



# Grid-Friendly Utility-Scale PV Plants

Brian Penner, Manager Power Plant Operations

- Over 4.0 GW Completed or In Development (  $10\text{MW}_{ac}$  –  $550\text{MW}_{ac}$  Plants)



- The First Solar Operations Center (FSOC) monitors and Operates over 3GW of utility scale Power Plants throughout North America

**2012 Special Assessment**  
Interconnection Requirements for  
Variable Generation

September 2012

RELIABILITY | ACCOUNTABILITY

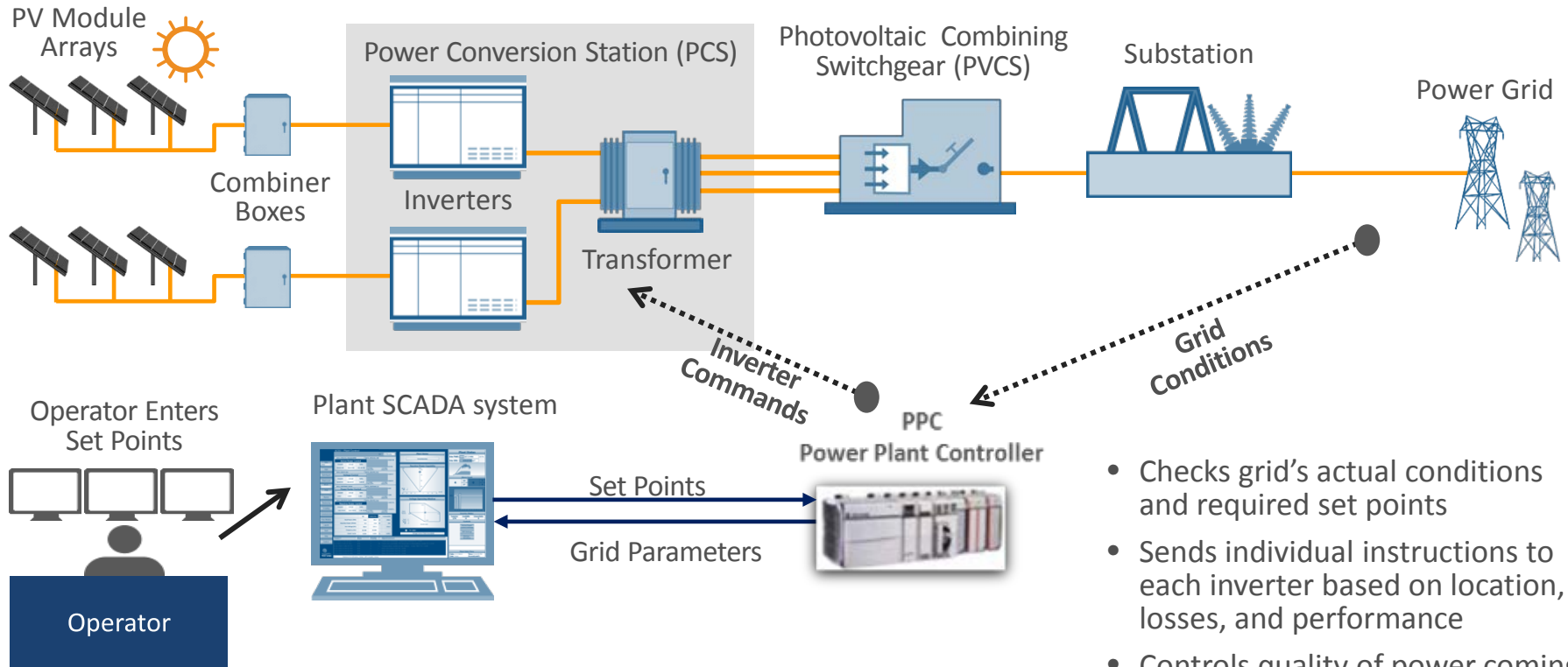


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*“Modern PV plants can now contribute to the **stability and reliability** of grid operation by offering the following capabilities:”*

- ✓ Voltage regulation
- ✓ Fault ride through
- ✓ Real power control, ramping, and curtailment
- ✓ Primary frequency regulation
- ✓ Frequency droop response
- ✓ Short circuit duty control

Utility-scale PV plants can provide this capability



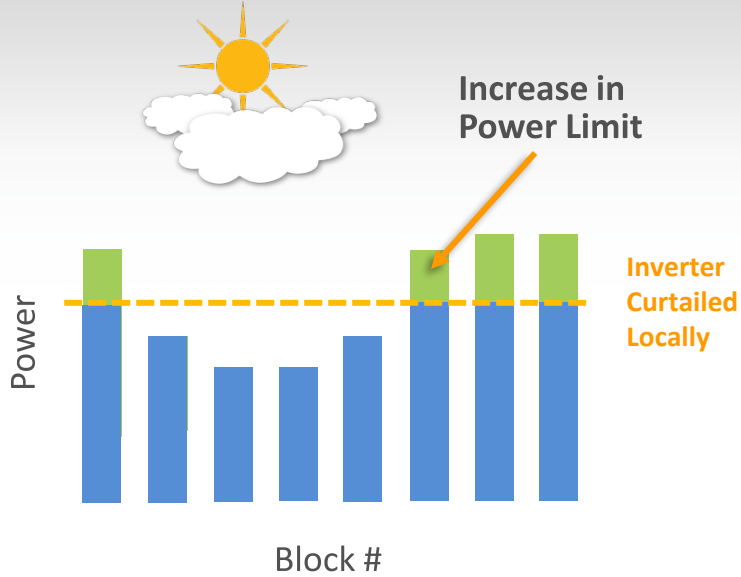
- Checks grid's actual conditions and required set points
- Sends individual instructions to each inverter based on location, losses, and performance
- Controls quality of power coming out of the PV plant

***All every 100 milliseconds!***

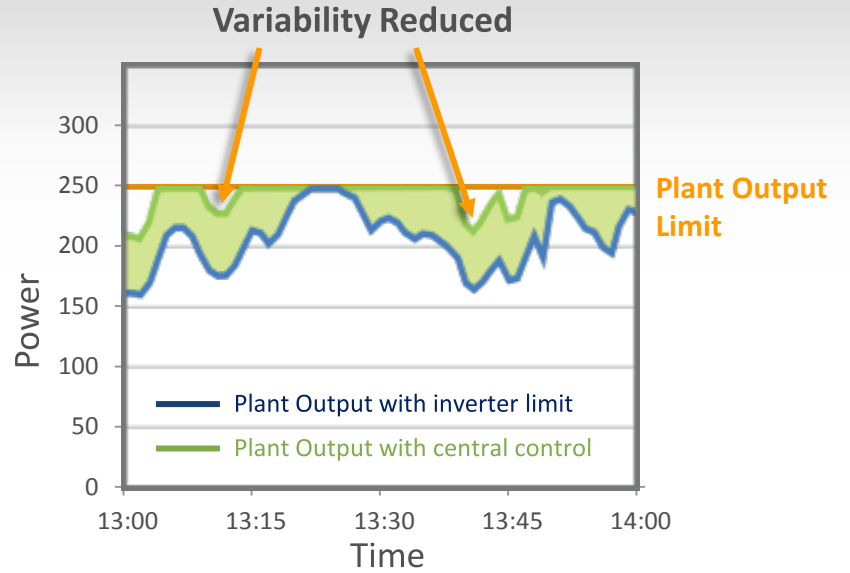
With

a central control system, inverters are individually controlled when needed to meet the plant limit ...

### Output of Each Block



### Plant Output Power

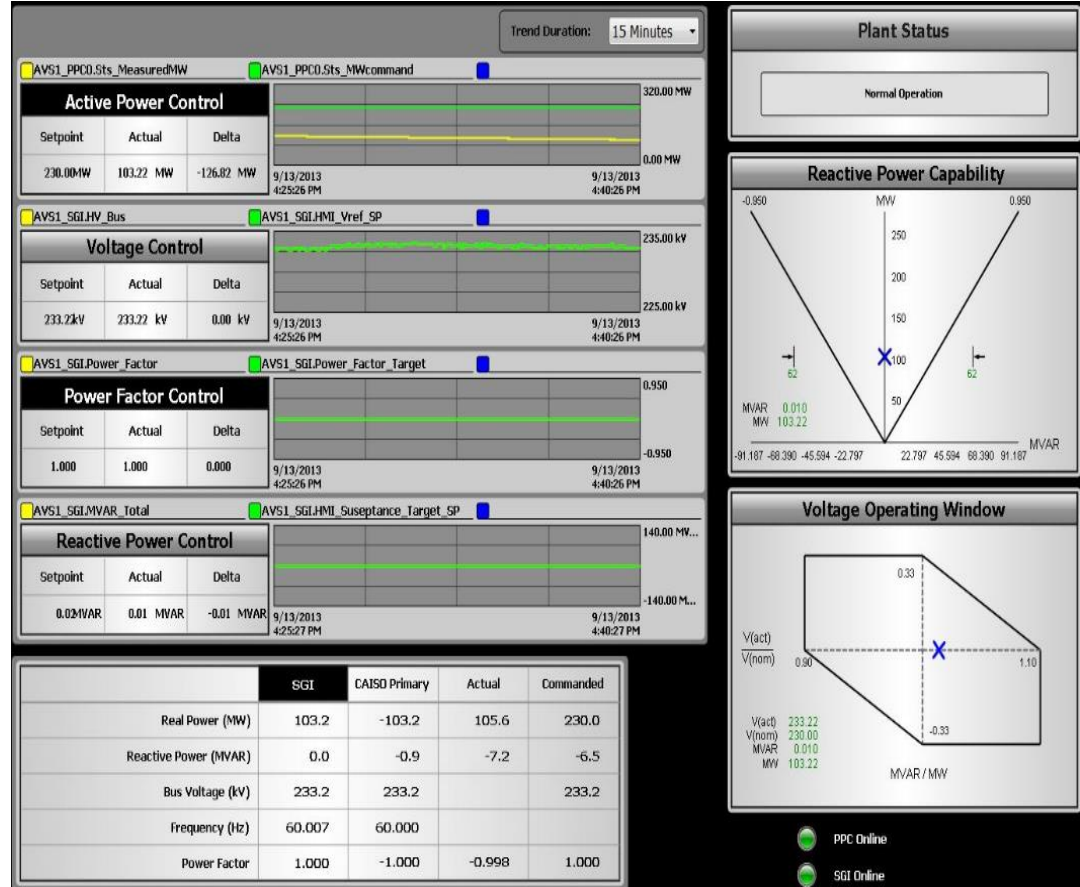


## Several Control Modes

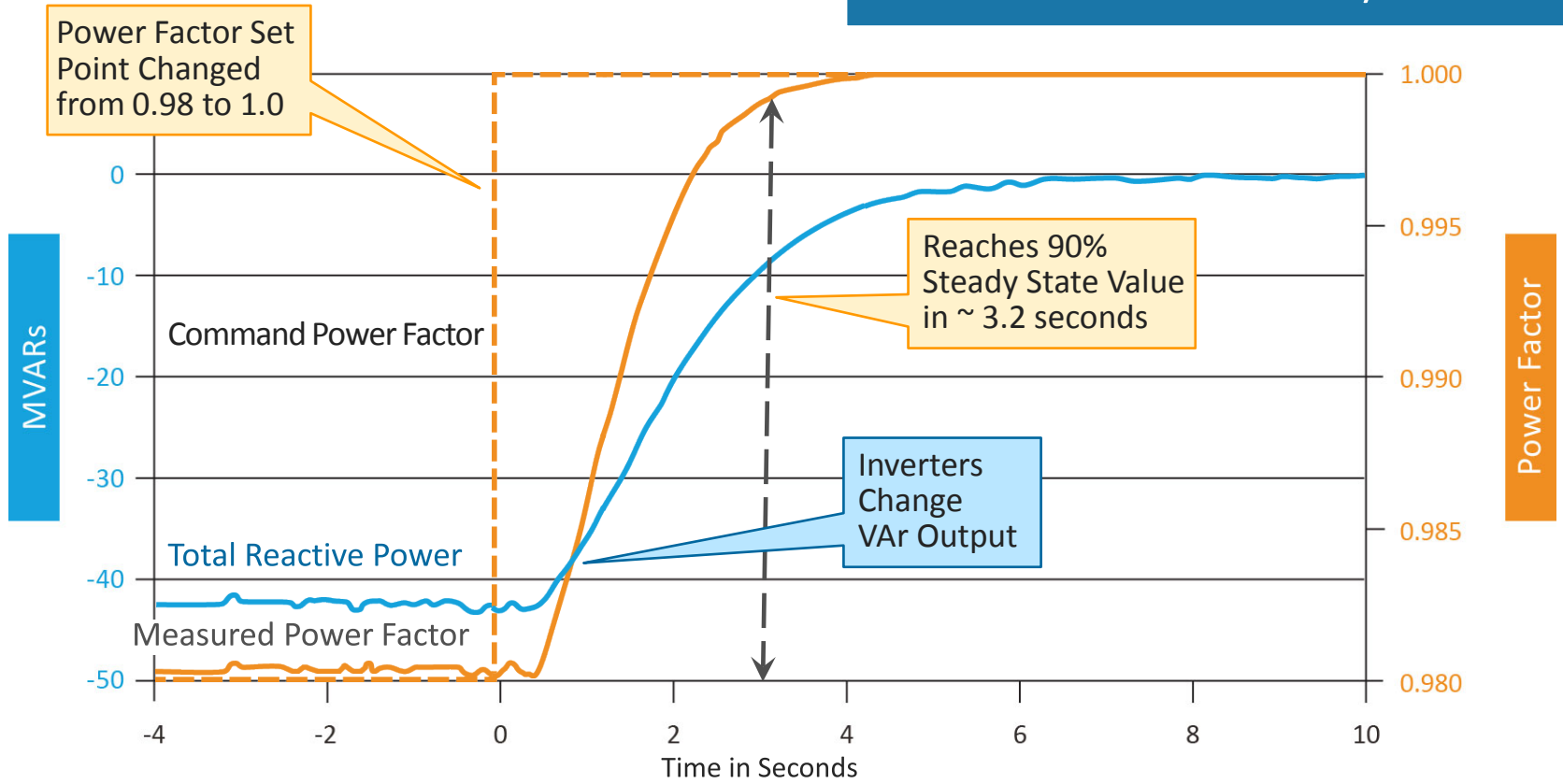
- Active Power
- Voltage
- Power Factor
- Reactive Power
- Ramp Rate
- Frequency Droop

Normal Control  
Power Factor Mode

PF=1.00 & MVAR = 0



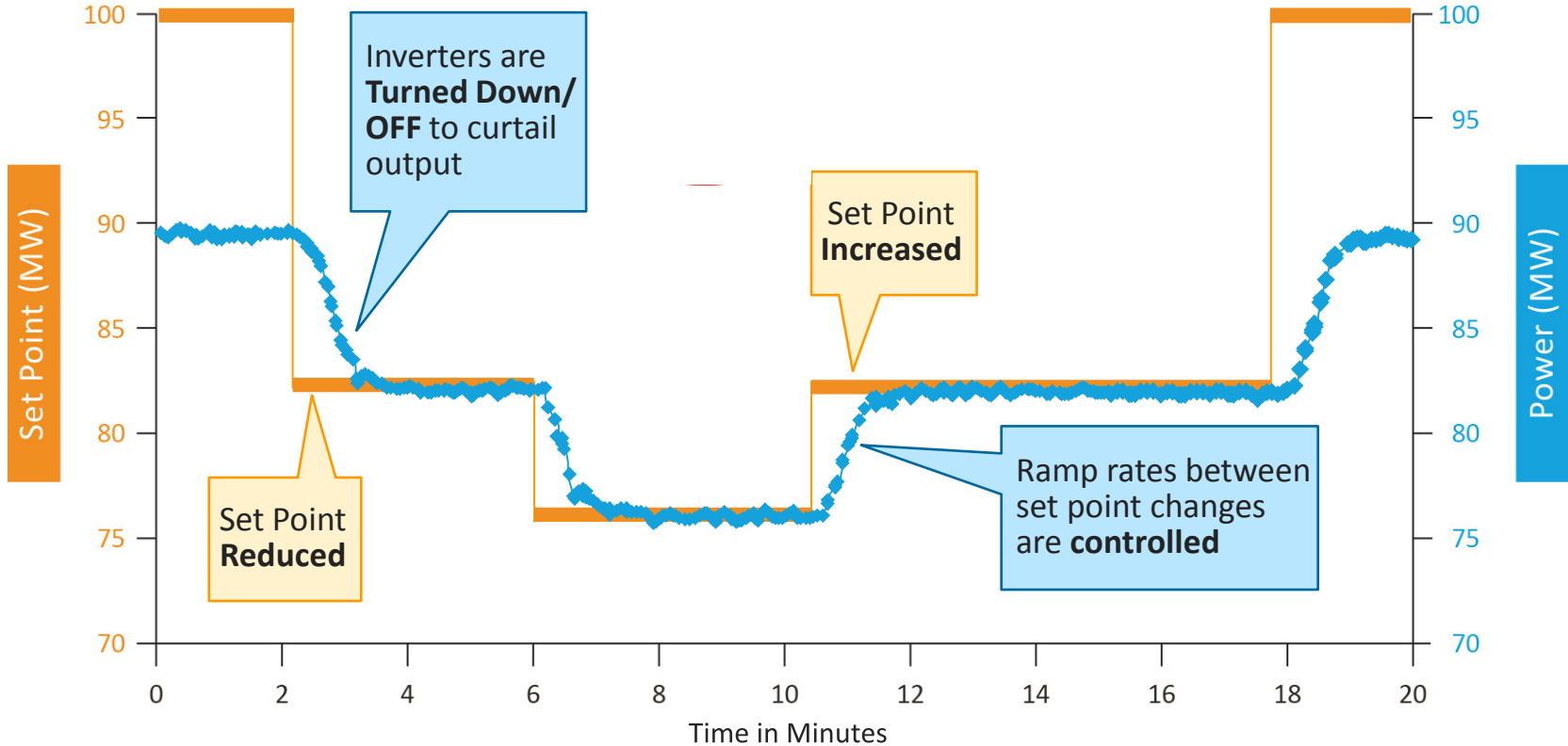
# Excellent Reactive Power Dynamic Control



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

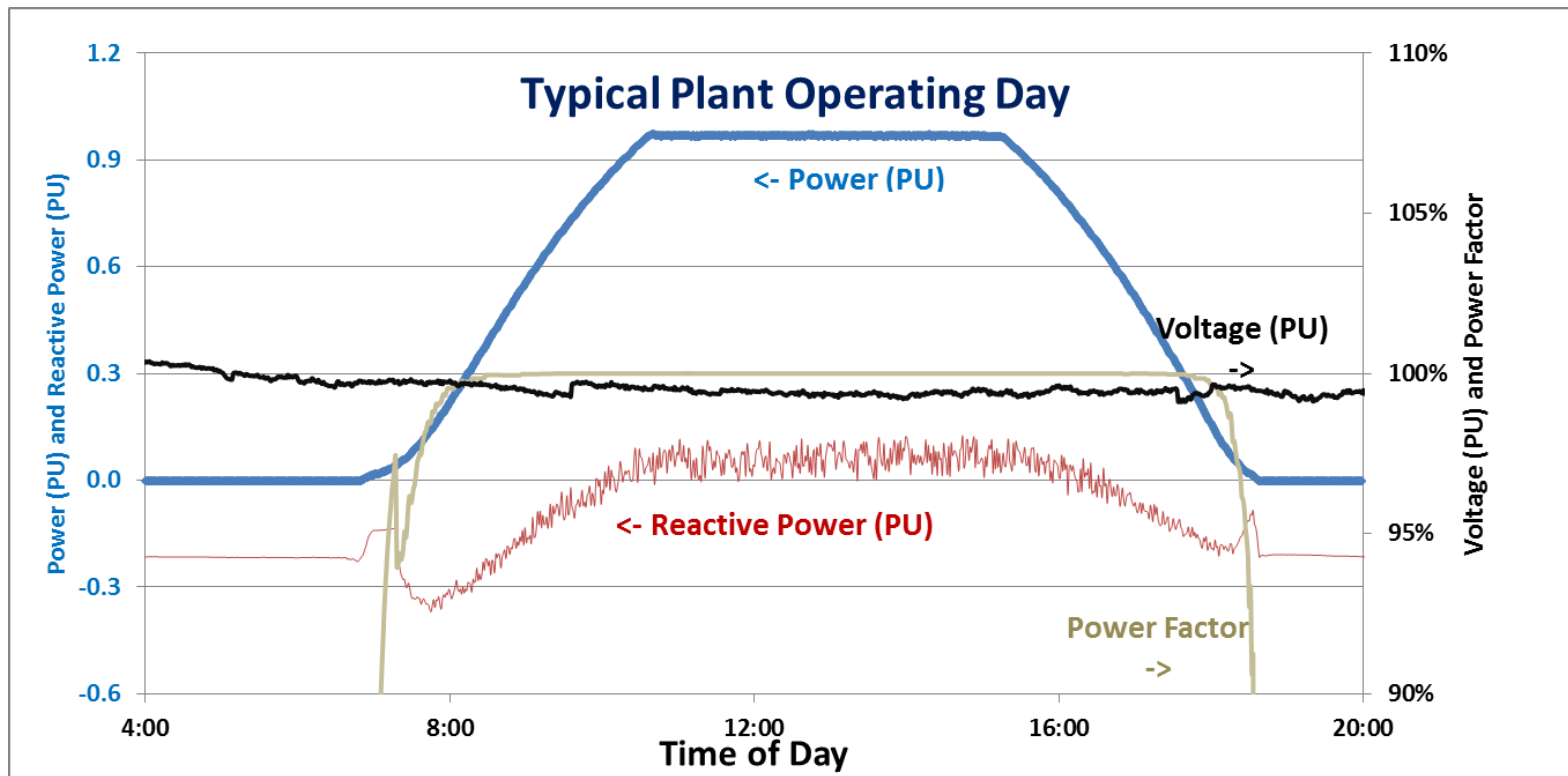
- Power Curtailment at Different Levels

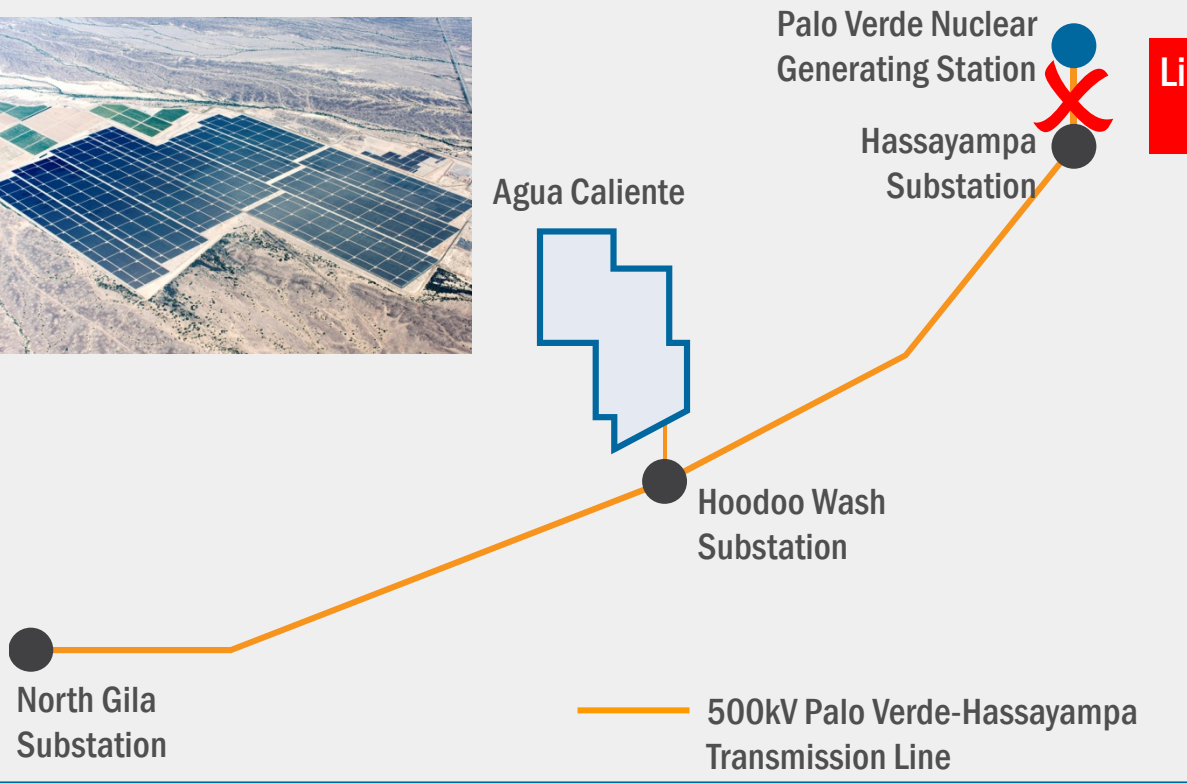
## Excellent Control over Active Power



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







# Plant Operating Under Voltage Control

