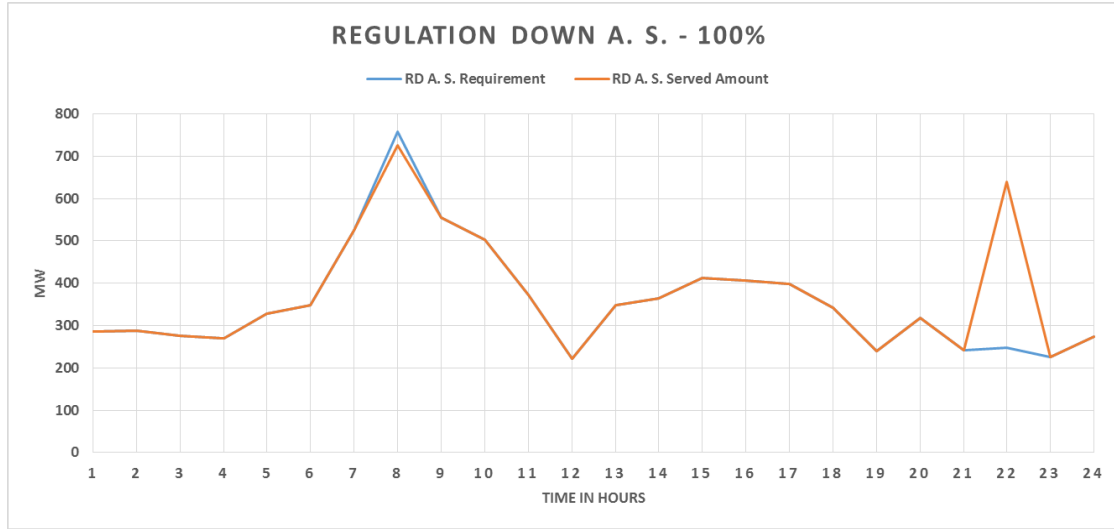
CAISO LOAD AND COMMITTED CAPACITY : SUMMER PEAK



CAISO LOAD AND COMMITTED CAPACITY : WINTER PEAK



Energy Market and Revenues – Ancillary Service Market



Energy Market and Revenues – Ancillary Service Market

- In 200% CEC scenario, capacity shortfalls were observed in Flexible Down and Regulation down .
- In 100% CEC scenario, capacity shortfalls were observed in Flexible Down.
- Maximum flexible down shortfall during spring off-peak day of 3000 MW.
- Uplift is difference between production cost and LMP payment. Uplift is increasing in 100% CEC and 200% CEC as the LMP's are lower than the cost during some hours of the day
- Uplift charges in 200 % cases lesser than 100 % due to improved net generator revenue by participation in ancillary service market.

Revenue from A.S and Energy Market

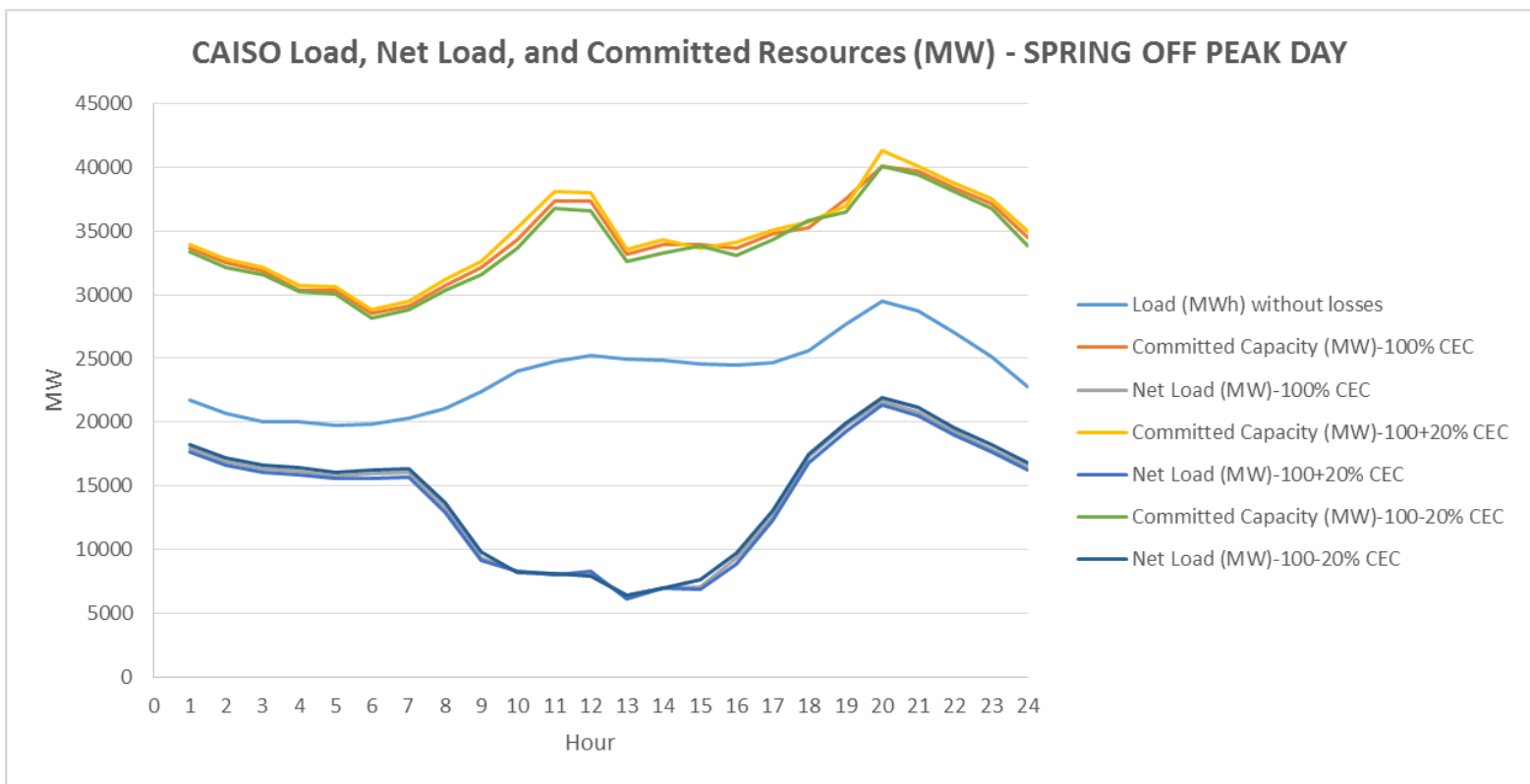
	Energy Market Revenue	Ancillary Service Market Revenue
100% CEC	9.40 B\$	3.8 B\$
200% CEC	8.50 B\$	15.31\$

Annual Uplift charges are shown below Base, 100% and 200% scenarios

Base	100% CEC	200% CEC
\$0.201B	\$1.01B	\$0.439B
200% CEC	8.50 B\$	15.31\$

Impact of Forecasting errors (+/- 20% Sensitivities)

- Study variability of DER forecast
- Study over commitment or under commitment of resources compared to the base forecast



- +20% Forecast errors in PV and non PV DGs result in down- ramp of following generation sub-types

Sub- Type	Total Dispatch change (delta)
CCWhole-NatGas-Industrial	-2910
CT-NatGas-Aero	-987
CCWhole-NatGas-SingleShaft	-496

- -20% Forecast errors in PV and non PV DGs result in ramping up of following generation sub-types.

Sub- Type	Total Dispatch change (delta)
CCWhole-NatGas-Industrial	3145
CCWhole-NatGas-SingleShaft	327
Hydro	99

- Committed Generation
 - Higher resource commitment due to variable resources
- Curtailment
 - Higher curtailment at +20% level during spring peak day
 - Summer and winter Peak Days do not show curtailment
- CCWhole-NatGas-Industrial and CCWhole-NatGas-Single Shaft observe largest dispatch changes through evaluated days .

Conclusions

- Comparison between simulated results for the 200% and 100% DER integration levels (and Base Case, as necessary) indicated that:
 - Utilization factor of the major ISO Internal and External paths do not show substantial change except for ties to AZ.
 - Steeper slope observed on net load curve during spring off peak and winter peak periods.
 - Gas and storage are critical resources to respond to the variability in net load and renewable production.
 - Significant increase in curtailments observed; more than doubled during peak PV production hours.
 - Reduction in average LMPs throughout CAISO system with increasing propagation of DER in the grid.
 - Increase in generator uplift costs compared to base case
 - Significant stress on flexible down and regulation down reserves.
 - Increased revenue from participating in ancillary service market than energy market for 200% scenario

Thank you!

Quanta Technology, LLC
4020 Westchase Blvd., Suite 300
Raleigh, NC 27607



(919) 334-3000



quanta-technology.com



info@quanta-technology.com



Facebook.com/quanta-technology-LLC



@QuantaTech



LinkedIn.com/company/quanta-technology



QUANTA
TECHNOLOGY