




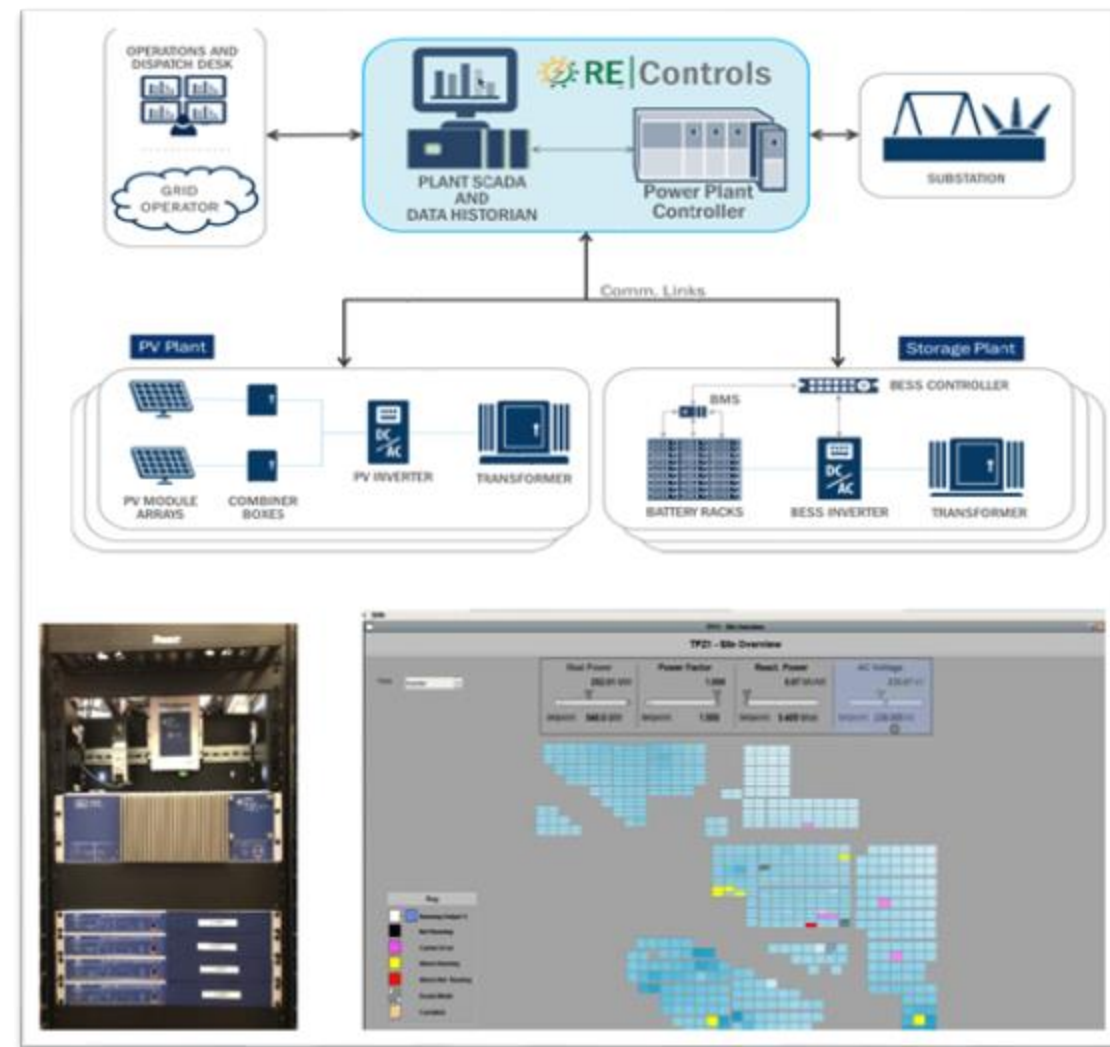
Plant Controls and SCADA System

January 2022

Controls & SCADA System --“Key to Making Smart Plant”

- Utility Ready Plant Controls & SCADA System for PV/ BESS/Hybrid Plant
- Meets stringent grid reliability features (NERC)
 - Active Power Controls
 - Voltage & Reactive Power Controls
 - Primary frequency droop response
- Real time supervisory control, monitoring, alarm management, historical data archiving
- Support for Operation and Maintenance (O&M) and performance analysis
- Developed by & under license from 
- Over 10 GW of Installed Base

Complete Hardware &
Software Solution



PPC/SCADA – Industry Leading Product

Product/Service

Site SCADA/PPC HW & SW

- Install
- Commission
- Test
- PPC models
- Upgrade/Retrofit

Customers

EPCs, Developers and Plant owners

Experience

- ~70 Plants with PPC/SCADA (~10GWs of PPC installed base)

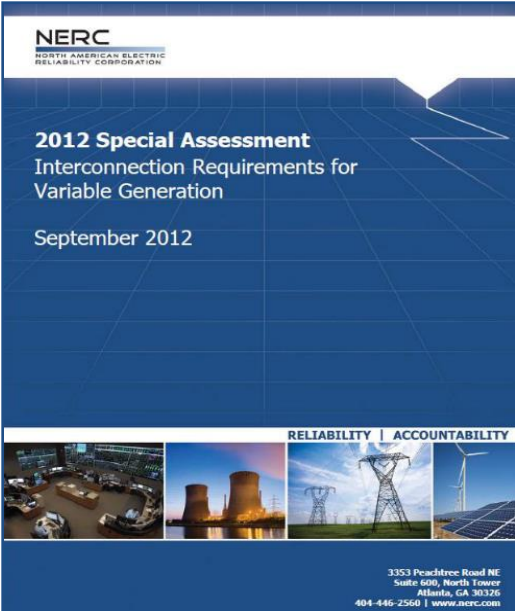
Differentiation

- Proven leadership in meeting rapidly evolving grid requirements, providing differentiated features and future proofing them
 - ✓ Fast response : <100ms
 - ✓ Scalability : demonstrated 700 inverters operation/PPC
 - ✓ Storage/Hybrid plant ready
 - ✓ ADS (Automated Dispatch) : minimizes imbalance charges
 - ✓ Flexible Solar : first in the world (operational at Stateline)
 - ✓ AGC (Automated Gen Control) : first in the world (operational at Stateline/Chile)
 - ✓ Weak Grids operation : up to 2.5 SCR
 - ✓ Night Vars : operational at Cal Flats

Testimonials

- 8 Minute Energy: *“You are one of the few PV side companies who via your questioning and feedback, truly understands the mechanisms necessary for integration both contractually and technically”.*
- Southern Company: *“We believe that First Solar PPC/SCADA is the best in the industry”*
- First Solar O&M: *“Trimark's controller seems to limit the plant based on irradiance and a shaded or failed pyronometer causes losses, and Nor Cal's controller produces excessive Var increasing I2R losses.”*

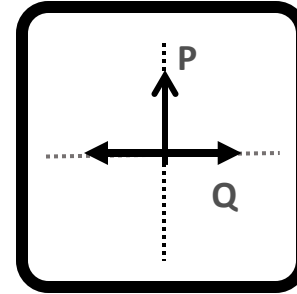
Grid-Friendly PV Plant



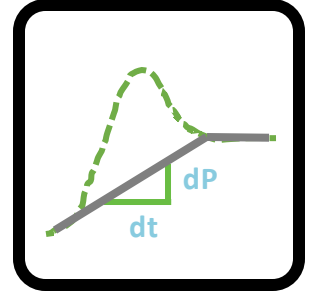
Features Required by NERC to be a Good Grid Citizen:

- Voltage regulation
- Active power control (ramping, curtailment)
- Grid disturbance ride through (voltage and frequency excursions)
- Primary frequency droop response
- Short circuit duty control

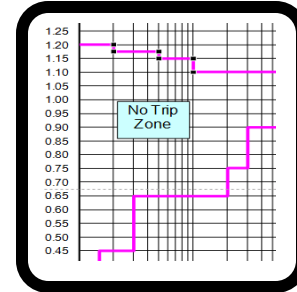
Voltage Support



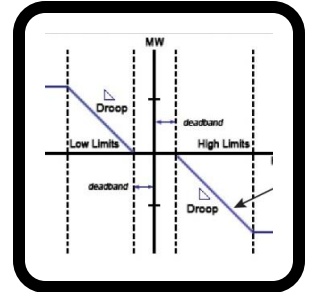
Power Control



Ride Through



Frequency Droop



Base Capability

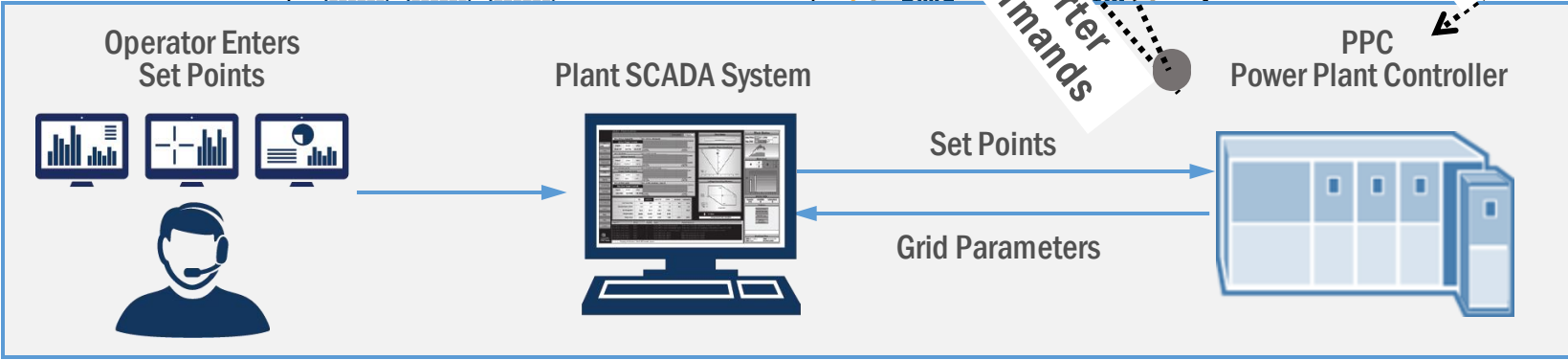
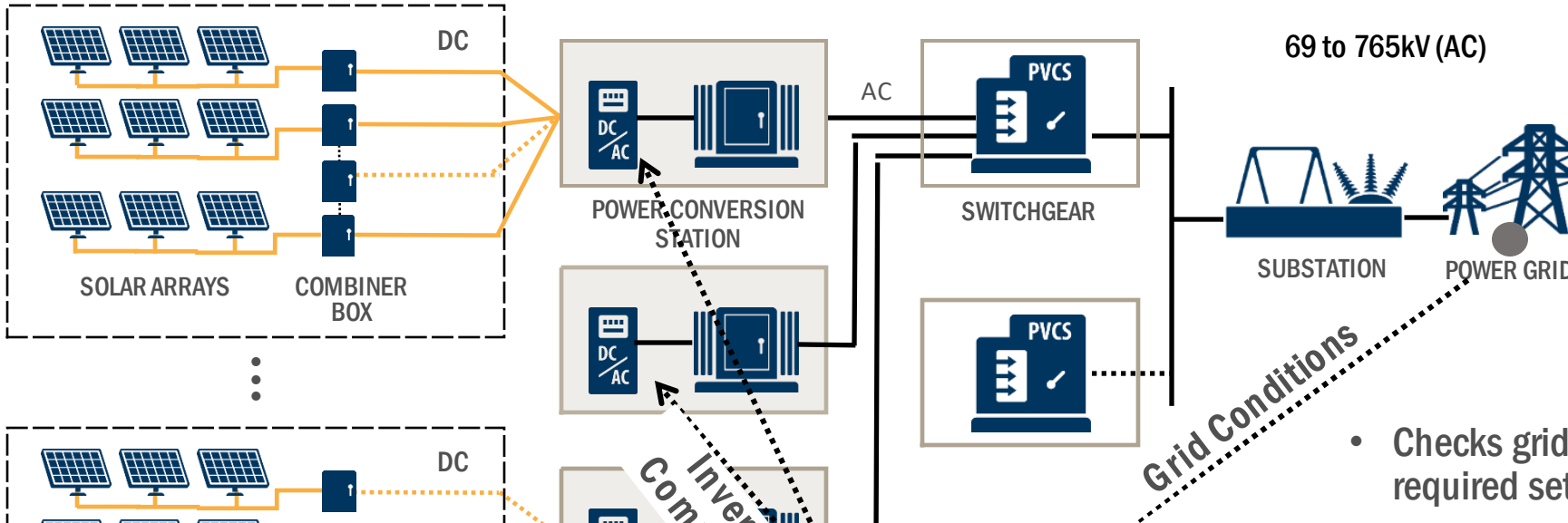
Sources: (1) NERC: 2012 Special Assessment Interconnection Requirements for Variable Generation
(2) M. Morjaria, D. Anichkov, V. Chadliev, and S. Soni. "A Grid-Friendly Plant." *IEEE Power and Energy Magazine* May/June (2014)

Smart Plant Control System Enables Grid Friendly Features

Sunlight to DC Power

DC Power to AC Power

AC Power to Grid



- 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

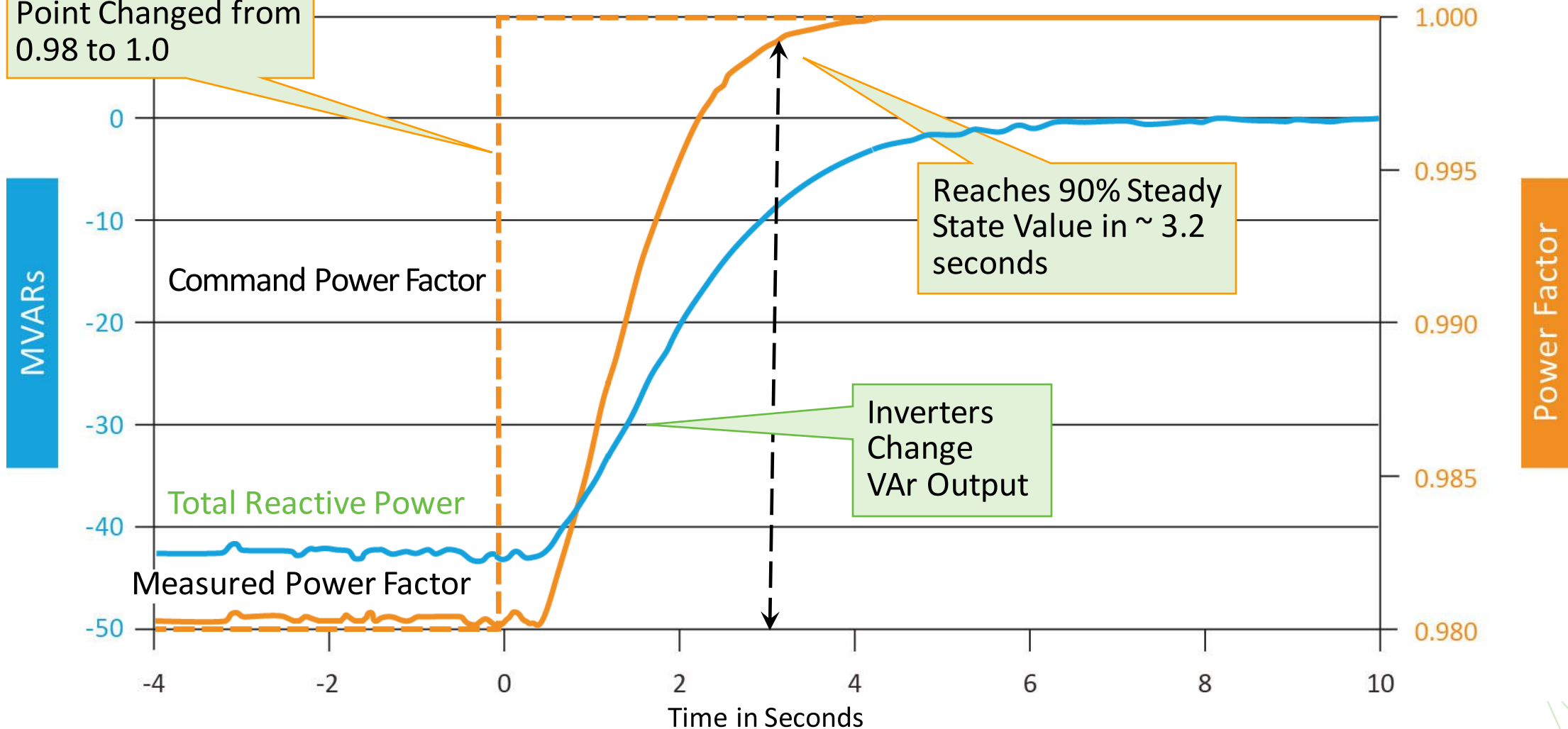
Closed-loop controls at 100 milliseconds!

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

Dynamic Power Factor Regulation

Excellent Reactive Power
Dynamic Control

Power Factor Set
Point Changed from
0.98 to 1.0

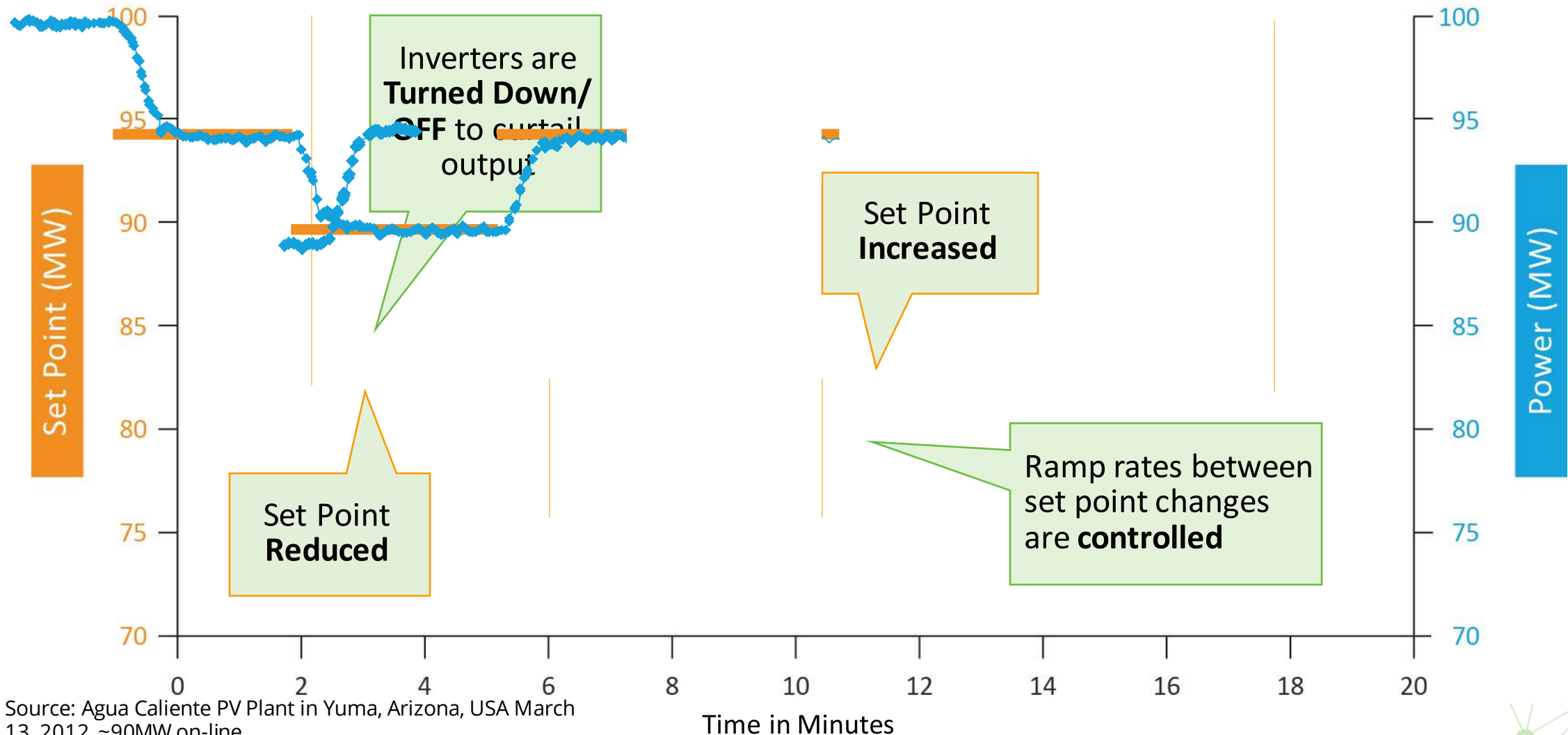


- Source: Agua Caliente PV Plant in Yuma, Arizona, USA May 23, 2012. ~212MW on-line.

Plant Curtailment Test

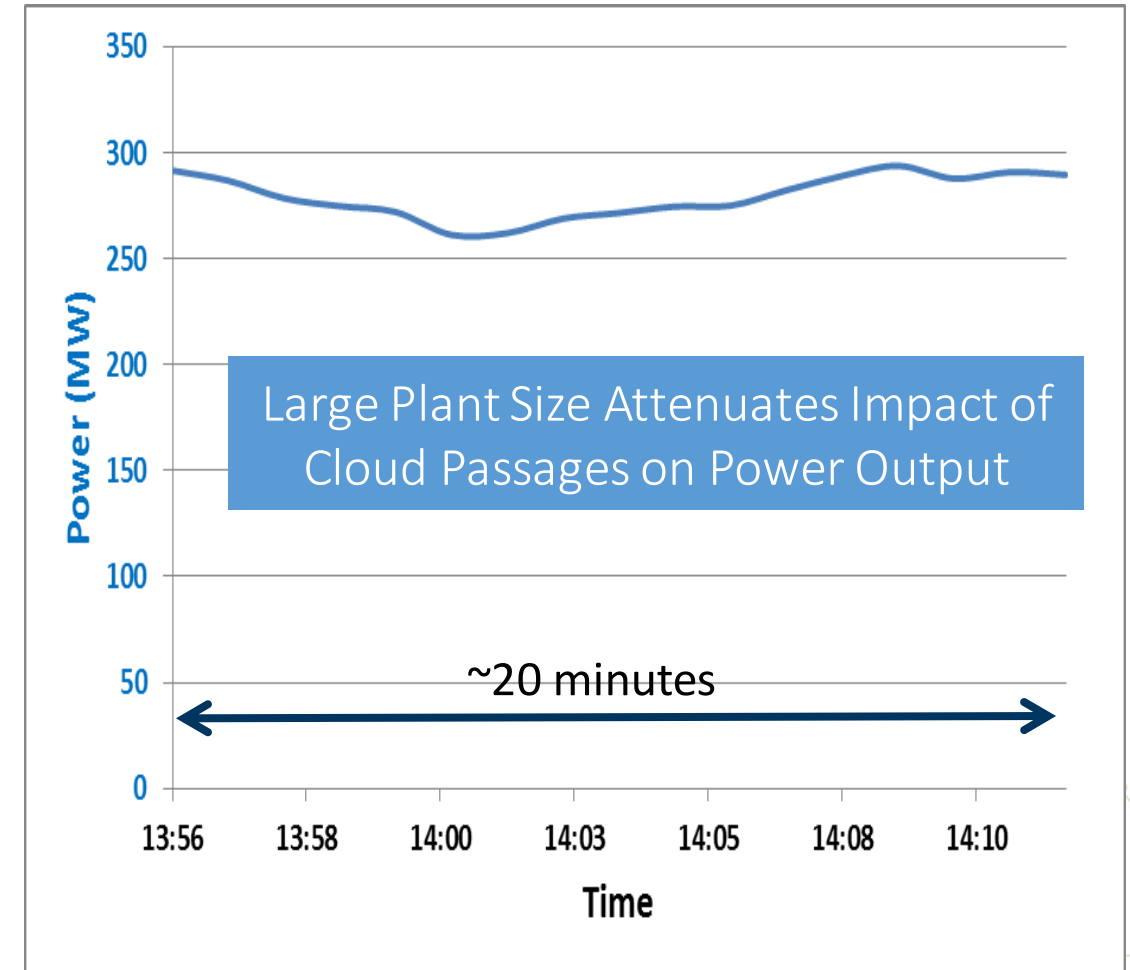
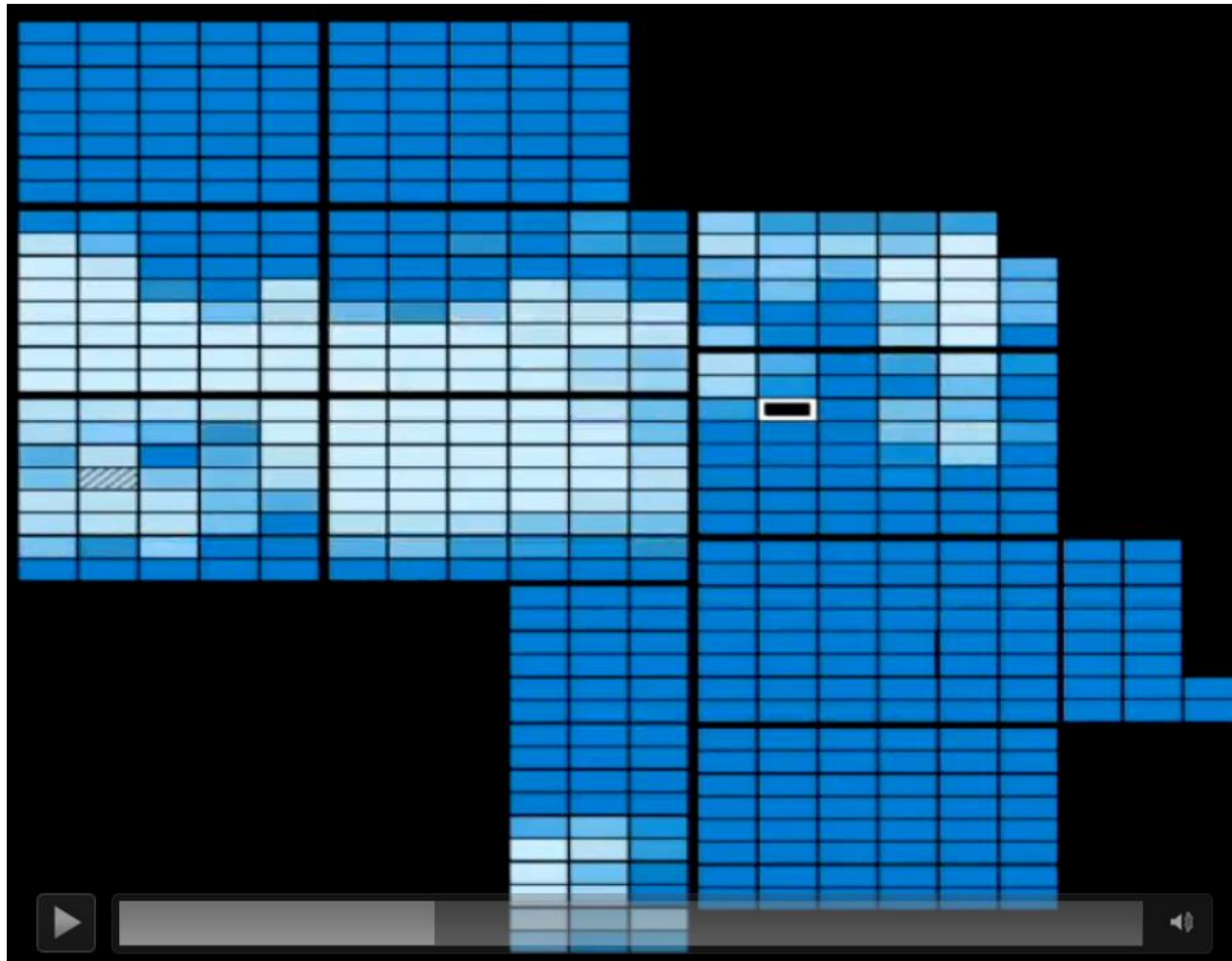
Power Curtailment at Different Levels

Excellent Control over
Active Power



- Source: Agua Caliente PV Plant in Yuma, Arizona, USA March 13, 2012. ~90MW on-line.

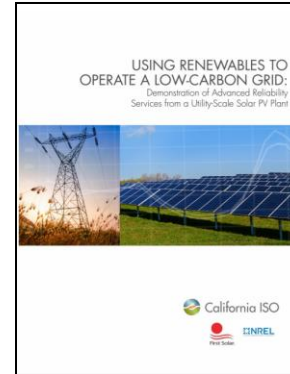
Geographic Dispersion Attenuates Short-Term Intermittency



Solar Plant Provides Essential Reliability Services

NERC: Essential reliability services

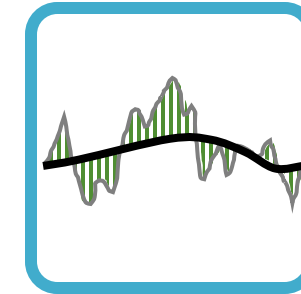
- Frequency Control
- Ramping capability or flexible capacity



2018 Intersolar
Outstanding
Project Winner

2017 NARUC
Award Winner

Power Regulation

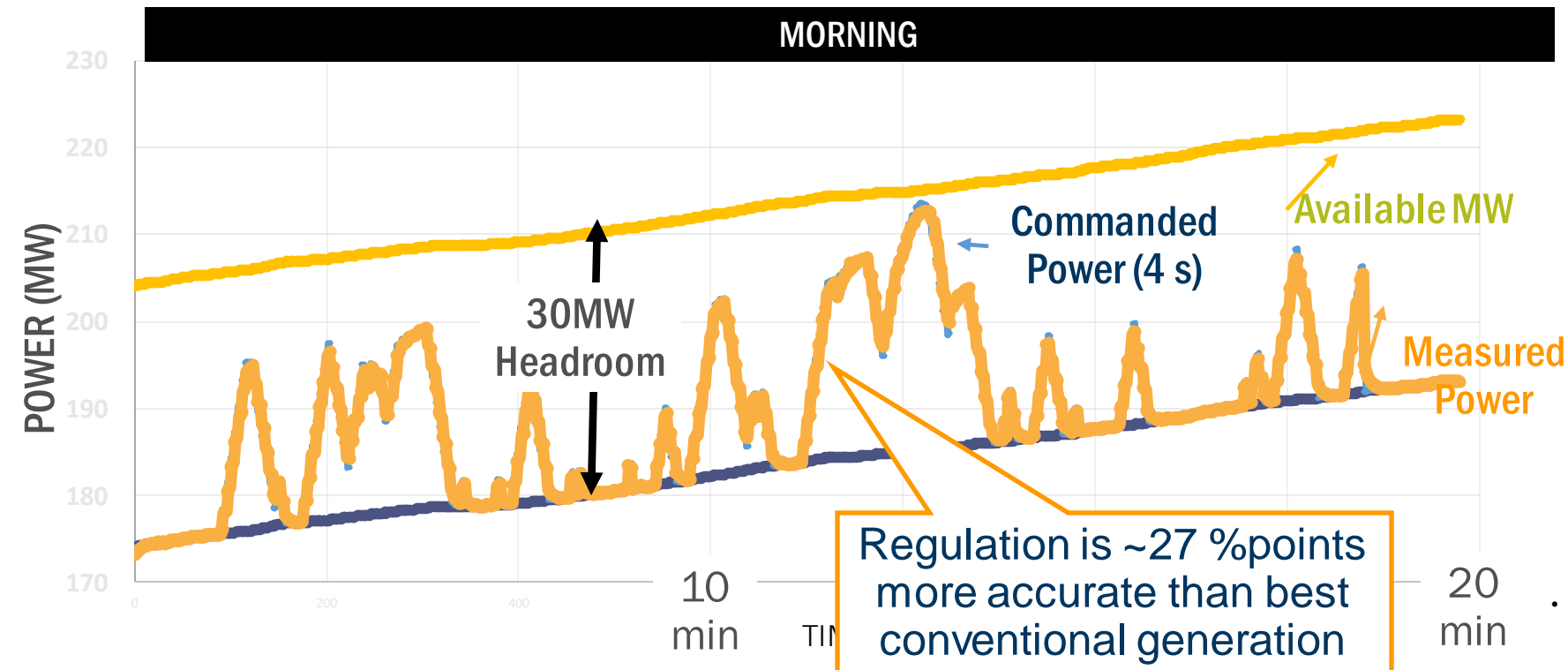


- AGC
- Up-Regulation
- Down-Regulation
- Frequency Regulation
- Flexibility

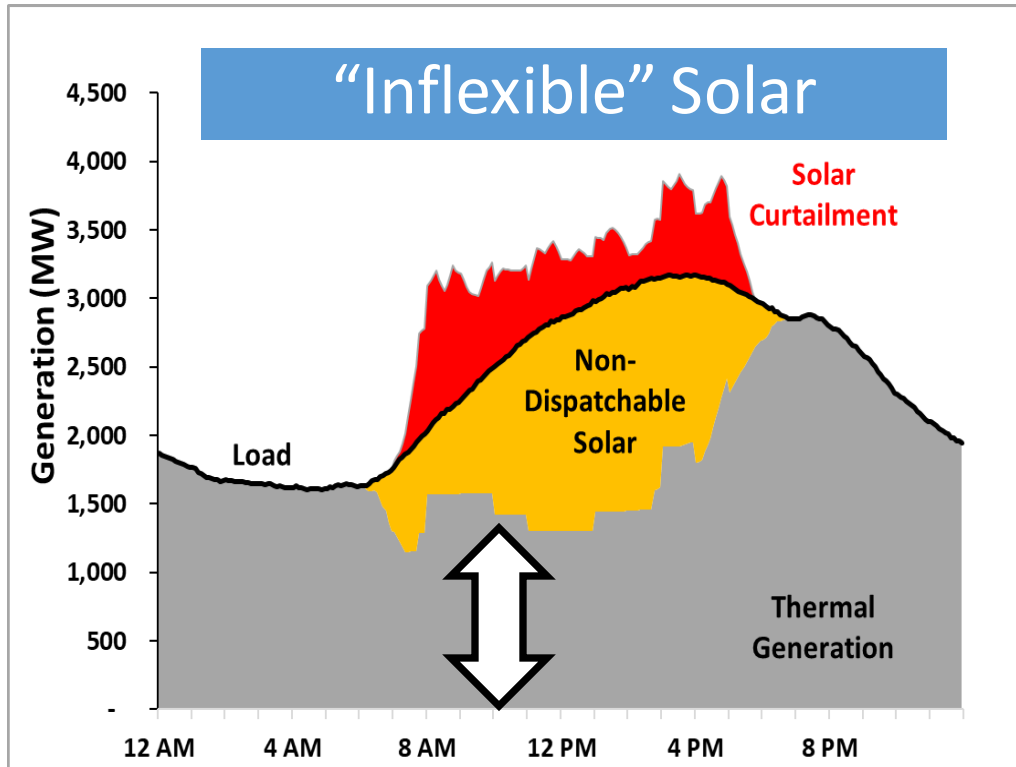
Grid Reliability Services



Source:
<http://www.caiso.com/Documents/TestsShowRenewablePlansCanBalanceLow-CarbonGrid.pdf>
AGC: Automated Generator Control

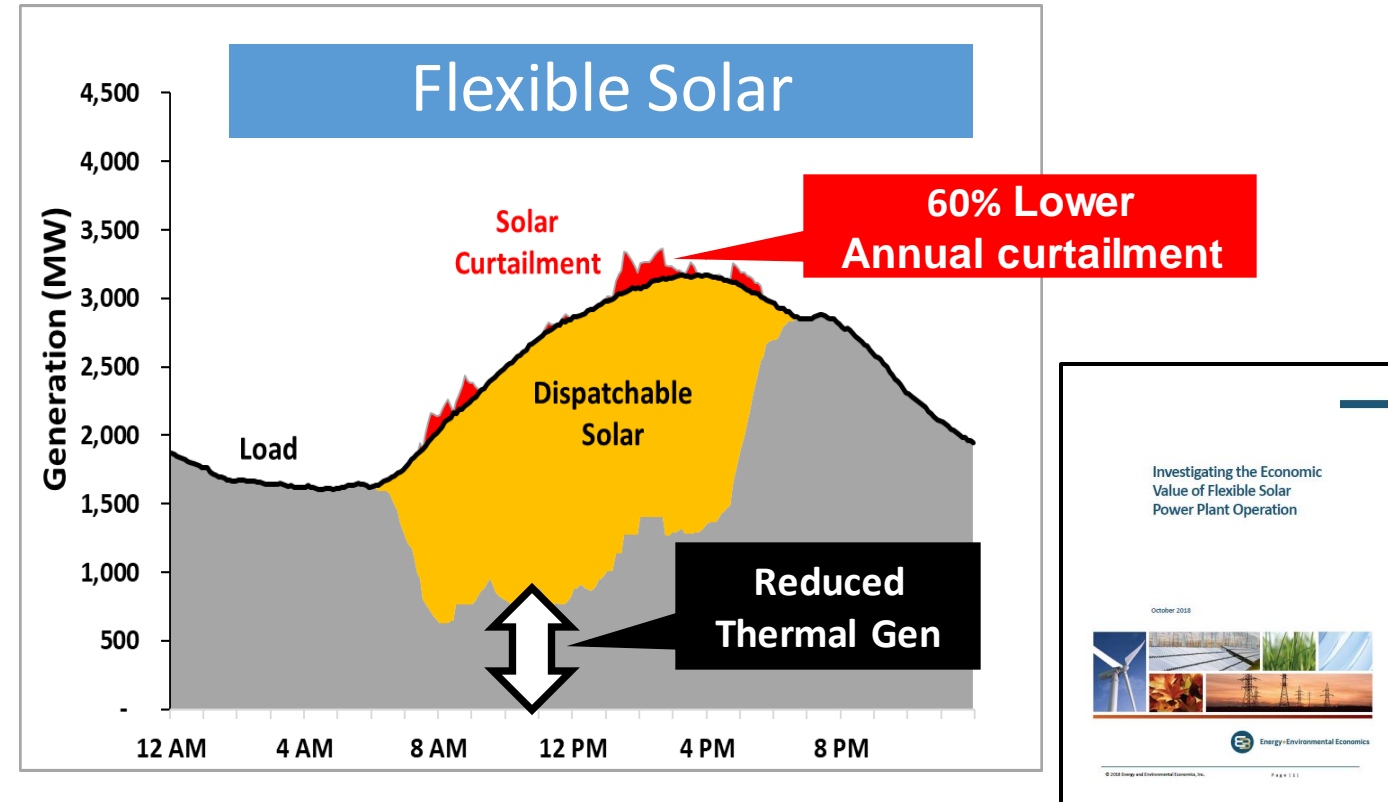


Solar Plant Provides Flexibility



- **Solar Provides No Regulation Reserves**

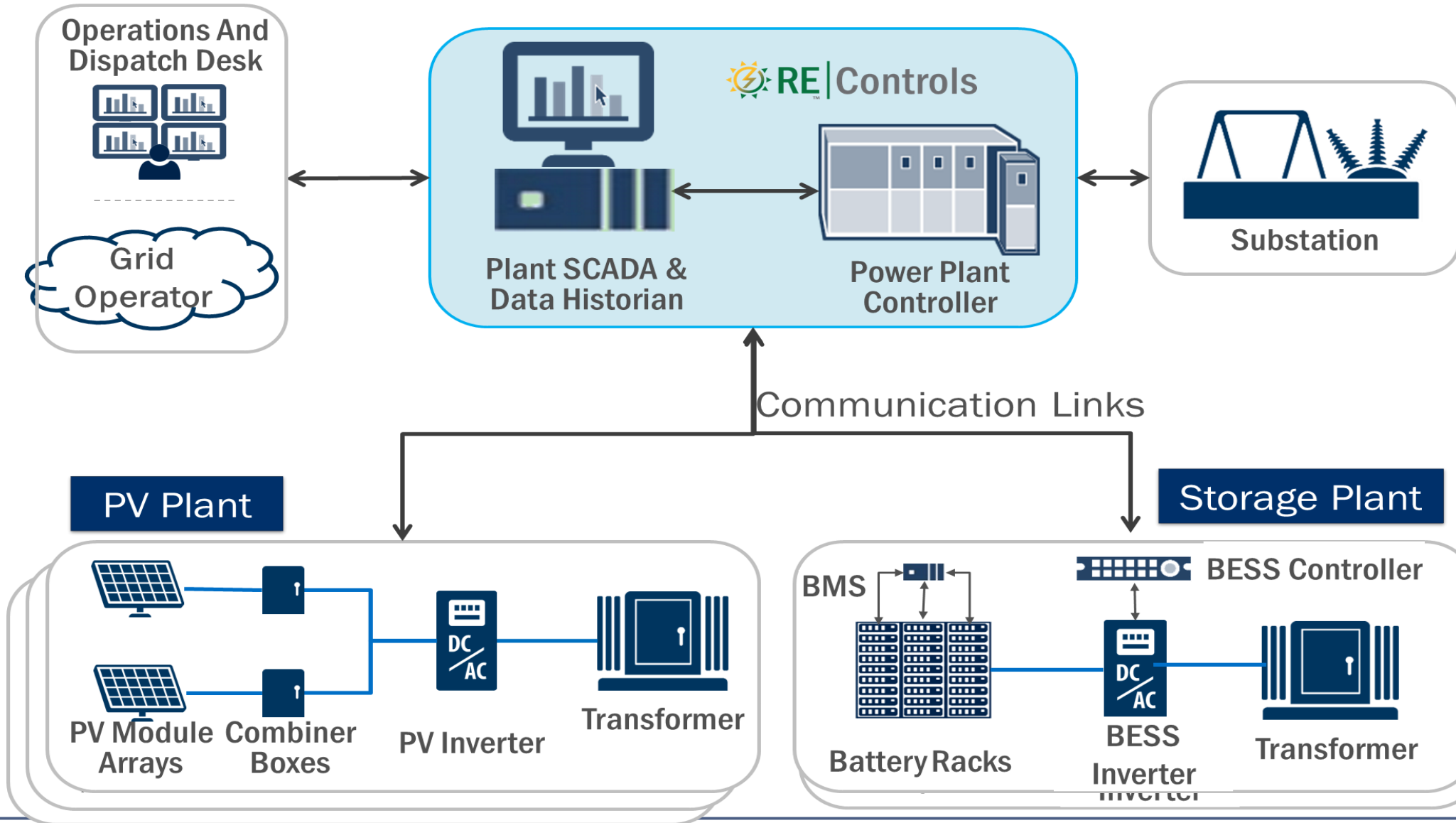
Source: E3, TECO, First Solar Report “Investigating the Economic Value of Flexible Solar Power Plant Operation”, <https://www.ethree.com/wp-content/uploads/2018/10/Investigating-the-Economic-Value-of-Flexible-Solar-Power-Plant-Operation.pdf>



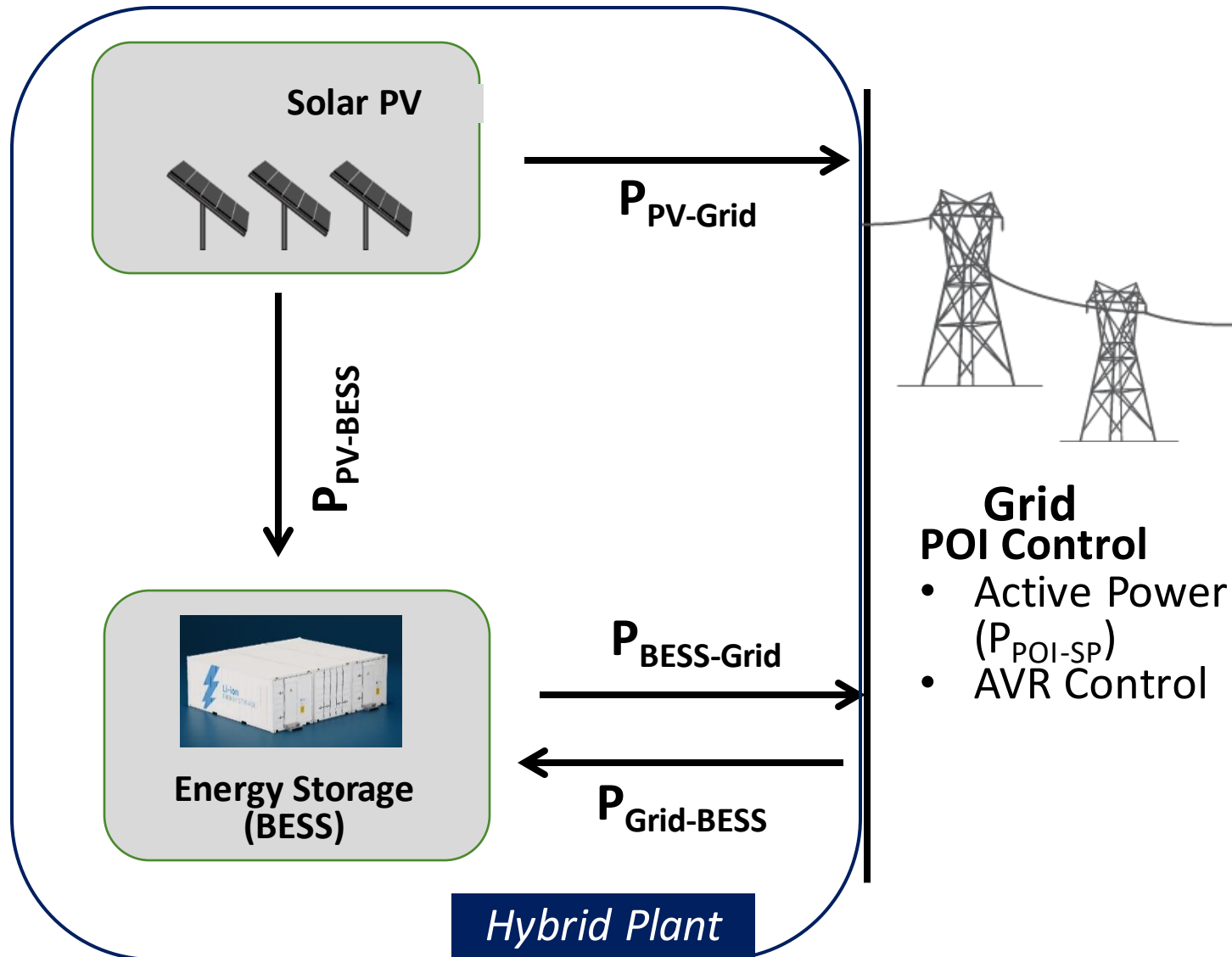
- **Flexible Solar: Provides regulation reserves.**



Utility Ready Plant Controls & SCADA System for PV/Hybrid Plant



Power Flow in a PV+Storage Hybrid Plant (Simplified)



- Grid
POI Control**
- Active Power (P_{POI-SP})
 - AVR Control



PV & Hybrid Plant-level Controls Include:

- ✓ **Active Power Controls**
 - Follows Automated Dispatch (ADS)
 - Ramp Rate Control
 - Primary Frequency Droop Control
 - Prevents Over-Generation
 - Automated Generation Control (AGC)
 - Flexible and Dispatchable Solar
- ✓ **Voltage and Reactive Power Controls**
 - Power Factor Control
 - Voltage Control Mode
 - Reactive Power Control Mode
 - Night VARs
 - Line Drop Compensation (LDC)
- ✓ **Works seamlessly with Battery Energy Storage System and supports the above features**

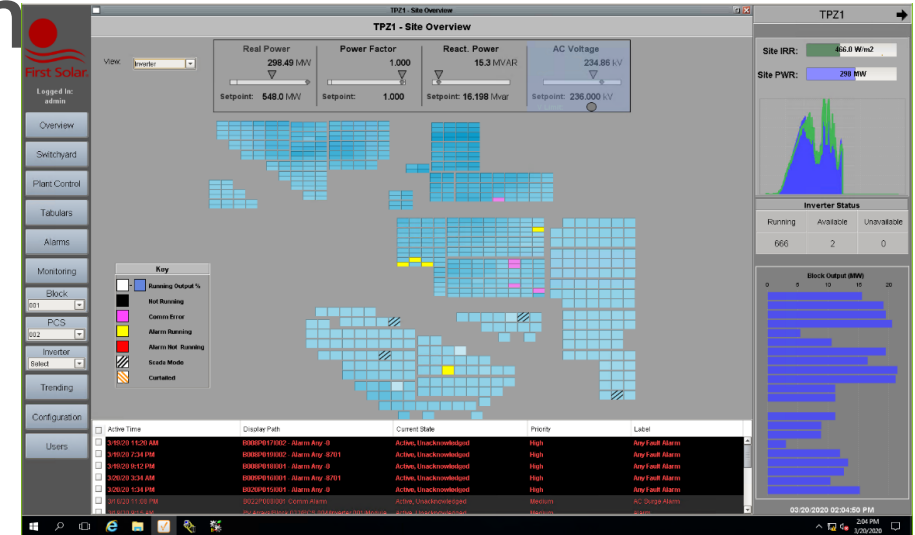
Hardware and Interfaces

- Works with Central and String Inverters
- Works with AC/DC coupled storage
- Uses industry standard platform SEL-3555 RTAC.
- SCADA uses communication interfaces including Modbus/OPC-UA
- It also supports multiple protocols with the utility including DNP3



PV & Hybrid Plant SCADA System

- ✓ Real-time monitoring, alarm management, historical data archiving,
- ✓ Supervisory control capability for the entire PV and BESS facility
- ✓ An interface to the PPC and its functions.
- ✓ Support for Operation and Maintenance (O&M) and performance analysis

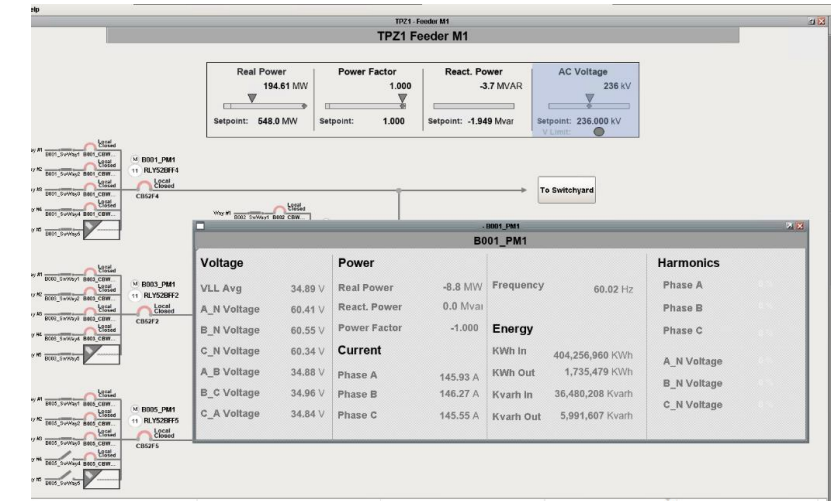


Hardware and Interfaces

- ✓ Graphical User Interface
- ✓ Historian Server
 - Onsite data retention capability,
 - One-second data scanning and storage
 - Accommodate up to 5 years' worth of data storage
- ✓ Device Polling
- ✓ Alarming
- ✓ Historical Data Transfer Capability
- ✓ Secure Remote Access

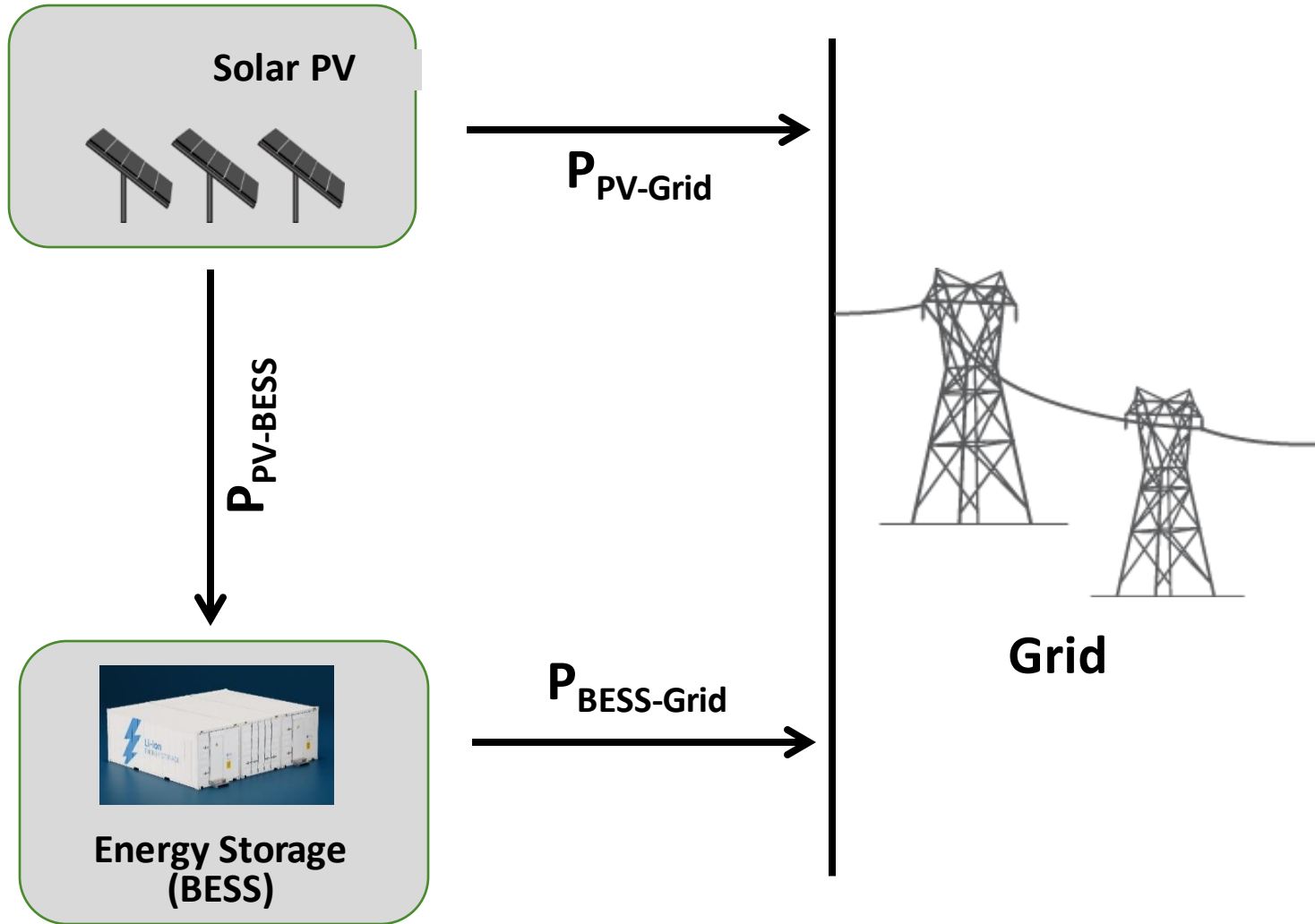


Plant Level Screen



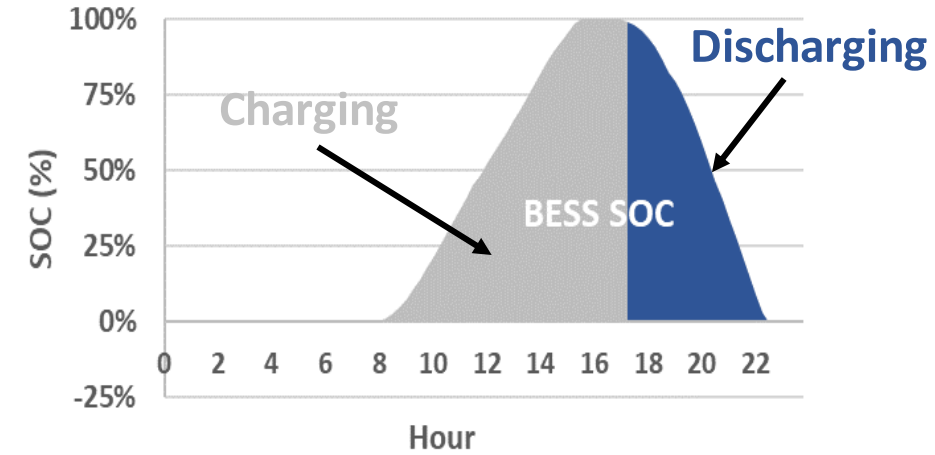
Representative SCADA Screen

Energy Shifting Capability of PVS

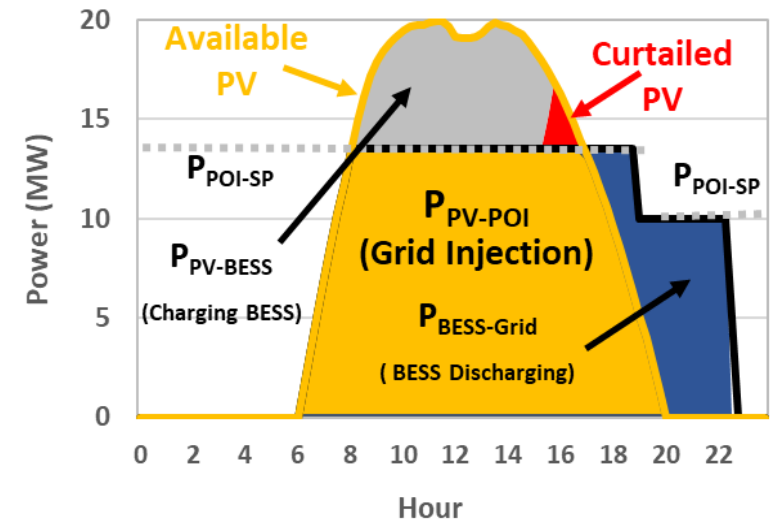


BESS SOC

BESS Charging & Discharging

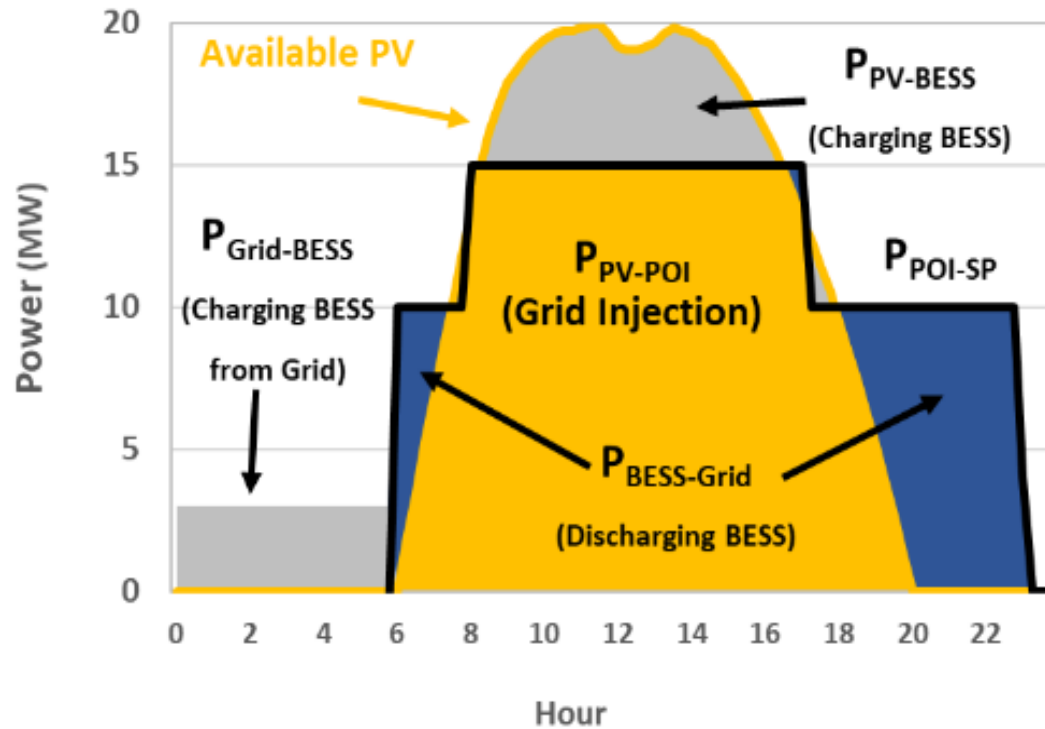


PVS Output Profile

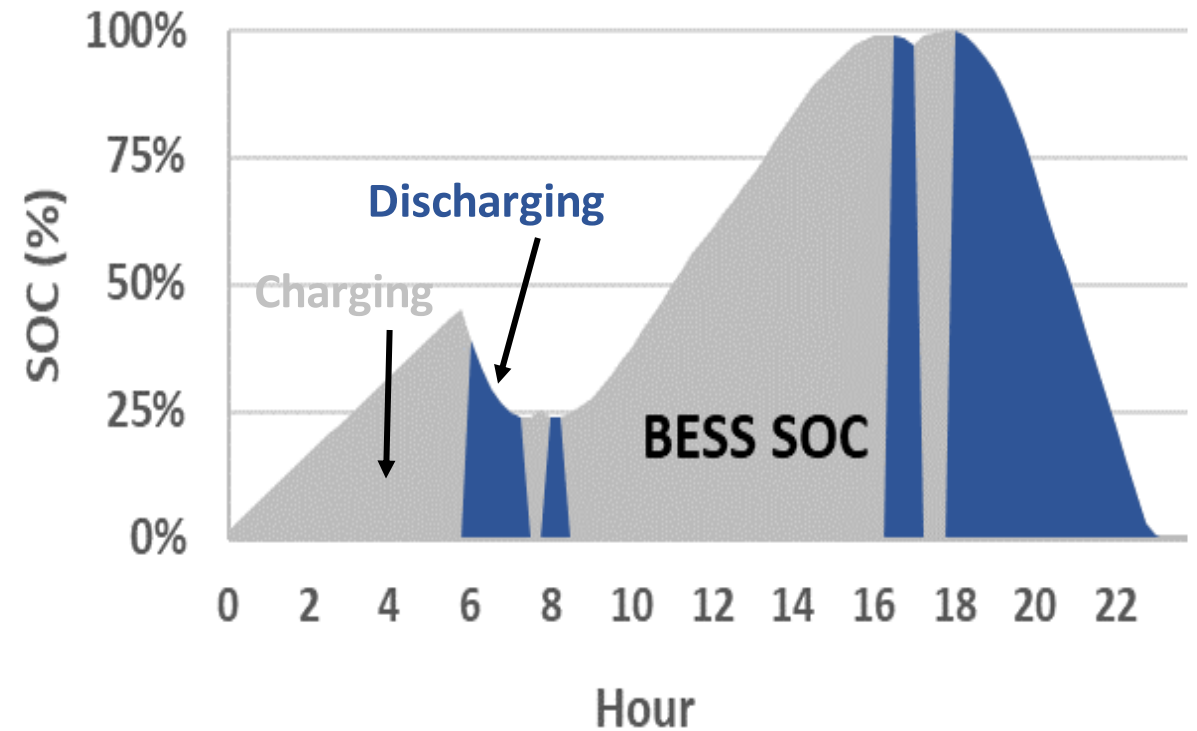


Schedule Driven Dispatch of PV and Storage (BESS)

PVS Output Profile



BESS Charging and Discharging

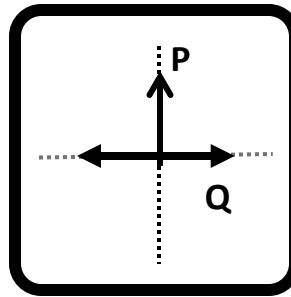


PPC Manages Operator-entered Schedule at POI by Charging and Discharging Storage as Required

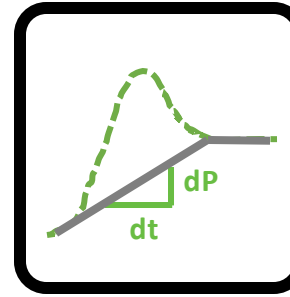
Adding Storage Enhances Grid Capability of a PV Plant



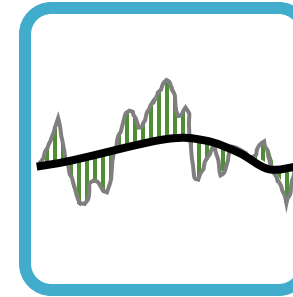
Voltage Support



Ramp Control



Power Regulation



- AGC
- Up-Regulation
- Down-Regulation
- Frequency Regulation

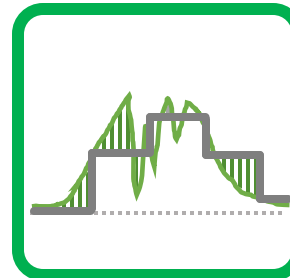
Base Capability

Grid Reliability Services

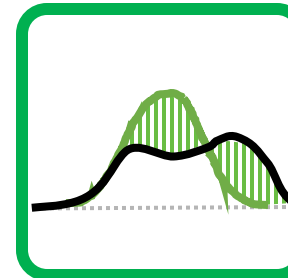
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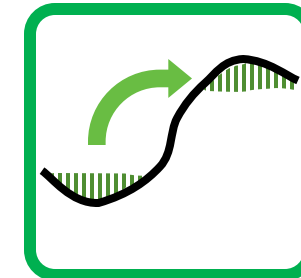
Capacity Firming



Energy Shifting



Flexibility



Grid Capabilities Enhanced with Storage

Capabilities of Plant Controls (PPC) & SCADA

Plant Controls



Widely known for its most advanced grid integration plant control features with over 10GWs of utility-scale plant controls installed in Americas, MENA and Australia.

Plant Monitoring



Monitors key components of the solar plant including inverters, meters, breakers and more. It provides secure remote monitoring and plant data access. It is a solution that works with all plant equipment from various manufacturers.

Plant Data



It logs all the plant data with 1 second resolution, providing the operators with an ability to perform effective analysis and reporting.

Plant Reports



It includes a suite of standard and ad hoc reports for plant production, plant availability, and detailed analysis for maintenance purposes.

Product Offering

- ✓ Site PPC/SCADA hardware & software
 - Works with both Central and String Inverters
 - Works with AC/DC coupled storage
- ✓ Site installation of PPC/SCADA
 - Detailed drawings and instructions provided to EPC for easy interfacing to all equipment
 - Data and Network
- ✓ PPC/SCADA commissioning, full verification and testing
- ✓ Project specific PPC load flow and dynamic models (PSLF, PSS/e, PSCAD) for interconnections updates
- ✓ NERC MOD-25/26/27/32 compliance testing and reports

Agua Caliente Solar Farm (COD 2014)



Advanced Plant Features

Agua Caliente is one of the first utility-scale PV plants of its size (290 MWac) to be connected to a 500kV transmission line in 2011. It employs First Solar's industry-leading grid integration and plant control system. It pioneered many grid friendly features that are critical for managing grid reliability and stability. The plant can be controlled remotely from First Solar's world-class Operations Center.

Advanced plant features include the ability to:

- Regulate voltage, frequency, and power factor
- Control active and reactive power, ramp rates, and curtail power when necessary
- Ride through grid faults and disturbances
- Minimize the impact of passing clouds through intelligent plant controller

Desert Sunlight Solar Farm (COD 2014)



The 550MWac Desert Sunlight Solar plant is co-owned by NextEra Energy Resources, GE Energy Financial Services, and Sumitomo Corporation of America. The project is located on land managed by the Federal Bureau of Land Management (BLM), about six miles north of the community of Desert Center. When it was commissioned it was one of the largest PV plant in the world. It also contains all the leading grid control capabilities that were pioneered at the Agua Caliente plant. Also it

- Controls and manages two separate grid connections (with PG&E and SCE)

Topaz Solar Farm (COD 2014)



Located on the northwestern corner of the Carisa Plains, the 550MWac Topaz Solar Farm produces sufficient electricity to power 160,000 average California homes. The Topaz location was selected after an extensive review of potential sites in California which considered the available solar resource, proximity to existing electrical transmission lines, current land uses, and environmental sensitivities. It also contains all the leading control capabilities that were pioneered at the Agua Caliente plant. Also, it

- Controls and manages multiple inverter types (2 different models of ABB inverter and 1 model from SMA)

Phoebe Solar Farm (COD 2019)



The Phoebe PV solar plant, located in Winkler County in Texas, is Innergex's largest solar project to date with an installed capacity of 250 MWac (315 MWdc). With an average annual power generation expected to reach 715,800 MWh, it produces enough to power more than 50,000 Texan households. At the time of its commissioning in November 2019, Phoebe is the largest solar farm in the State of Texas. In addition to all the grid friendly features implemented in other First Solar plants, it

- Demonstrated advanced voltage stability controls in weak grids

Tampa Electric Big Bend PVS Project (COD 2019)



The Big Bend PV project located in Florida is a 20 MWac capacity plant. A BESS system of 26MWh was added at this existing plant. The First Solar team integrated the storage system and added new plant controls and SCADA system that integrated the whole plant. The system is now able to provide many advanced grid integration features:

- Energy Shifting
- Dispatch Scheduling
- Firm Capacity
- Up and Down Regulation and Frequency Control
- Load Following

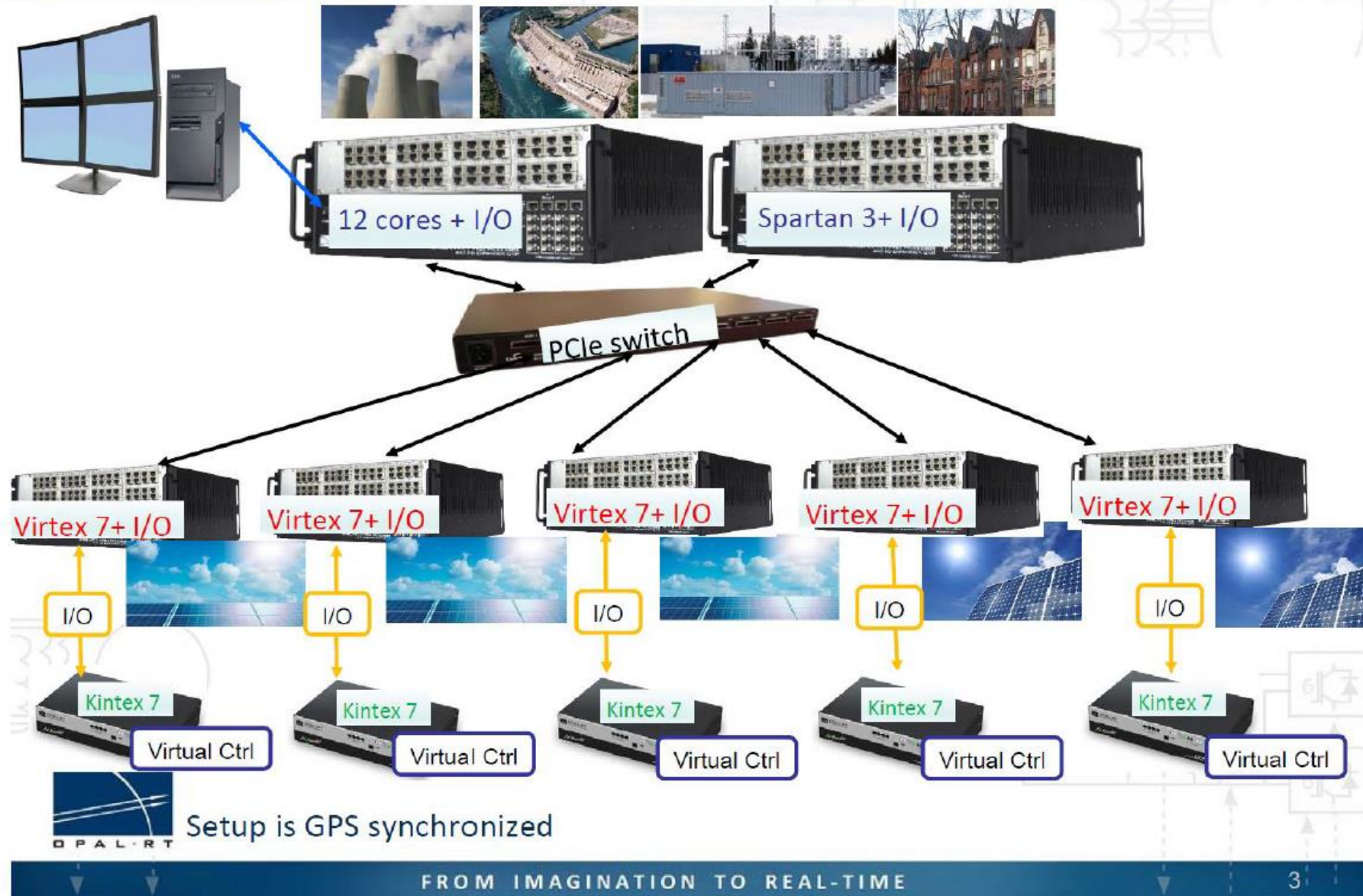
CD Arevon California Flats Project (COD 2019)



The California Flats PV Project located in Monterey County, CA is a 280MWac capacity plant with PPAs held by Apple and PG&E. A BESS system of 240MWh is being added at this existing plant. The Terabase Energy team is providing the plant controls and SCADA system that integrates the two resources. It will provide many of the advanced features required for co-located solar and storage resources in CAISO market.

- Energy Shifting
- Automated Dispatch System (ADS) & Automated Generation Control (AGC)
- Up and Down Regulation
- Solar Dispatch on Target (DOT) variation control with storage
- LGIA Limit Compliance Control

Terabase Full Configuration





terabase
ENERGY