Demonstration of Essential Reliability Services by a 300-MW Solar PV Power

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First Solar

KEY MESSAGES

- **Utility-Scale PV Plants Can Contribute to Grid Stability & Reliability Like Conventional Generation**

- **Modern solar PV plants can contribute to the reliability and efficiency of grid operation by offering the following capabilities:**
  - **Voltage regulation**
  - **Real power control, ramping, and curtailment**
  - **Primary frequency regulation**
  - **Frequency droop response**
  - **Short circuit duty control**
  - **Fault ride through**

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Demonstration of Essential Reliability Services by a 300-MW Solar PV Power Plant

California ISO

First Solar®

Can variable energy resources provide essential reliability services to reliably operate the grid?

- NERC identified three essential reliability services to reliably integrate higher levels of renewable resources
  1. Frequency Control
  2. Voltage Control
  3. Ramping capability or Flexible Capacity

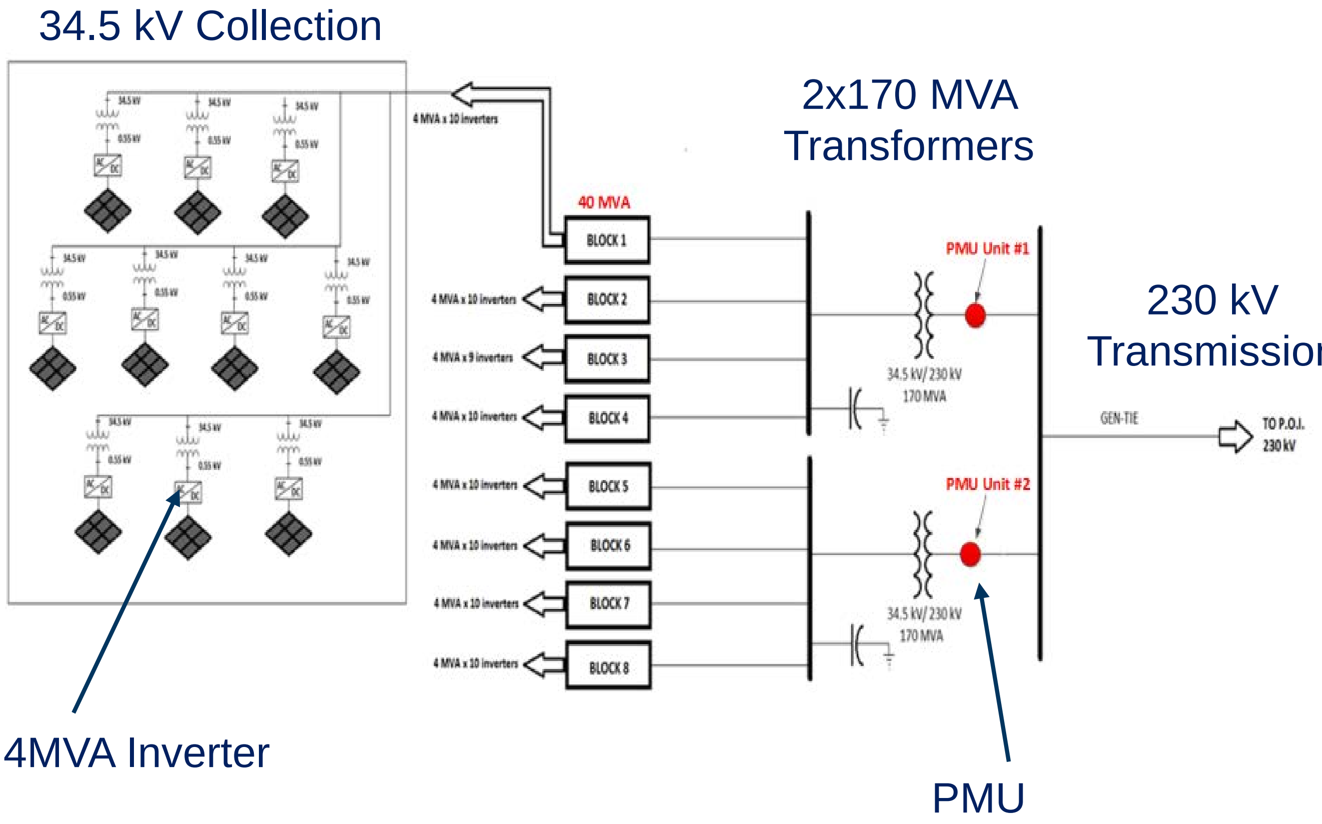
- Test results demonstrated utility-scale PV plant has the capability to provide these essential reliability services

- Advancement in smart controls technology allows these plants to provide services similar to conventional resources

- VERs (Variable Energy Resources) with the right operating characteristics are necessary to decarbonize the grid

PV POWER PLANT DESCRIPTION

- First Solar PV modules
- 4 MVA PV inverters
- 8 x 40 MVA blocks
- 34.5 kV collector system
- Two 170 MVA transformers
- Tie with 230 kV transmission line
- PMUs collecting data on 230 kV side



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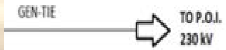
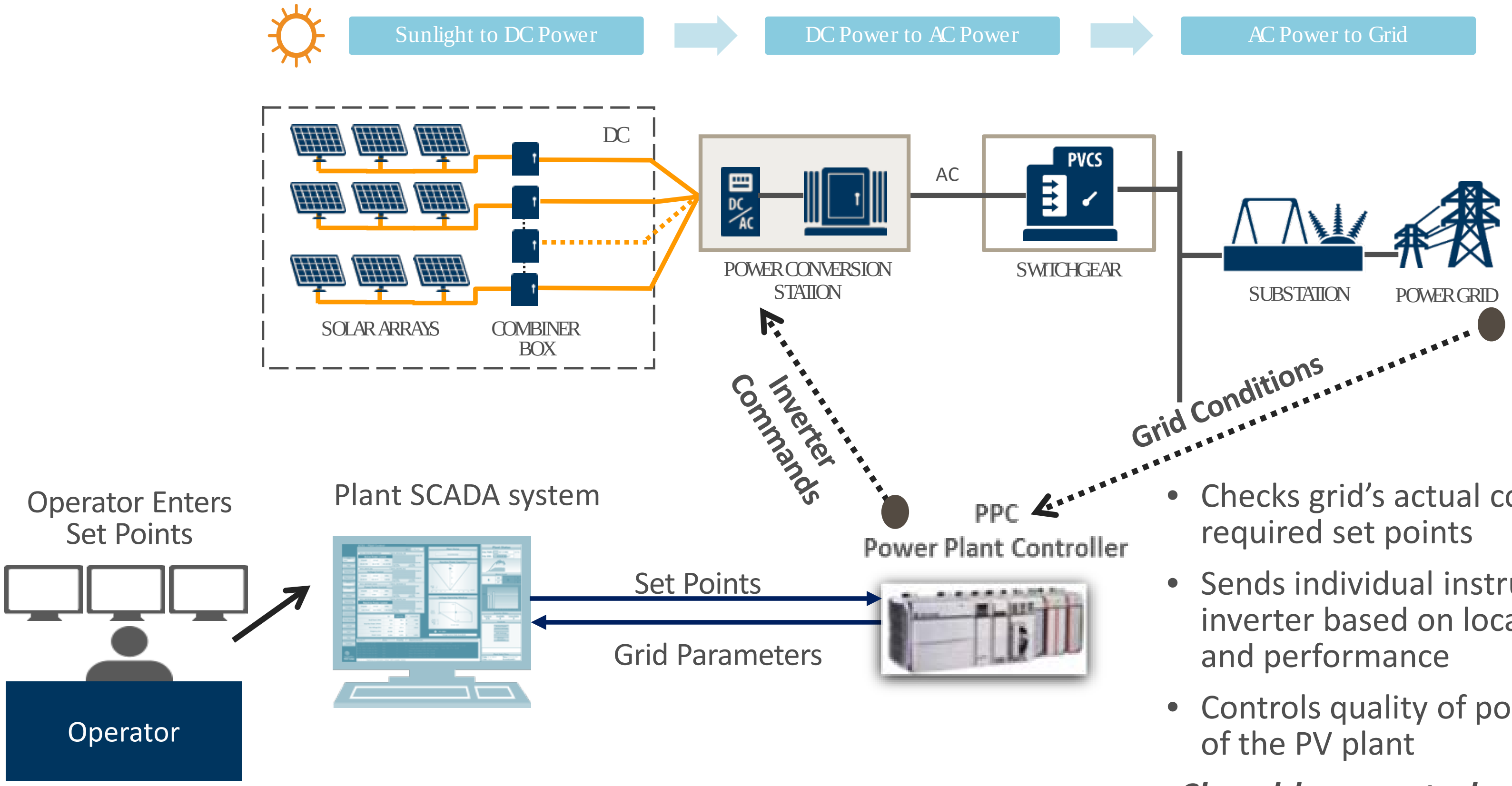
Transmission



PMU

Plant Control System Enables Grid Friendly Features



- Checks grid's actual conditions and required set points
- Sends individual instructions to each inverter based on location, losses, and performance
- Controls quality of power coming out of the PV plant

Closed-loop controls at 100 milliseconds!

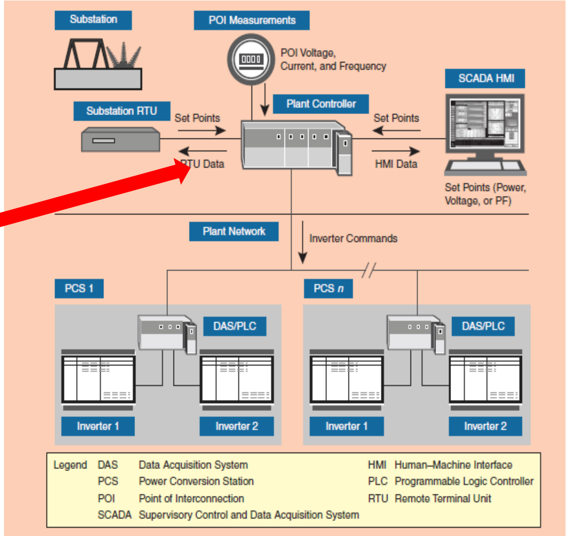
Patent No. 8,774,974. Real-time photovoltaic power plant control

TESTING PROCESS

- Remote testing form First Solar operations center in Tempe, AZ:
  - Supervision of testing activities
  - Tracking plant performance
  - Making changes in set points and plant control parameters

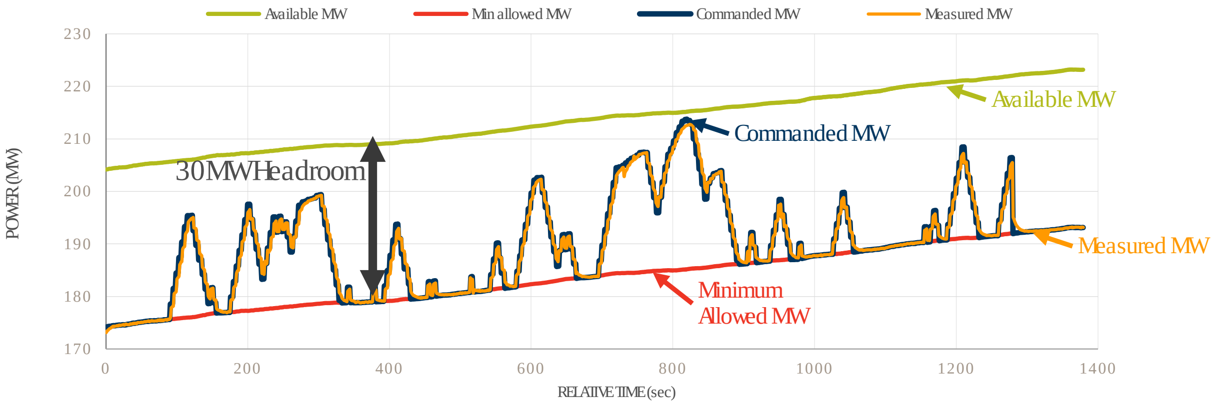
San Bernardino County, CA

Tempe, AZ

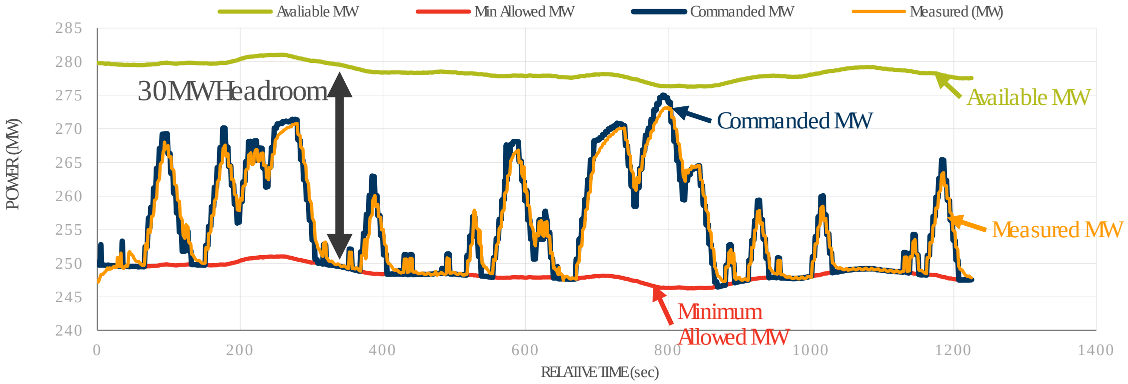


AGC Participation Tests – 300 MW Utility-Scale PV Plant

MORNING

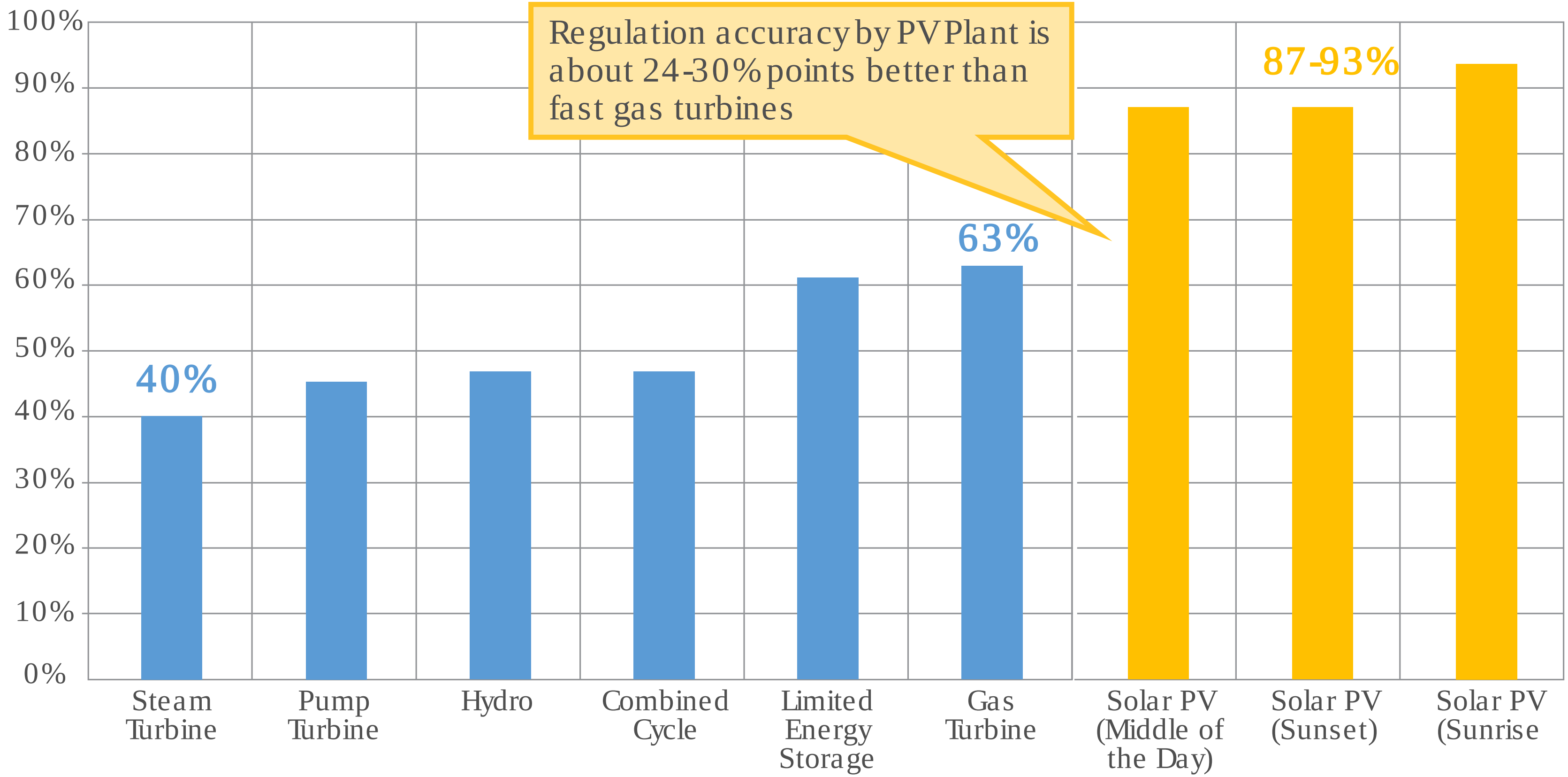


MIDDAY



- 30MW headroom
- 4-sec AGC signal provided to Plant Controller
- Tests were conducted for
  - Sunrise
  - Middle of the day
  - Sunset

PVPlants Outperform Conventional Resources in Frequency Regulation

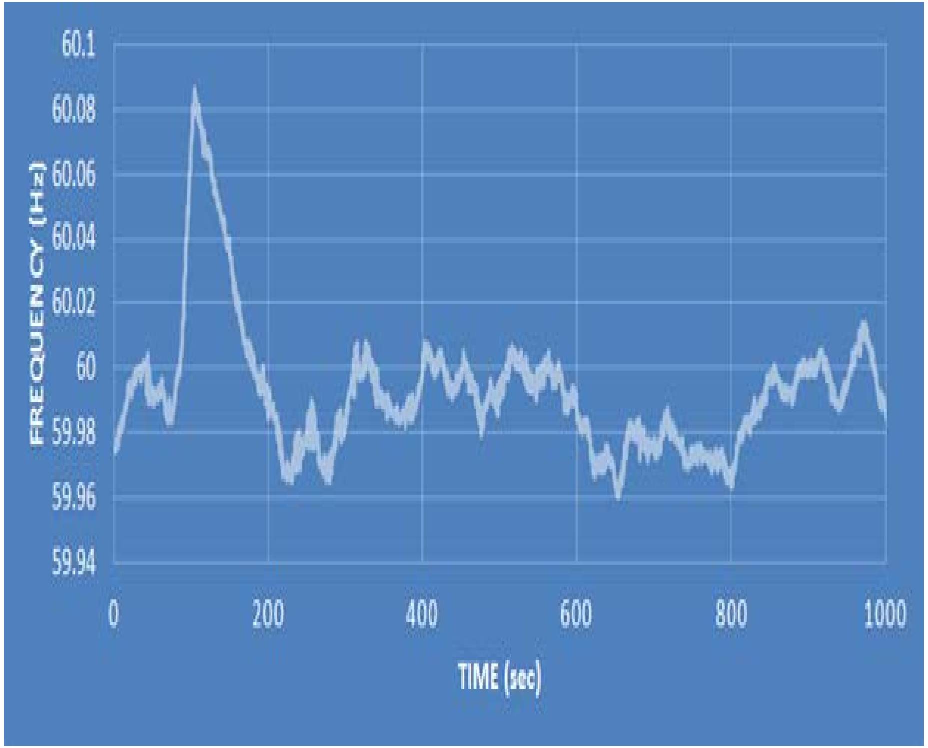


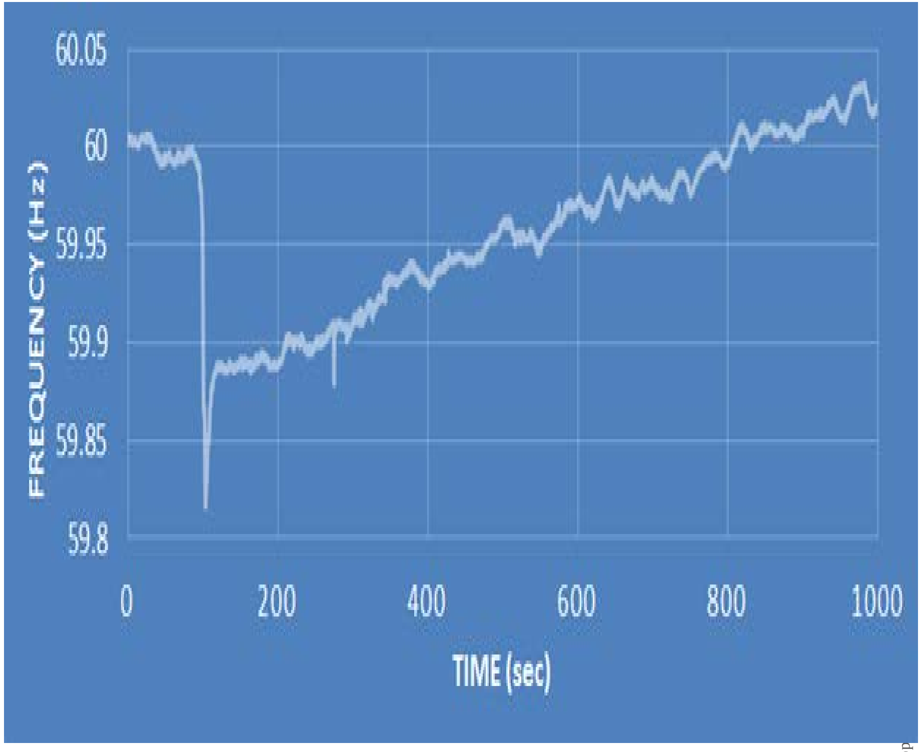
California ISO

Blue bars taken from the ISO's informational submittal to FERC on the performance of resources providing regulation services between January 1, 2015 and March 31, 2016

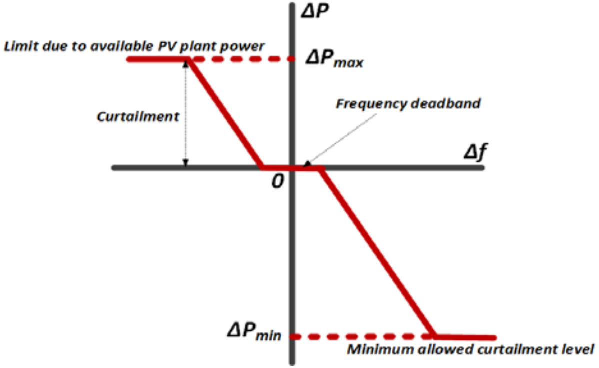
http://www.caiso.com/Documents/TestsShowRenewablePlantsCanBalanceLow-CarbonGrid.pdf

SUMMARY OF CONDUCTED TESTS - FREQUENCY EVENTS IN THE WECC





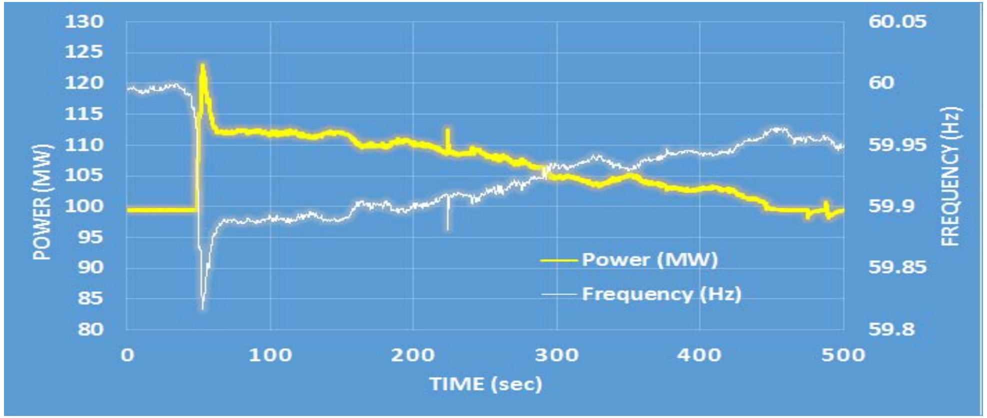
FREQUENCY DROOP TESTS



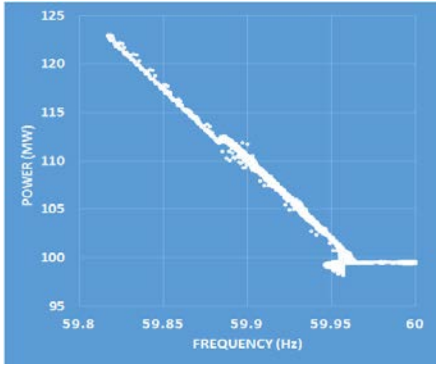
$$Droop = \frac{\Delta P / P_{rated}}{\Delta f / 60Hz}$$

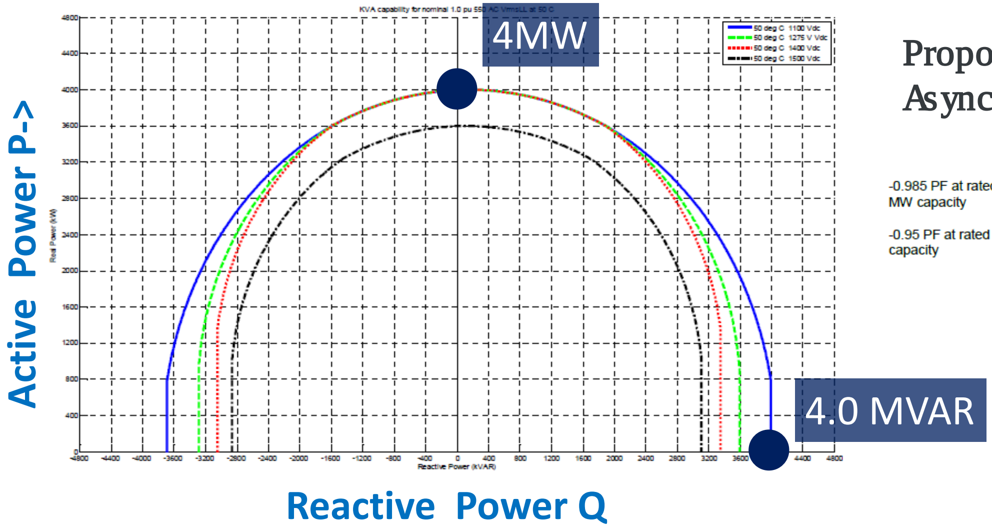
- 3% and 5% under and over-frequency tests
- 20% headroom
- ±36 mHz dead band
- Actual frequency event time series measured in the U.S. Western Interconnection

Example of 3% droop test (under-frequency)

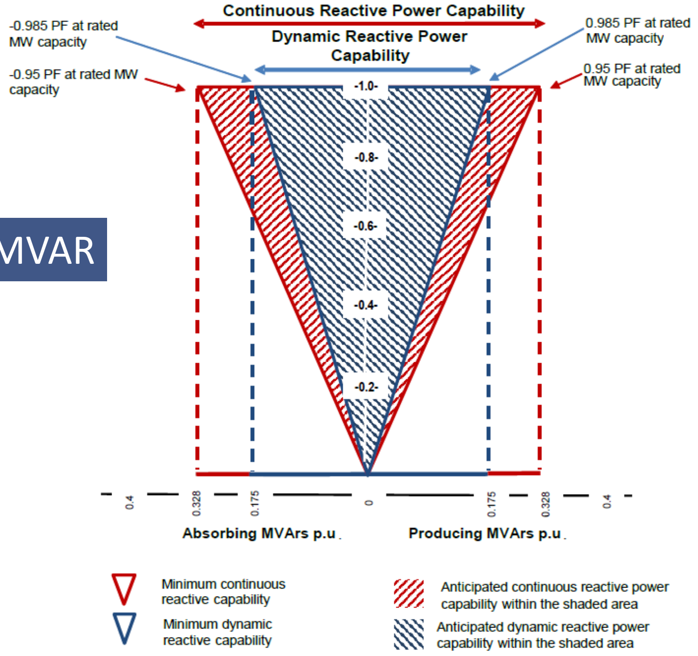


Measured 3% droop response is showing linear dependence between frequency and measured power.



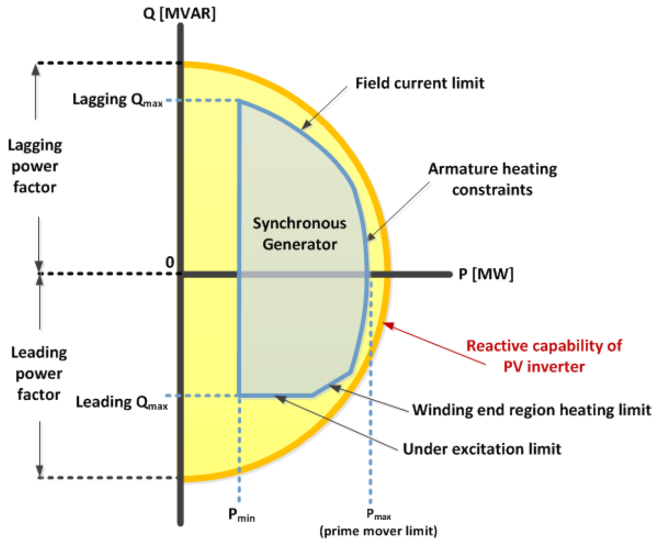


Proposed CAISO Reactive Capability for Asynchronous Resources



REACTIVE POWER AND VOLTAGE CONTROL TESTS

Comparison of reactive power capability for a synchronous generator and PV Inverter



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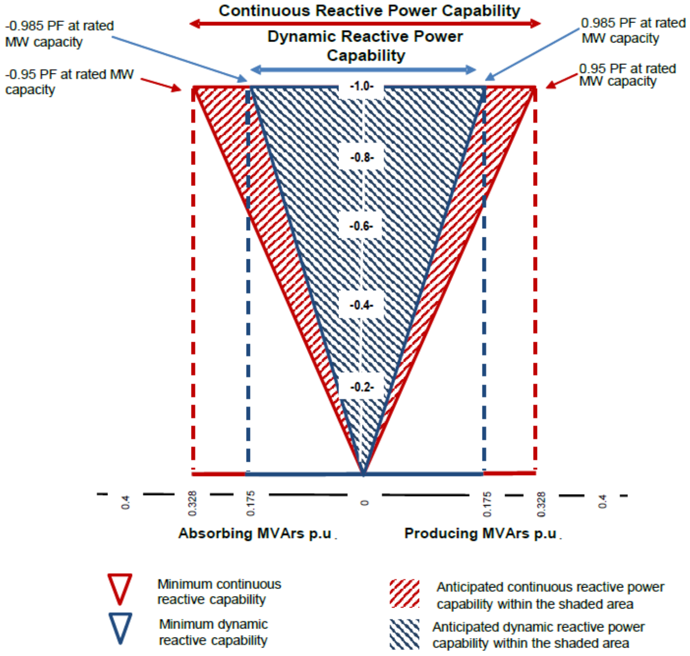
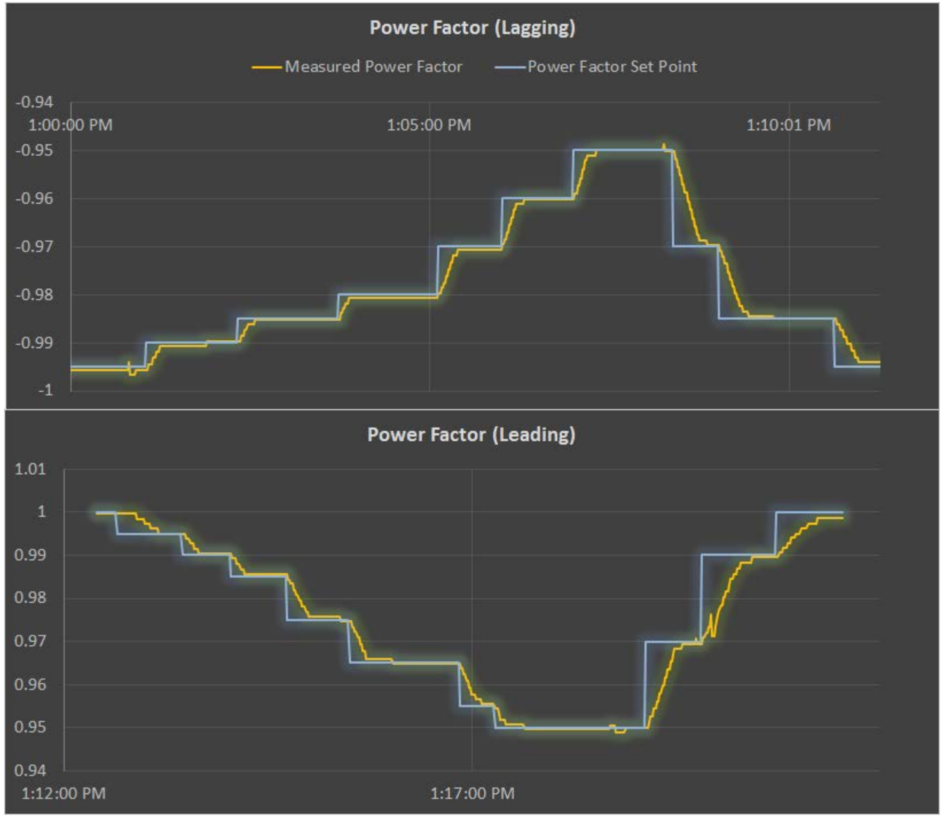
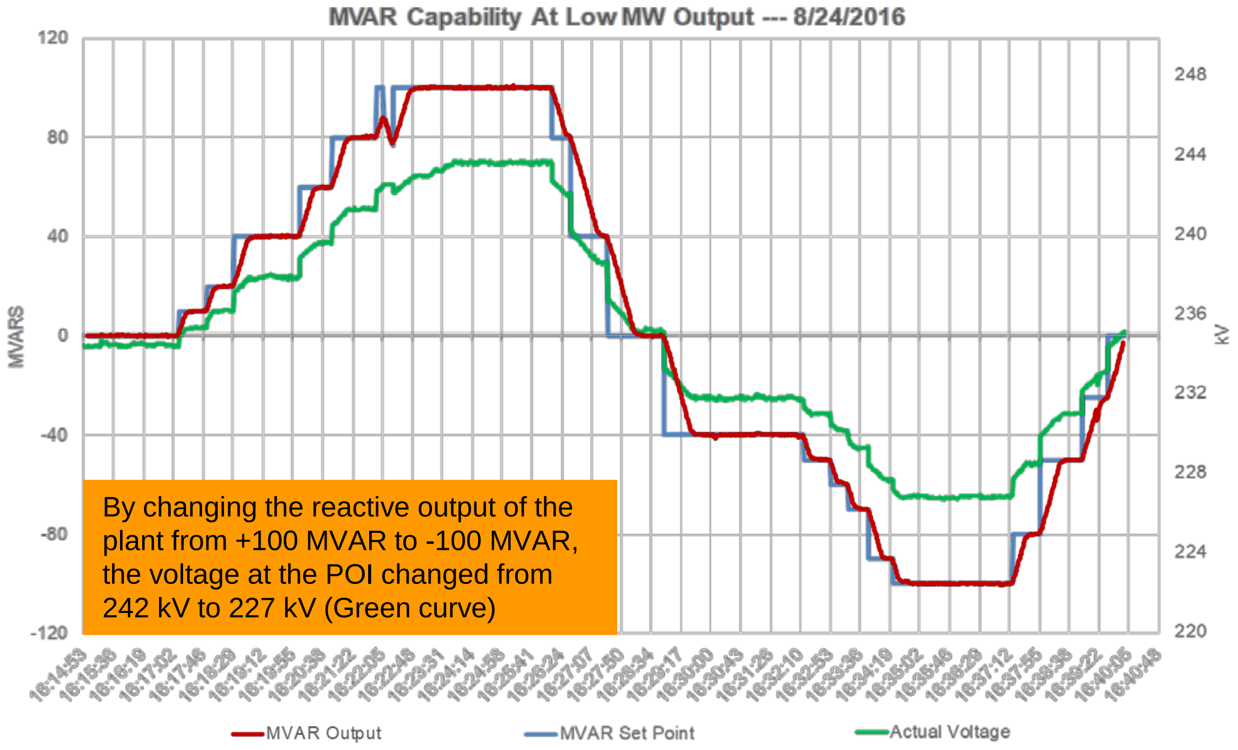


LAGGING AND LEADING POWER FACTOR CONTROL TESTS

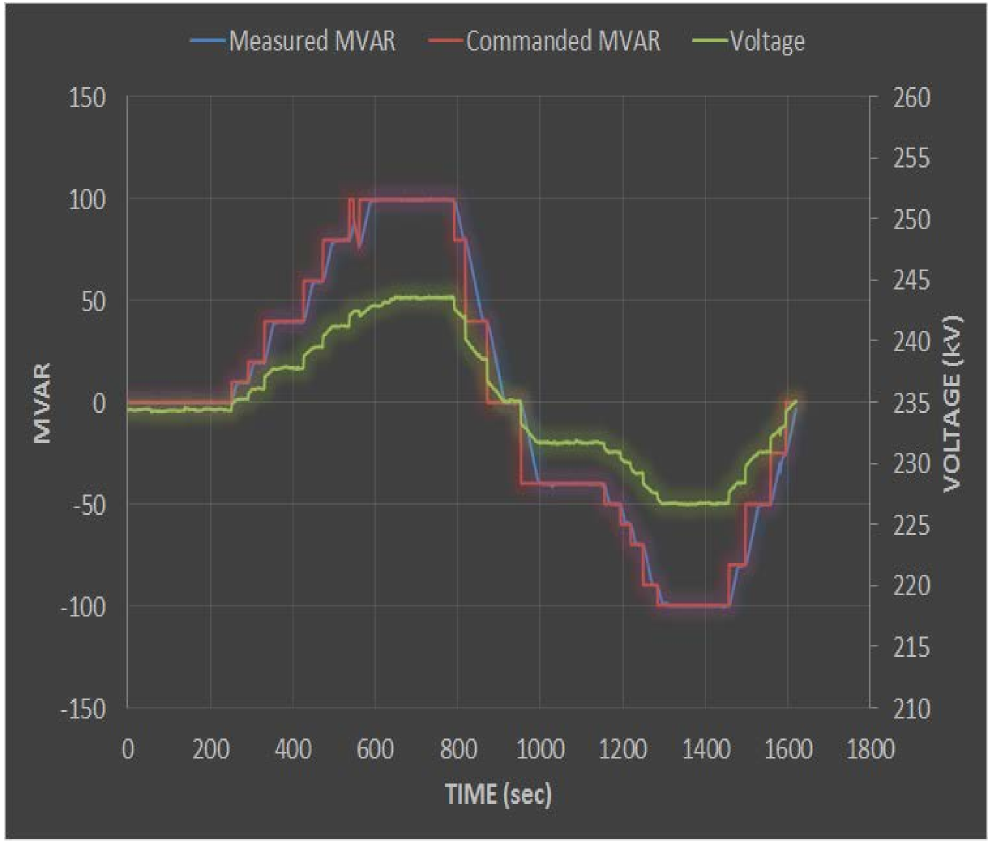


- ±100 MVAR/min ramp rates applied
- PF limit = ±0.95
- Tests conducted at nearly full power output

VOLTAGE CONTROL: THIS TEST DEMONSTRATED THE PLANT'S CAPABILITY TO CONTROL SYSTEM VOLTAGE

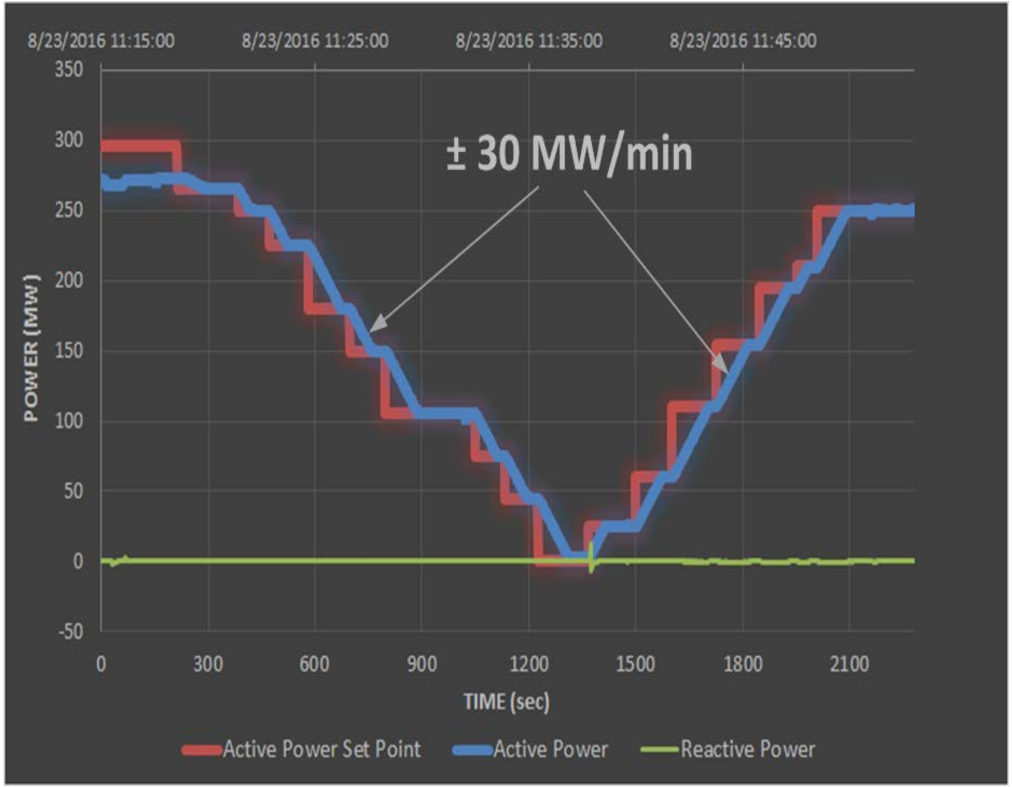


LOW GENERATION REACTIVE POWER CONTROL TEST



- Plant was curtailed down to 5 MW output level
- Ability of the plant to produce or absorb VARs (±100 MVAR) was demonstrated

ACTIVE POWER CURTAILMENT TEST



- The curtailment control test was conducted to demonstrate the plant's ability to limit its active power production and then restore it to any desired level.
- The plant was accurately following the active power set point from nearly full production level to zero level with pre-set ramp rate of 30 MW/ min.

CAISO/ NREL Conclusions

- Advancements in **smart inverters** technology combined with **advanced plant controls** allow solar PV plants to provide power regulation, voltage support, and frequency response during various modes of operations.
- Solar PV resources with these **advanced grid-friendly capabilities** can enhance system reliability by providing:
  - Essential reliability services during periods of oversupply
  - Fast frequency response (inertia response time frame)
  - Frequency response for low as well as high frequency events.
  - Voltage support when the plant's output is near zero
- Variable energy resources with the right operating characteristics are **necessary to decarbonize the grid**

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