QUANTA TECHNOLOGY

External

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

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CIGRE **Grid of the Future (GOTF)** Conference

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Contents

Study Objectives

- Evaluate the reliability impacts on ISO controlled grid under forecasted levels of self-generation (BTM-DER).
- In these simulations, CAISO system is considered for analysis.
  - California Energy Commission (CEC) forecasted levels of self-generation for year 2024.
- Evaluate impacts associated with
  - Reverse Power Flow
  - Steady state system analysis
  - Transient voltage response
  - System Frequency response
- GE PSLF is used for simulation studies. Snapshots of the system were exported from production simulation and converged in power flow.
  - Representative of system dispatch and load levels consistent with Security constrained optimal power flow and economic dispatch.
  - Studies cover the most conservative system conditions (Spring off-peak, Summer peak and Winter peak)

Methodology and Assumptions

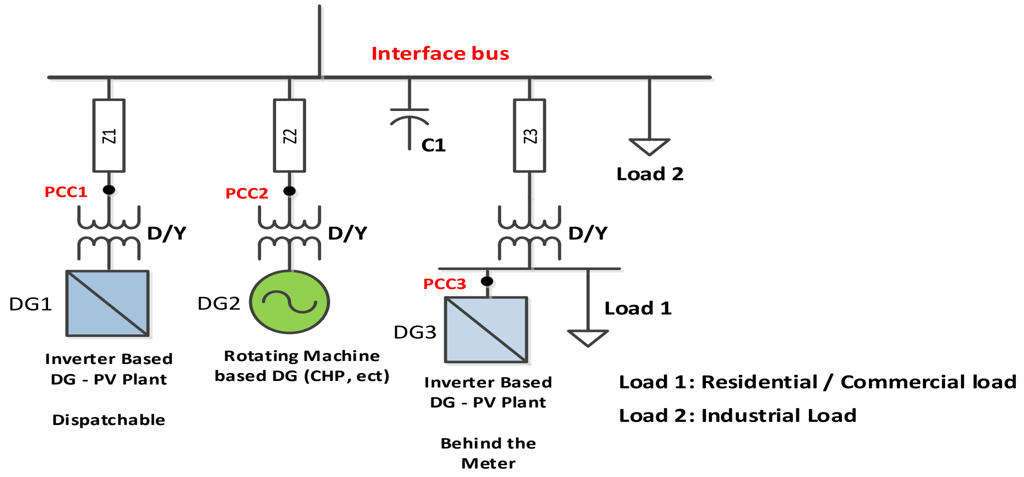
- Forecast for three utilities: PG&E, SCE, SDG&E
  - 973 buses, 4.7 kV to 230 kV
  - PV and non-PV
    - PV: Residential
    - non-PV: Commercial
  - Number of added generators: 973 PV, 973 non-PV
  - MW of added generators: 3,985 MW (100%)
    - PV: 2,097 MW, non-PV: 1,888 MW
  - MW of added generators: 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

	CEC Forecast (MW) 100% Forecast (Baseline)		200% Forecast (MW)	
Entity	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

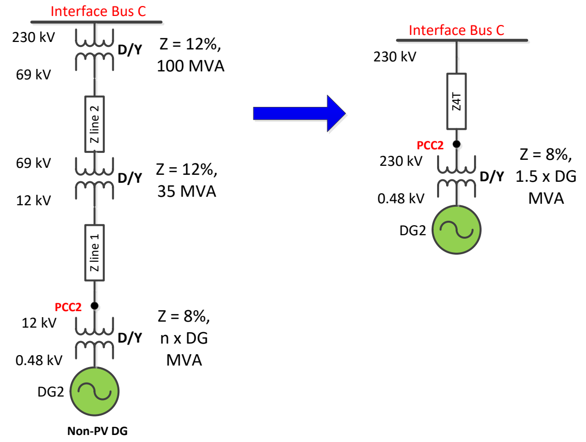
Methodology and Assumptions

- 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.
- PV DER modelled as PVD1, and non-PV DER modelled as GENROU.

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



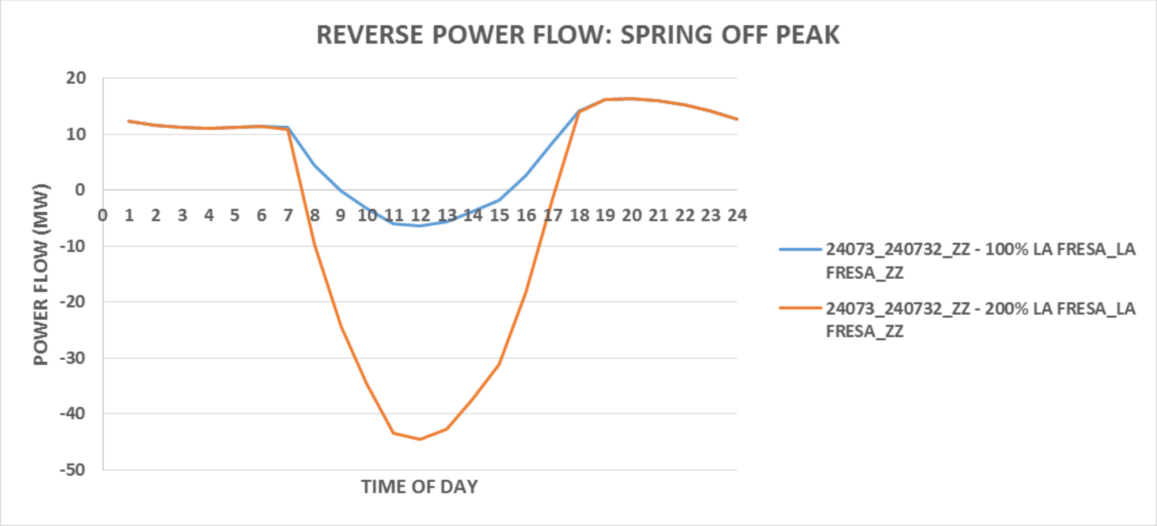
Proposed model for representation of Interface Bus
DG1: CAISO dispatch-able DG, not part of CEC forecast
DG2: non-PV DG, part of CEC forecast
DG3: PV DG, part of CEC forecast

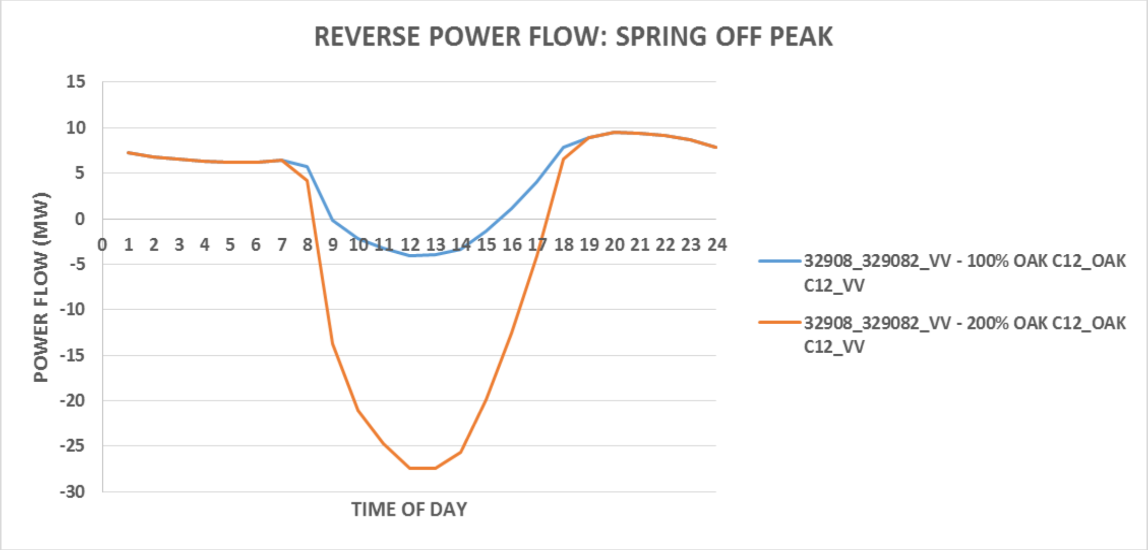


Sample PV-DG connected to distribution bus
Bus type C: 230 kV interconnection

Reverse Power Flow

- DER at both 100% and 200% CEC levels were used to evaluate potential reverse power flow conditions at T-D interfaces.
- With the increase in levels of DER production, conditions with High Generation, Low Load could occur within the distribution network, causing reverse power flow at the T-D interface.
- Several T-D interfaces spread across all utilities in CAISO jurisdiction demonstrate this trend. Reserve Power Flows observed at T-D interfaces of various 12, 66 and 230 kV buses.
- Maximum reverse power flows identified in spring off peak conditions. Power flow is directly correlated to T-D interface transformer impedances and PV plant capacity.



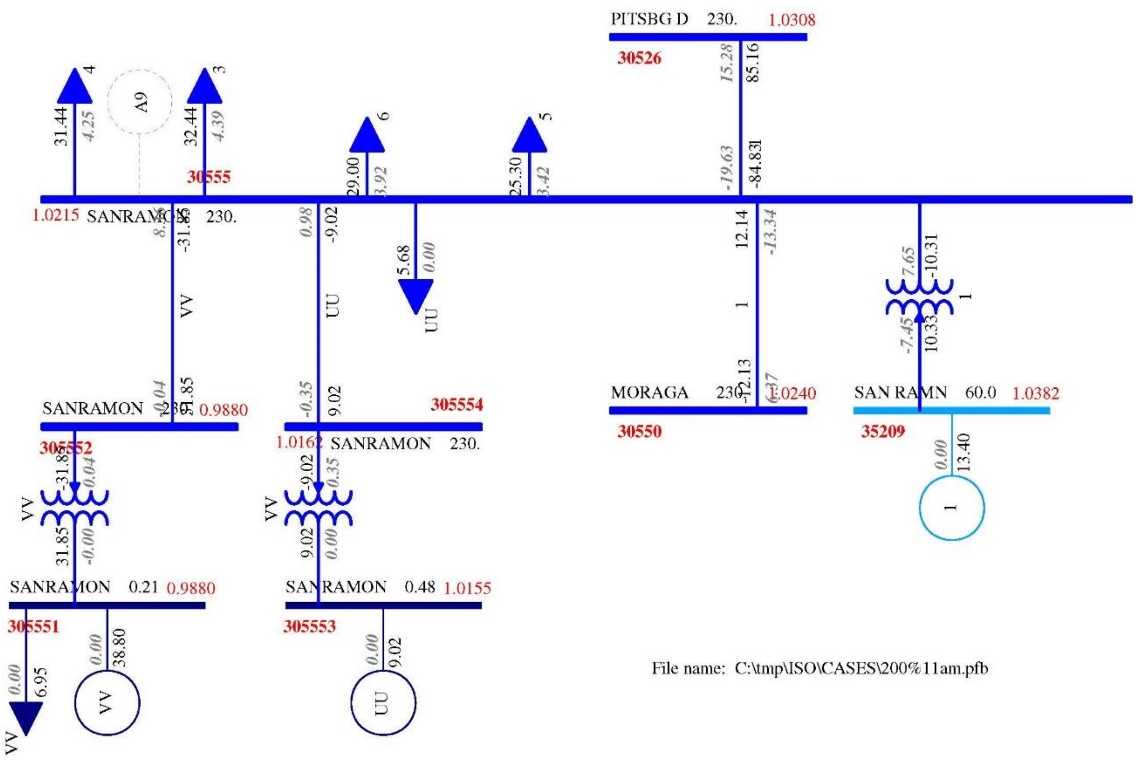


Scope of analysis

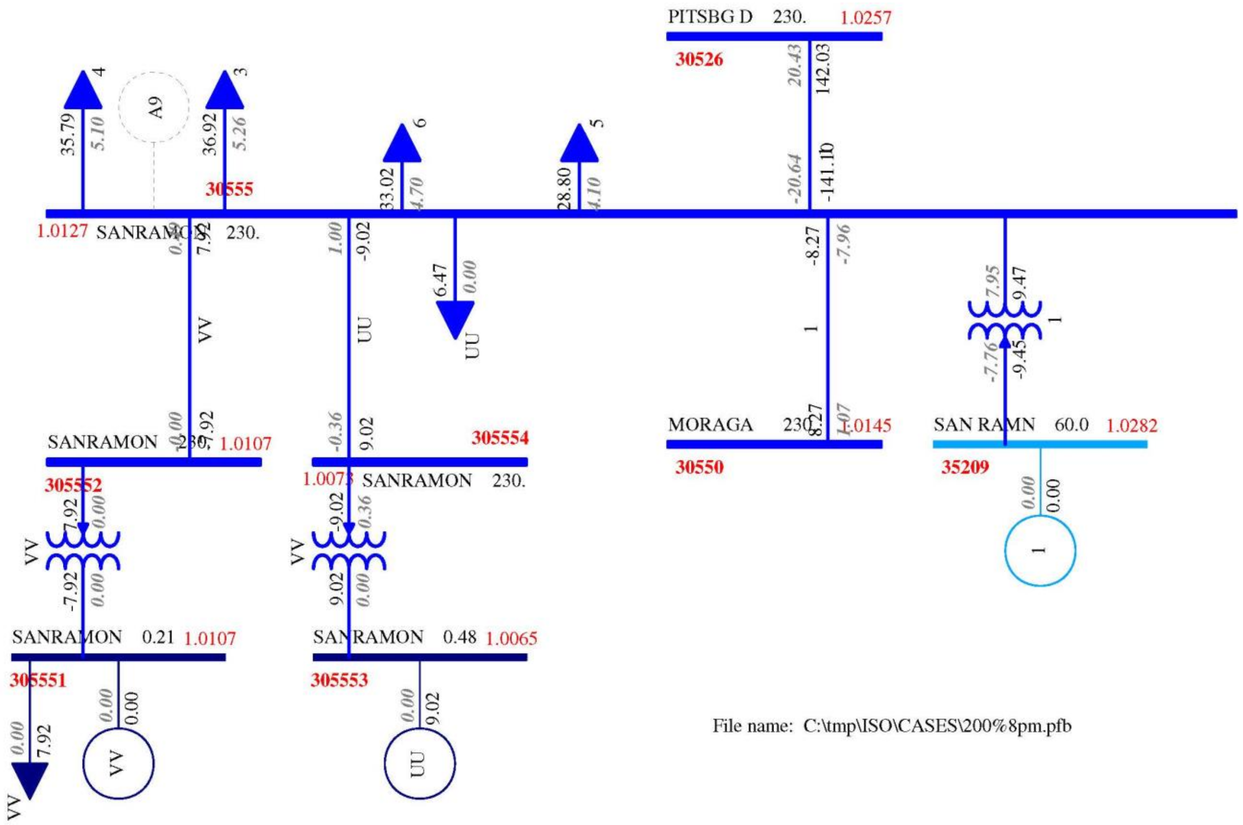
- Study local area voltage impacts of two DER integration levels.
  - 100% CEC
  - 200% CEC
- The local area studies include the following-
  - Steady state contingency assessment
    - Contingencies closest to the T-D interface were selected.
  - Transient voltage response at T-D interface buses.
- The following assumptions were made for this study:
  - All CEC generation and load added at unity Power Factor: fixed MW, 0 MVAr.
  - Generator dispatch and load obtained from production simulation results.
  - Post-contingency steady state solution include tap changers, SVD and Phase shifter actions disabled.
  - Pre-contingency cases include phase shifter, tap changer and SVD actions enabled
- Two models considered, status quo (no reactive power support) from DER and enhanced DSO (with reactive power support and frequency response capability).

Scope of analysis

11am



8pm



Steady State Analysis

- CAISO Region wide voltage trends

	DG	Time	V_{max}	V_{min}	Bus# (kV level)	Description
Status Quo	100%	11 am		0.935	34468 (70kV)	trans KEARNEY 230.00 BRKR to BRKR KEARNEY 70.00
			1.072		34903 (70kV)	isol KERN PP 70KV BUS 1 & 2
		8 pm		NA		
			1.106		38026 (115kV)	line STATIN J 115 to BRKR to BRKR JENNY 115
	200%	11 am		0.936	24725 (60kV)	OWENSCON 230.0 to INYO 230.0
			1.113		38026(60kV)	Oakland J - Alameda 115kV Cable
		8 pm		0.926	34413(70kV)	BUS 2 FAULT AT 34412 HERNDON 115.00
			1.095		38026 (70kV)	Oakland J - Alameda 115kV Cable

	DG	Time	V_{max}	V_{min}	Bus#	Description
Extended	100%	11 am		0.96	34468 (70kV)	trans KEARNEY 230.00 BRKR to BRKR KEARNEY 70.00
			1.042		34903 (70kV)	isol KERN PP 70KV BUS 1 & 2
		8 pm		0.925	34468 (70kV)	trans KEARNEY 230.00 BRKR to BRKR KEARNEY 70.00
			1.072		34903 (70kV)	isol KERN PP 70KV BUS 1 & 2
	200%	11 am		NA		
			1.106		38026(60kV)	Oakland J - Alameda 115kV Cable
		8 pm		0.956	34413(70kV)	BUS 2 FAULT AT 34412 HERNDON 115.00
			1.095		38026 (70kV)	Oakland J - Alameda 115kV Cable

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Steady State Analysis – San Ramon 230kV bus

200%

VOLTAGES PRE & POST CONTINGENCY				11AM	8PM	ΔV
Pre Cont		Base Case		1.021	1.013	0.008
Post Cont	C1_11	BUS 2D FAULT AT 30526 PITSBG D 230.00		1.009	0.999	0.01
			ΔV	0.012	0.014	
Post Cont	C2-10	CB FAULT AT PITSBG 230 CB822		1.009	0.998	0.011
			ΔV	0.012	**0.015**	
Post Cont	C2-11	CB FAULT AT PITSBG 230 CB402		1.008	0.994	0.014
			ΔV	0.013	0.019	
Post Cont	C2-8	CB FAULT AT PITSBG 230 CB502		1.008	0.994	0.014
			ΔV	0.013	0.019	
Post Cont	C2-9	C2-9 "CB FAULT AT PITSBG 230 CB812"		1.015	1.003	0.012
			ΔV	0.006	0.01	
		Loss of DER		1.02	1.013	0.007
			ΔV	0.001	0	

100%

VOLTAGES PRE & POST CONTINGENCY				11AM	8PM	ΔV
Pre Cont		Base Case		1.022	1.012	0.01
Post Cont	B3_20	BUS 2D FAULT AT 30526 PITSBG D 230.00		1.017	1.006	0.011
			ΔV	0.005	0.006	
Post Cont	B3_21	CB FAULT AT PITSBG 230 CB822		1.017	1.006	0.011
			ΔV	0.005	0.006	
Post Cont	C2-11	CB FAULT AT PITSBG 230 CB402		1.012	1	0.012
			ΔV	0.01	0.012	
Post Cont	C2-8	CB FAULT AT PITSBG 230 CB502		1.012	1	0.012
			ΔV	0.01	0.012	
Post Cont	C2-13	C2-9 "CB FAULT AT PITSBG 230 CB812"		1.014	1.001	0.013
			ΔV	0.008	**0.011**	
		Loss of DER		1.021	1.012	0.009
			ΔV	0.001	0	

200%

VOLTAGES PRE & POST CONTINGENCY				11AM	8PM	ΔV
Pre Cont		Base Case		1.0150	1.0120	0.0030
Post Cont	C2-8	CB FAULT AT PITSBG 230 CB502		0.9930	0.9930	0.0000
			ΔV	0.0220	0.0190	
Post Cont	C2-11	CB FAULT AT PITSBG 230 CB402		0.9930	0.9930	0.0000
			ΔV	0.0220	0.0190	
Post Cont	C5_16	Panoche - Schindler #1 & #2 115 kV Lines		1.0070	0.9970	0.0100
			ΔV	0.0080	0.0060	
		Loss of DER		1.0140	1.0120	0.0020
			ΔV	0.0010	0.0000	

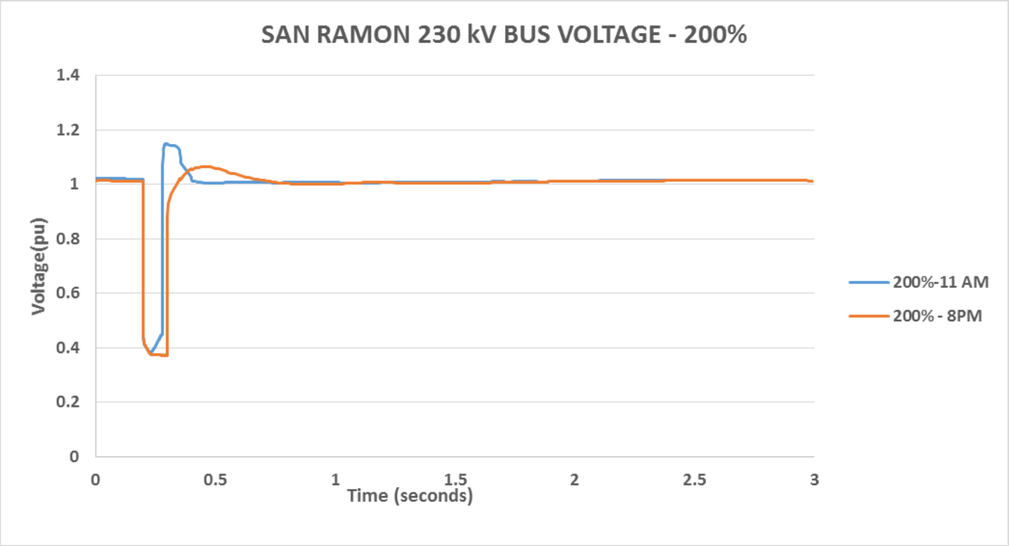
100%

VOLTAGES PRE & POST CONTINGENCY				11AM	8PM	ΔV
Pre Cont		Base Case		1.0180	1.0170	0.0010
Post Cont	C2-11	CB FAULT AT PITSBG 230 CB402		1.0060	0.9990	0.0070
			ΔV	0.0120	0.0180	
Post Cont	C2-8	CB FAULT AT PITSBG 230 CB502		1.0060	0.9990	0.0070
			ΔV	0.0120	0.0180	
Post Cont	C5_16	Panoche - Schindler #1 & #2 115 kV Lines		1.0120	1.0050	0.0070
			ΔV	0.0060	0.0120	
Post Cont	C2-13	CB FAULT AT 30550 MORAGA 230 CB202		1.0110	1.0100	0.0010
			ΔV	0.0070	0.0070	
		Loss of DER		1.017	1.0170	0.0000
			ΔV	0.0000	0.0000	0.0000

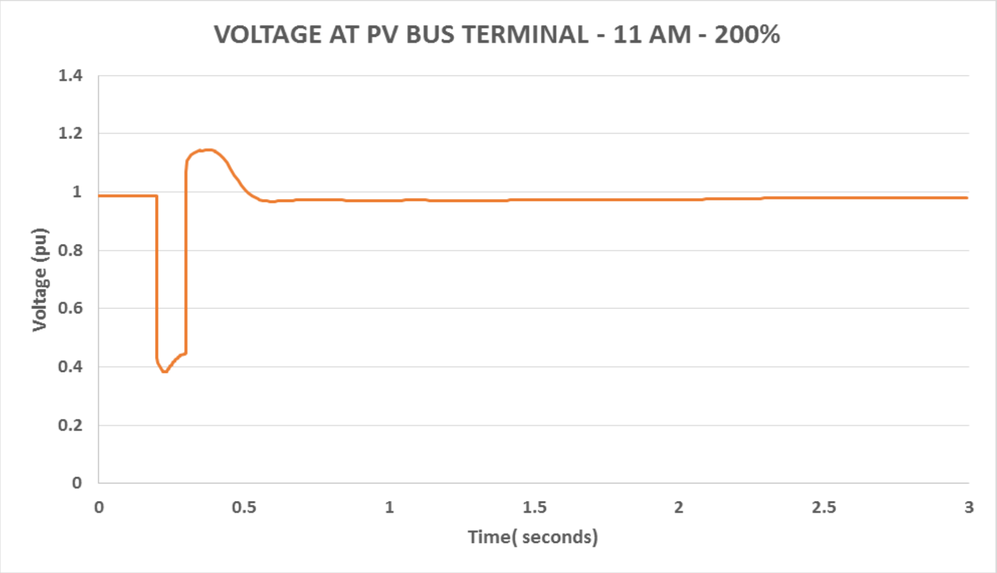
High Level Observations

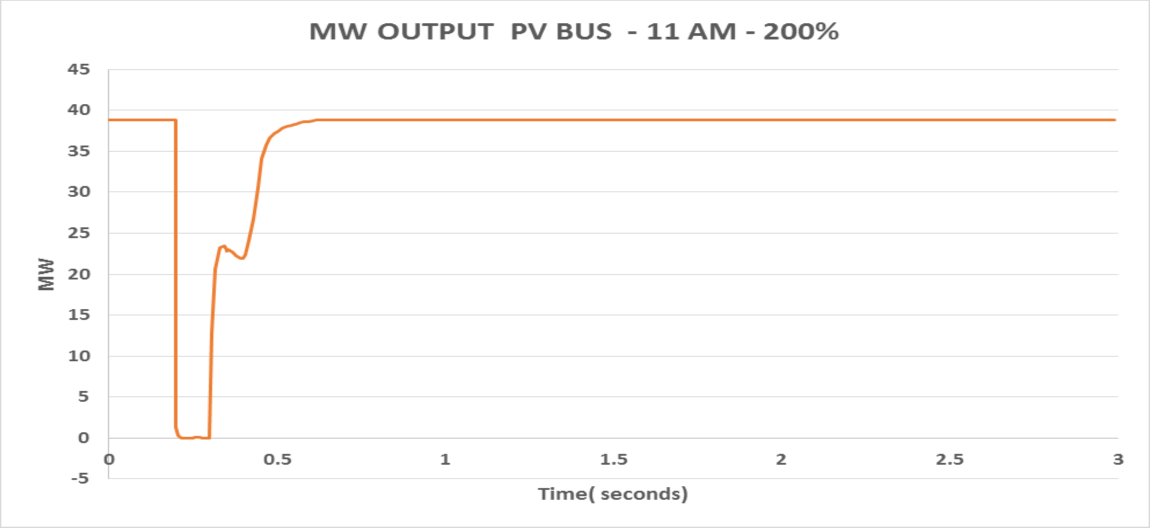
- Significantly high voltages observed in the system under light loading conditions (N-0)
- By comparison, the considered contingencies including loss of DER units, do not demonstrate significant impact on T-D interfaces.
- The response is more significant at lower voltage levels (below 100kV)
- No delta V deviations greater than 0.05 pu were recorded @ T/D interface: (Pre-Post)/Pre
- Range of voltage spread from 0.925 pu to 1.106 pu under all considered outages.

Dynamic Simulation Studies



- Voltage response within WECC criteria.
- Influence of PV DG with non-PV generation causes swell in voltage following fault clearing.
    - The effect of non-CEC renewables included.
- Response from composite load models reviewed
    - The Power output from composite load models recorded a maximum reduction of 10 MW post fault clearing.
    - No motor stalling or no delayed voltage recovery was observed.
- Higher voltages (>100kV) stronger to support the DG ride through
- PV DG tripping recorded due to frequency and voltage trip settings.





Frequency Response studies

- Double outage of Palo Verde units generating at maximum capacity.
- No frequency support capability enabled from CEC DER units (pvd1 models) or any other inverter-based generation.
- WECC frequency measured at large generation unit (MBPP-2 generator & SAN-JUAN generator)
- Case I refers to the scenario ~ 26 GW of headroom in WECC
- Case II refers to scenario with ~ 13.7 GW of headroom in WECC

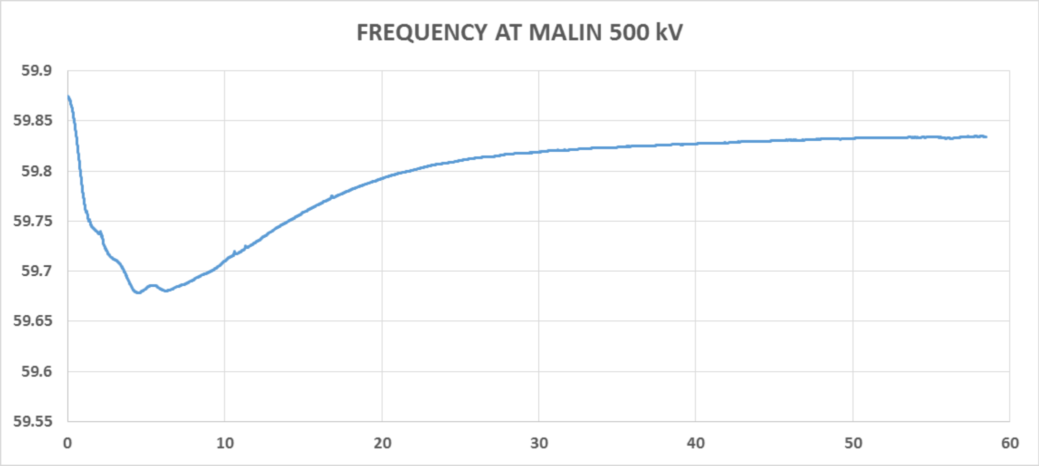
- Frequency Response (FR) :
  - FR = $\frac{\Delta P}{\Delta f}$ $[\frac{MW}{0.1Hz}]$
- FRO for the interconnection is established in BAL-003-1 Frequency Response & Frequency Bias Setting Standard.
- For WECC FRO is 840 MW/0.1 Hz
- Balancing Authority FRO allocation

$$FRO_{BA} = FRO_{Int} \frac{Pgen_{BA} + Pload_{BA}}{Pgen_{Int} + Pload_{Int}}$$

- For the CAISO, FRO is approximately 30% of WECC FRO (252 MW/0.1 Hz)

Status Quo

Case 1

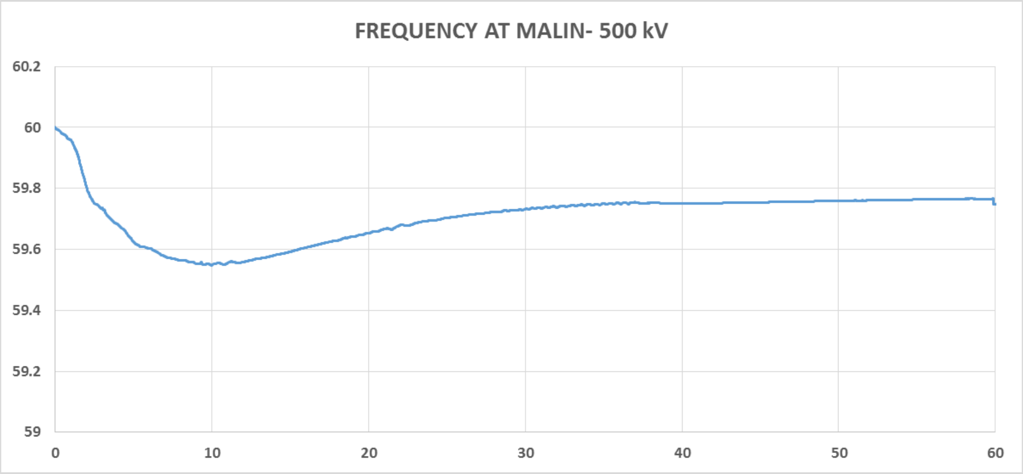


- Frequency Nadir(Cf) = 59.68
- Frequency Nadir(Cf)- WECC region = 59.685
- Frequency Nadir Time (Ct) = 6.79 sec
- Settling Frequency (B) = 59.834 Hz

Frequency Response (MW/0.1Hz)

- CAISO region : 259.1 Hz
- WECC region : 2236 Hz

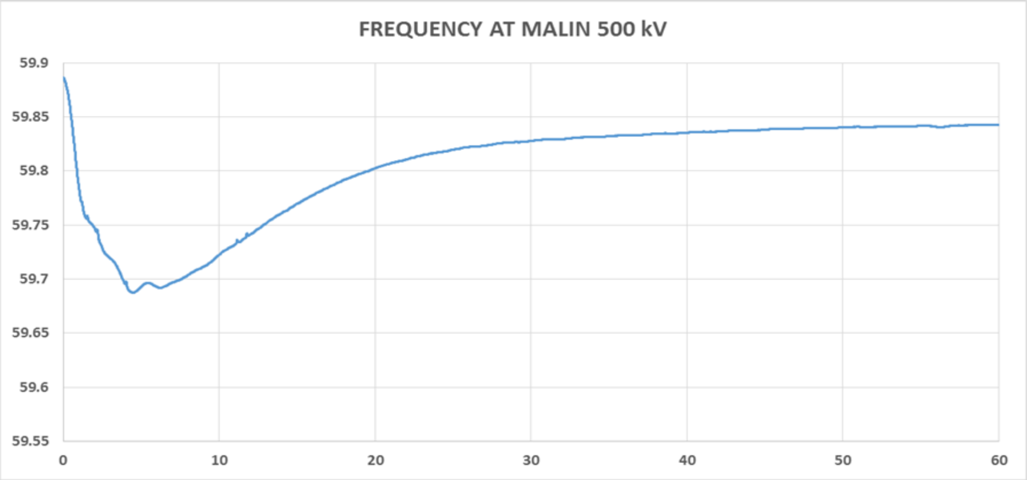
Case 2



- Frequency Nadir(Cf) = 59.54
- Frequency Nadir(Cf)- WECC region = 59.54
- Frequency Nadir Time (Ct) = 9.12 sec
- Settling Frequency (B) = 59.751 Hz
- ~ 30 MW of load tripped in British Columbia due to under frequency relays.
- Frequency Response (MW/0.1Hz)
  - CAISO region : 158.9 Hz
  - WECC region : 1324 Hz

Extended DSO

Case 1

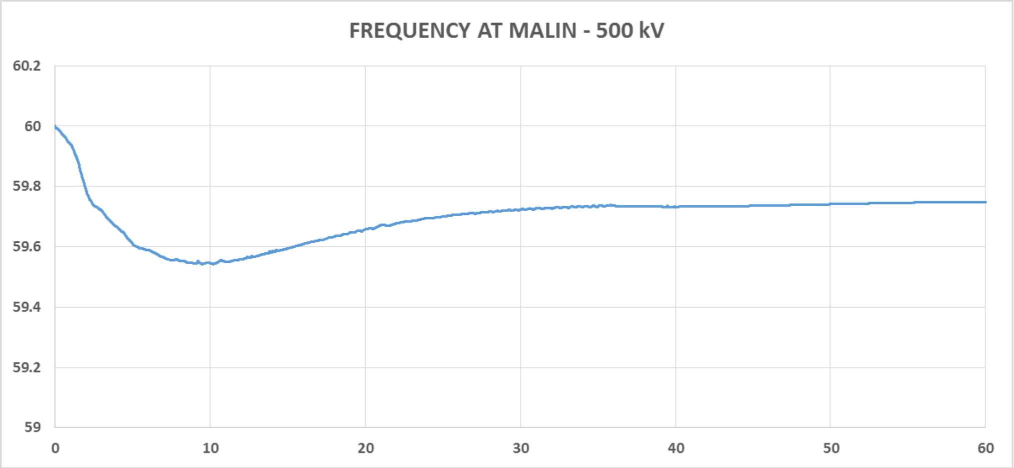


- Frequency Nadir(Cf) = 59.691
- Frequency Nadir(Cf)- WECC region = 59.691
- Frequency Nadir Time (Ct) = 6.80 sec
- Settling Frequency (B) = 59.836 Hz

Frequency Response (MW/0.1Hz)

- CAISO region : 268.0672 Hz
- WECC region : 2210.084 Hz

Case 2



- Frequency Nadir(Cf) = 59.55
- Frequency Nadir(Cf)- WECC region = 59.56
- Frequency Nadir Time (Ct) = 9.1 sec
- Settling Frequency (B) = 59.758 Hz
- ~ 30 MW of load tripped in British Columbia due to under frequency relays.

Frequency Response (MW/0.1Hz)

- CAISO region : 160.9 Hz
- WECC region : 1320 Hz

Conclusions

- Acceptable Frequency performance within WECC for status quo and enhanced DSO.
- CAISO's Frequency Response is less than its Frequency Response Obligation
- Headroom or unloaded synchronized capacity is incapable of meeting the CAISO's FRO.
- Sufficient generators with governors cannot be synchronized to the system due to high levels of nondispatchable generation
- WECC system response slightly reduced in enhanced DSO. However CAISO region response increases.
  - Marginal difference between status quo and extended.
  - ISO extended FR improvement due to the large PV frequency latching and wider setting.

Thank you!

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