Essential Reliability Services from Solar Plants

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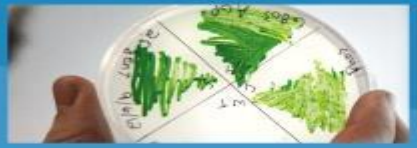
2017 NARUC Award Winner

Utility Industry Innovative Pilots or Demonstration Projects





- Vahan Gevorgian
- Clyde Loutan
- Vladimir Chadliev
- Mahesh Morjaria

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

California ISO

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Motivation

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

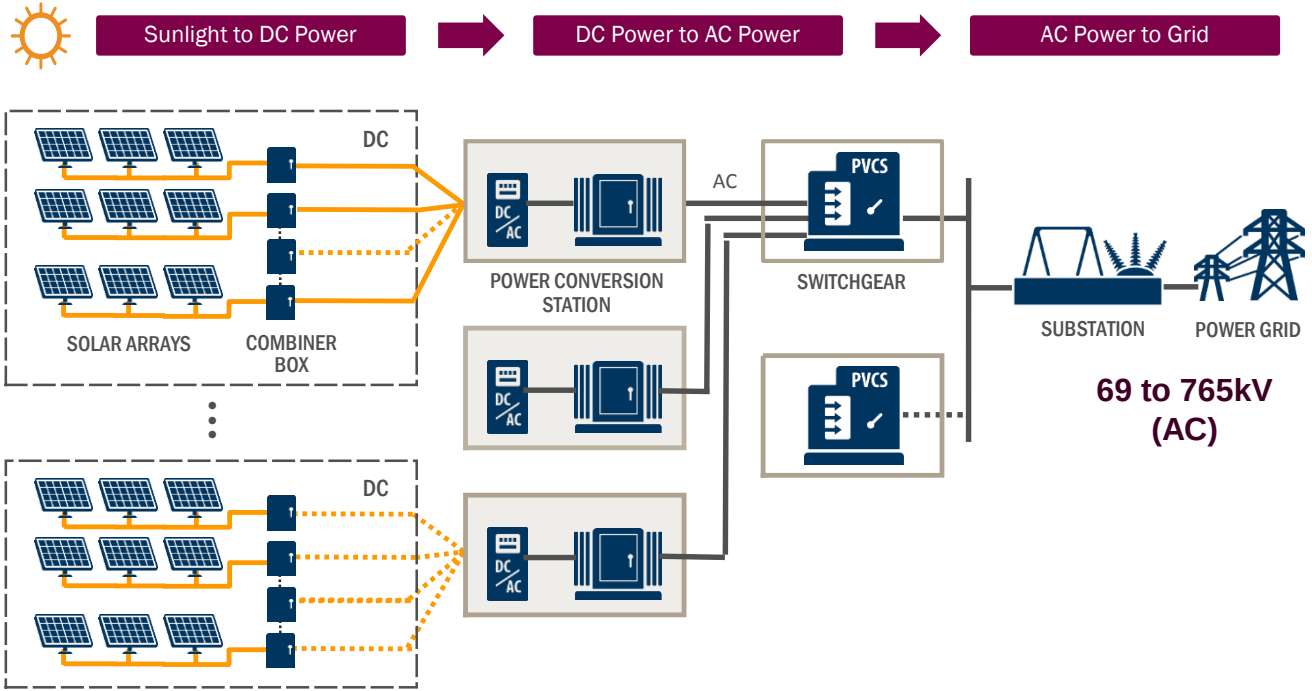
- Test results demonstrated utility-scale PV plant has the capability to provide these essential reliability services

- 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

First Solar Plant & Controls

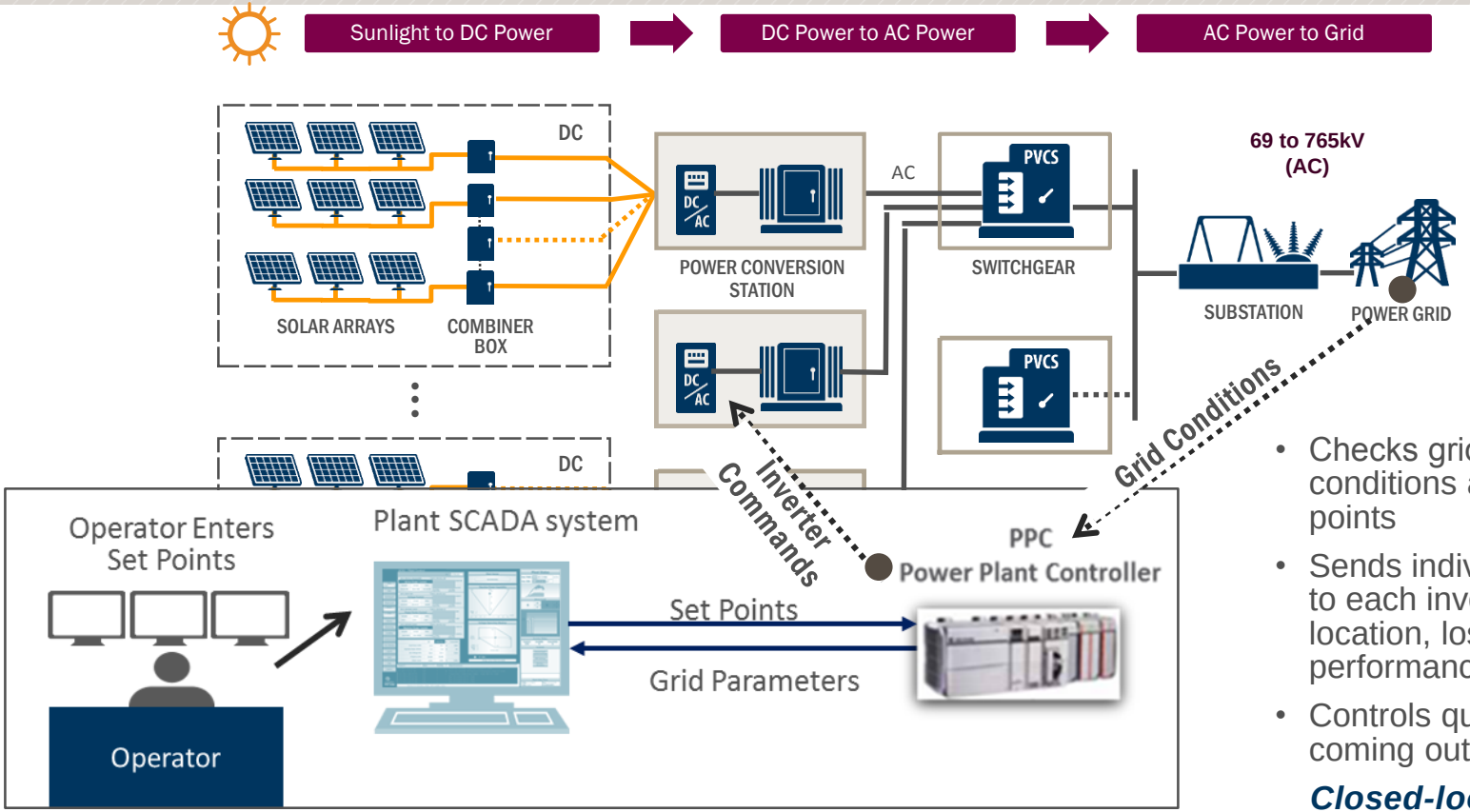
PV Plant Schematic



Typical DC Voltage 1kV or 1.5kV

Typical AC Collection Voltage 34.5kV (Alternatives 4.16kV to 27.6kV)

Plant Control System Enables Grid Friendly Features



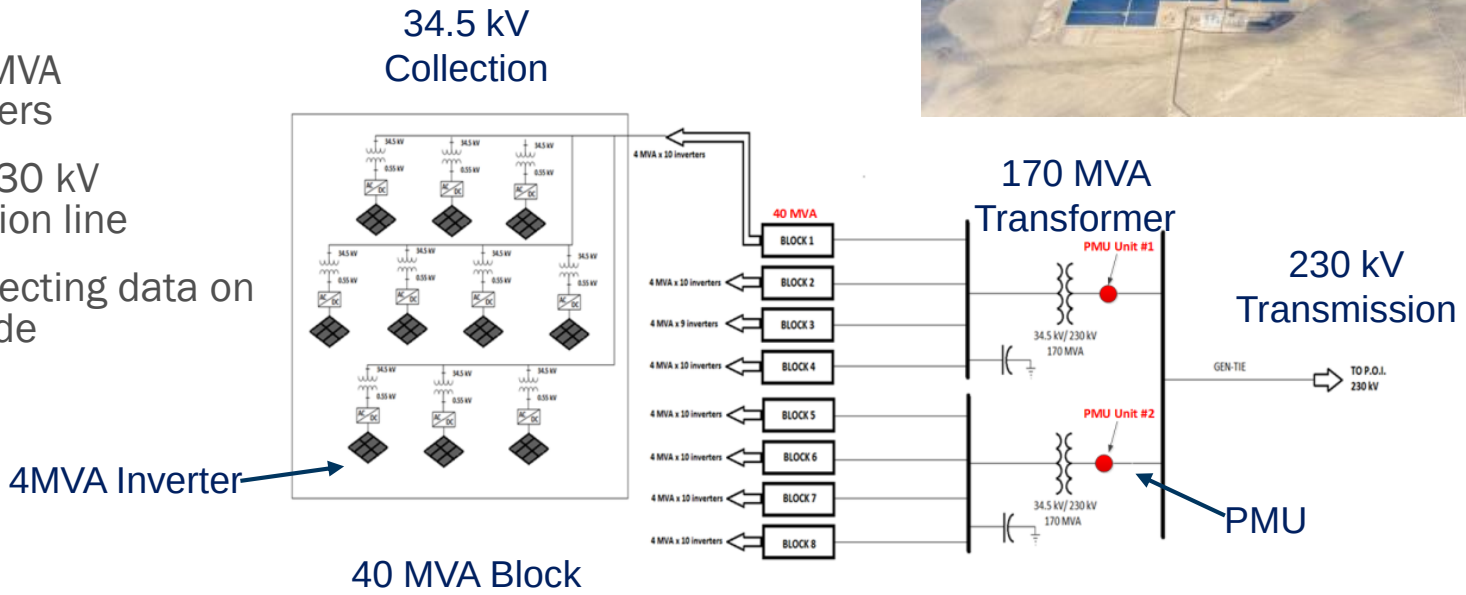
- Checks grid's actual conditions and required set points
- Sends individual instructions to each inverter based on location, losses, and performance
- Controls quality of power coming out of the PV plant

Closed-loop controls at 100 milliseconds!

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

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

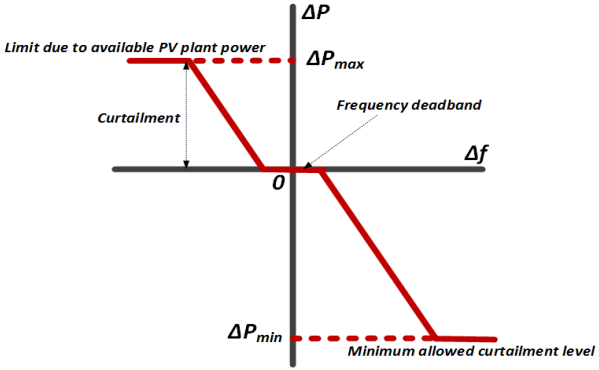


Test Results

Summary of Conducted Tests

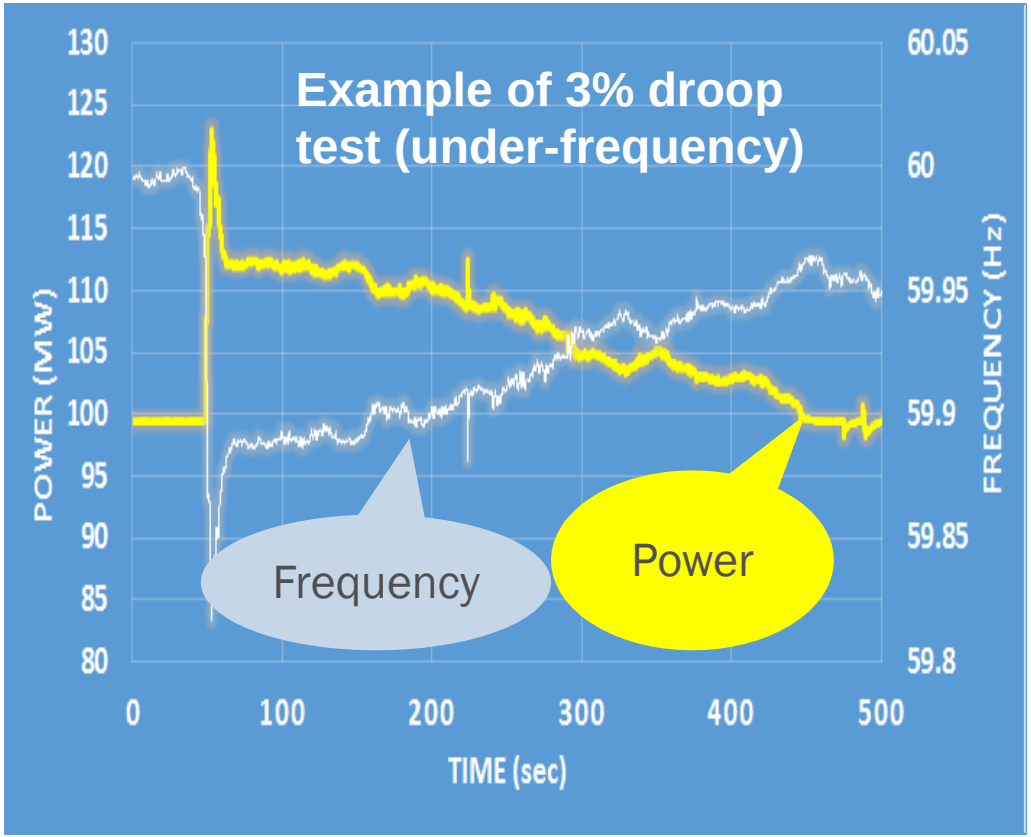
- *Regulation-up and regulation-down*, or AGC tests during sunrise, middle of the day, and sunset
- *Frequency response* tests with 3% and 5% droop settings for over-frequency and under- frequency conditions
- *Curtailment and APC* tests to verify plant performance to decrease or increase its output while maintaining specific ramp rates
- *Voltage and reactive power* control tests
- *Voltage control* at near zero active power levels (nighttime control)

Frequency Droop Tests

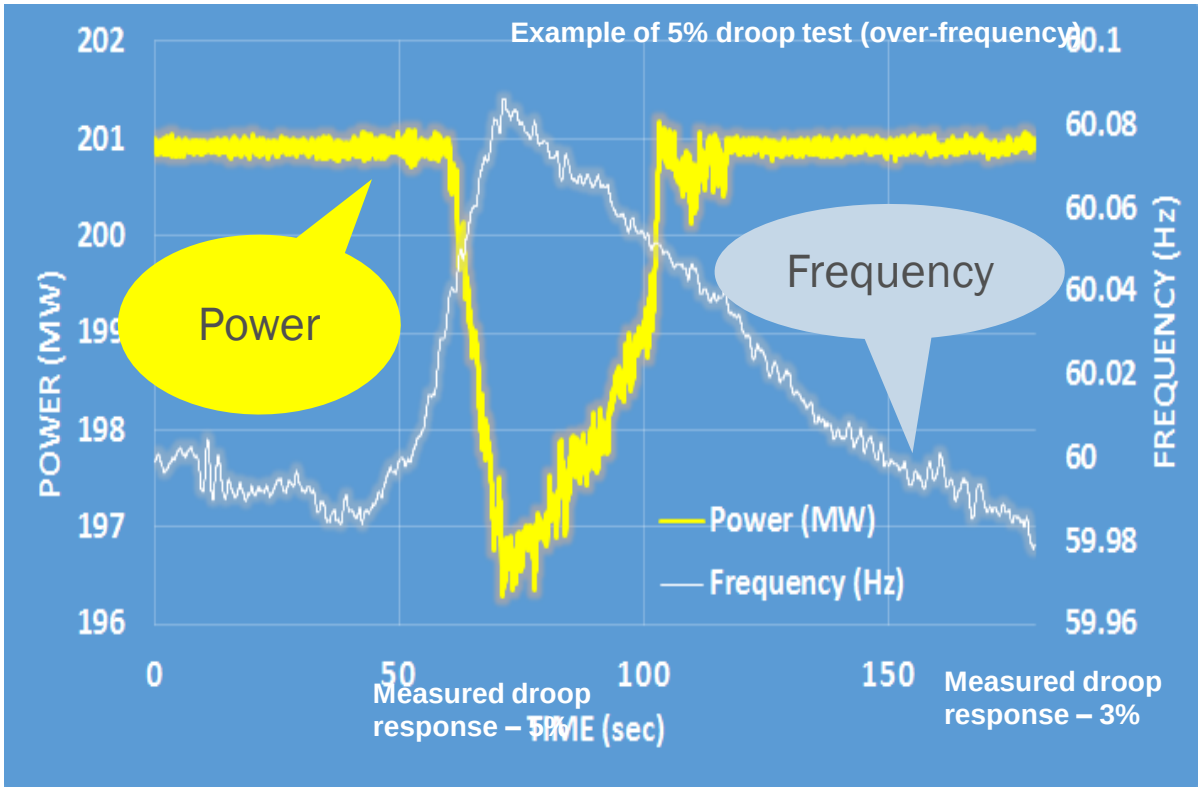


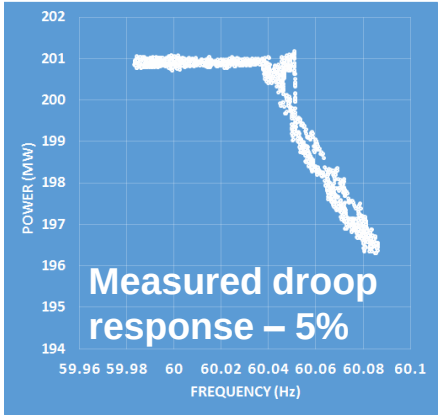
$$Droop = \frac{\Delta P / P_{rated}}{\Delta f / 60Hz}$$

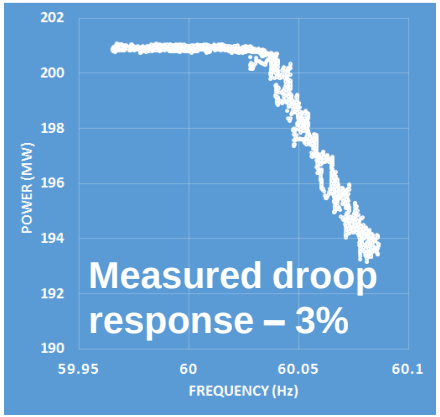
- 3% and 5% under and over-frequency tests
- 20% headroom
- ±36 mHz dead band
- Used actual frequency event time series measured in the U.S. Western Interconnection



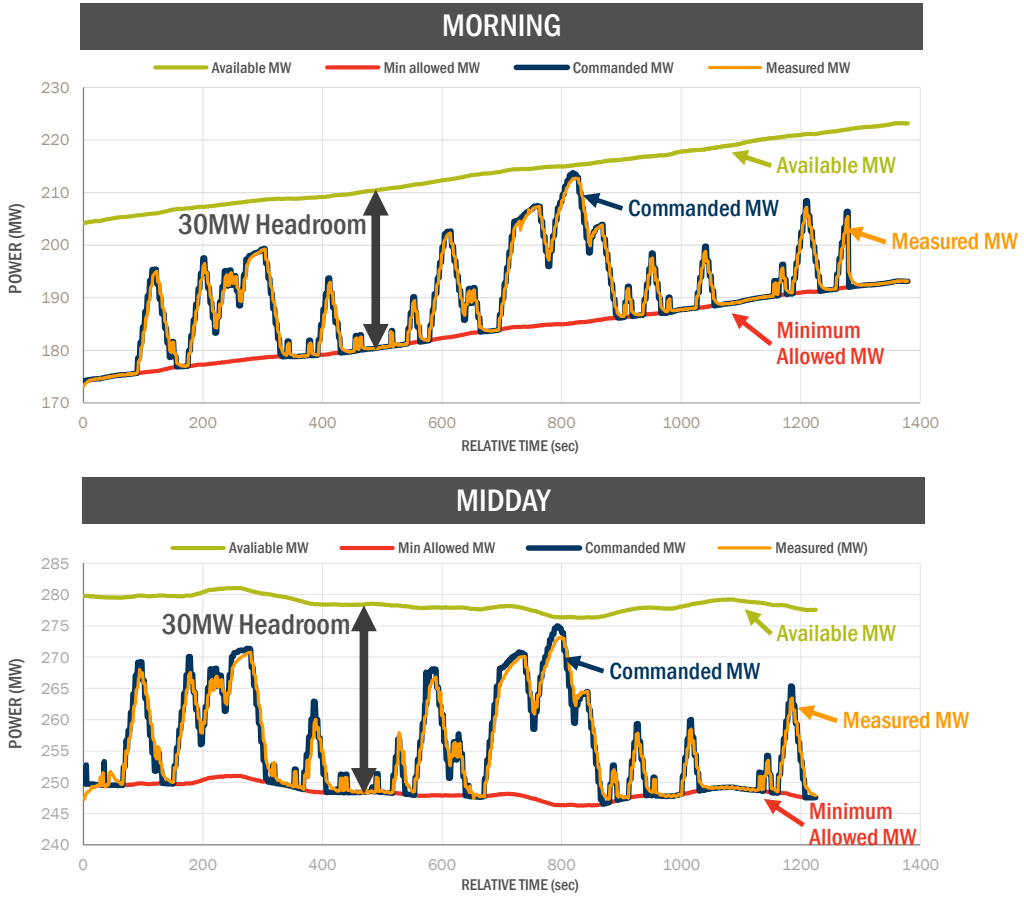
Examples of Over-Frequency Droop Tests





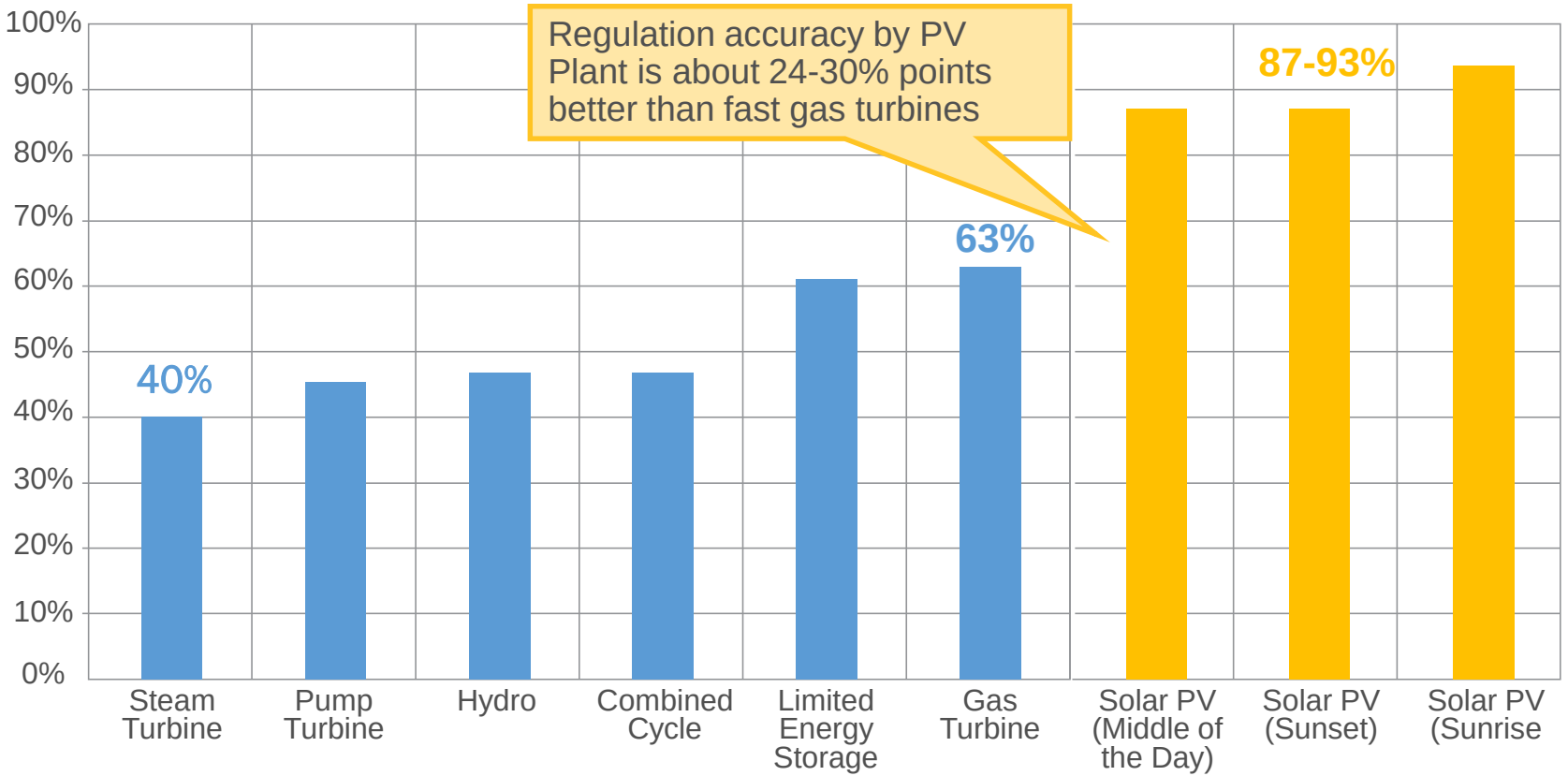


AGC Participation Tests – 300 MW Utility-Scale PV Plant



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

PV Plants 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

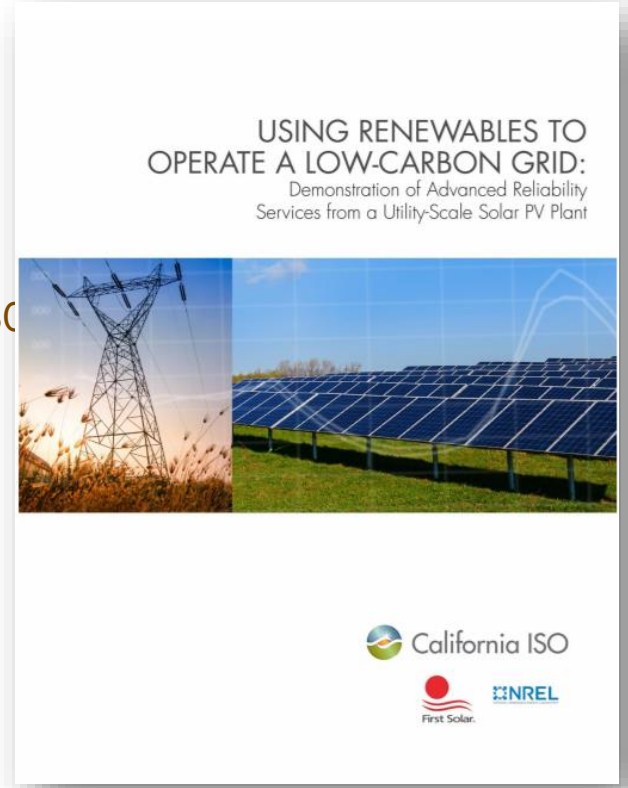
Dispatchable Resources

Utility-scale PV solar is a *flexible resource* that can enhance grid reliability

Dispatchable PV Plant

- Solar can provide NERC-identified essential services to reliably integrate higher levels of renewable resources, including:
  - Frequency Control
  - Voltage Control
  - Ramping capability or flexible capacity
- Automated Generation Control (AGC) regulation accuracy of 24-30 %points better than fast gas turbines
- Reduces need for services from conventional generation
  - Goes beyond simple PV energy value
  - Enables additional solar
  - Reduces need for expensive storage

CAISO: "Grid Friendly Utility-Scale PV Plants are Essential for Large-Scale PV Integration"



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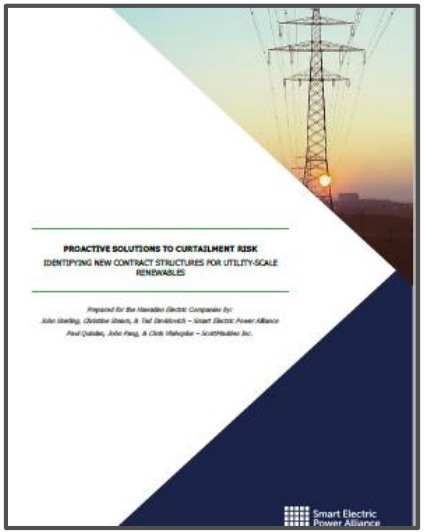
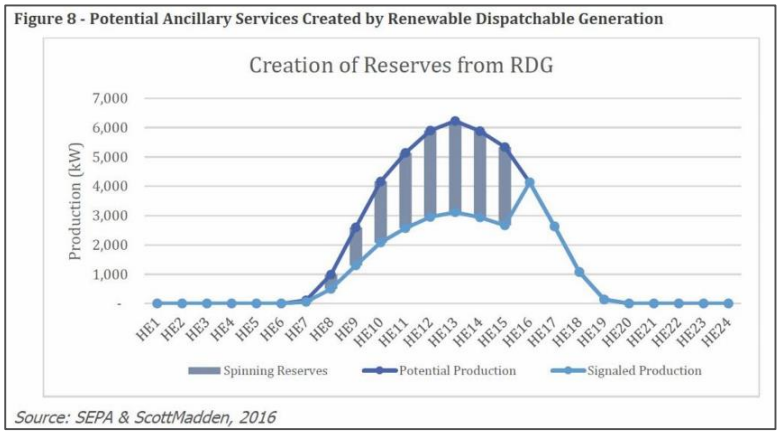
Changing Solar PPAs Could Turn Curtailed Power into Dispatchable Resources

"Too often, curtailment is automatically viewed negatively," said Chris Vlahoplus, Clean Tech and Sustainability Practice Leader at ScottMadden.

"We wanted to explore a thoughtful approach to curtailment that might actually produce more flexible operations and better results for all parties involved."





"You're not curtailing; you're turning the power into ancillary services that create a new value stream for the grid, and customers are getting the benefit. "
John Sterling, SEPA's Senior Director

The Evolving Role of Solar

The Evolving Role of Solar

Solar 1.0: Traditional

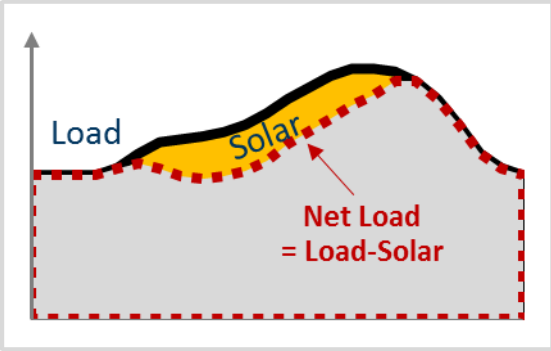
- Solar is part of mid-day load offsets peak or near-peak demand
- Energy-Only Value

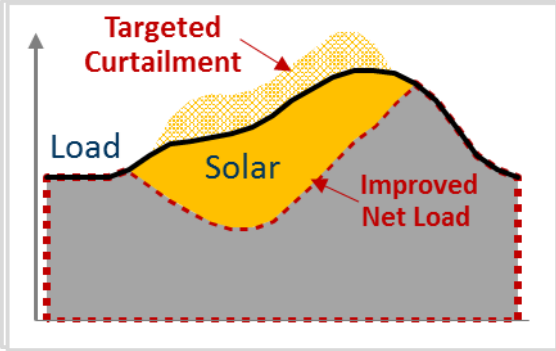
Solar 2.0: Dispatchable

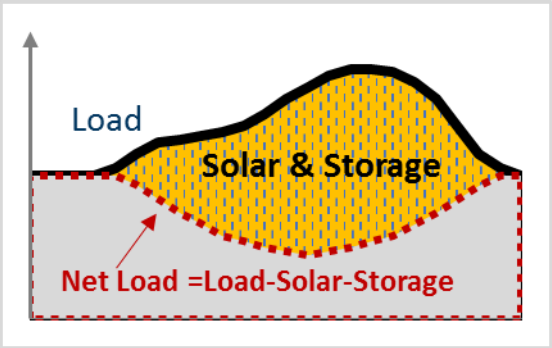
- Solar mitigates value erosion through plant controls
- Adds **Grid Services & Flexibility** Value

Solar 3.0: Fully Dispatchable

- Storage (hours, not days) time-shifts solar - dispatchable
- Adds **Targeted Firm Capacity** and increased flexibility







Flexible & Dispatchable Solar … Key to Market Expansion & Value Retention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