



# PETRA SOLAR<sup>®</sup>

*Intelligent Energy By Design*



## **Smart Distributed Solar PV**

*A novel approach to integrating grid reliability and solar PV technology*

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Chief Technology Officer***

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Sr. Manager – Technology Management***

# Executive Summary

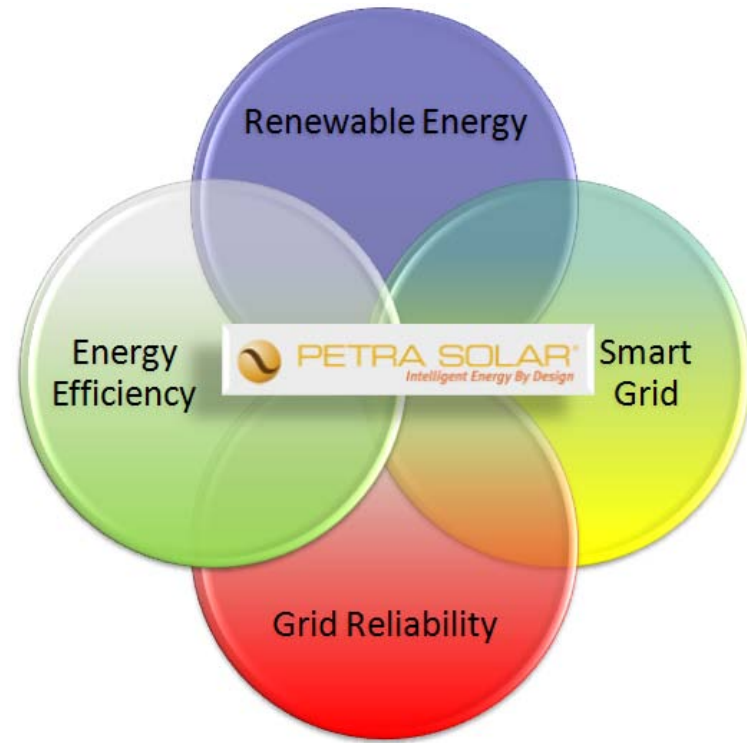
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**Petra Solar** - US company with technologies that are leveraged to create innovative Solar, Smart Grid, and Grid Reliability Solutions

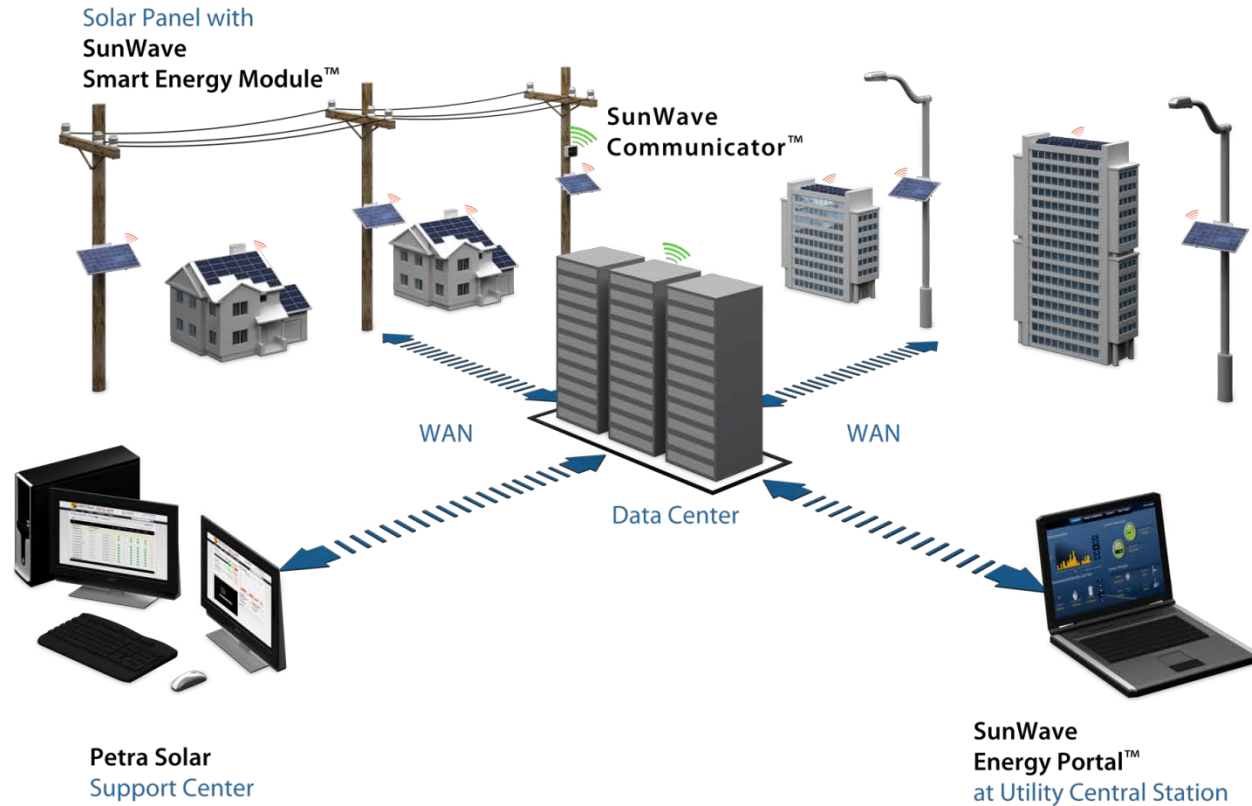
- **Market and Technology Leader**

- World's first, pole-attached, smart grid interactive SunWave™ solar system
- Partnership with world's largest PV manufacturer
- Complete cost effective integrated Solar, Smart Grid Communications, and Grid Reliability solution
- Tested and verified by Electric Utilities



# The SunWave™ System

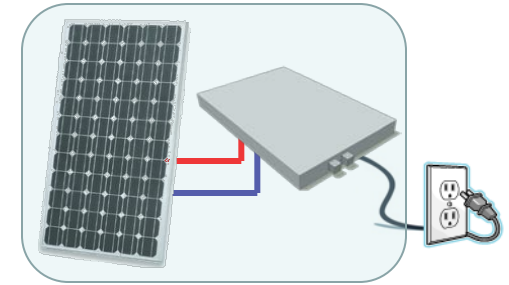
## Convergence of Solar and Smart Grid



**Solar Power Generation • Smart Grid Communications • Grid Reliability**

# Utility-Grade Solar Power Generation

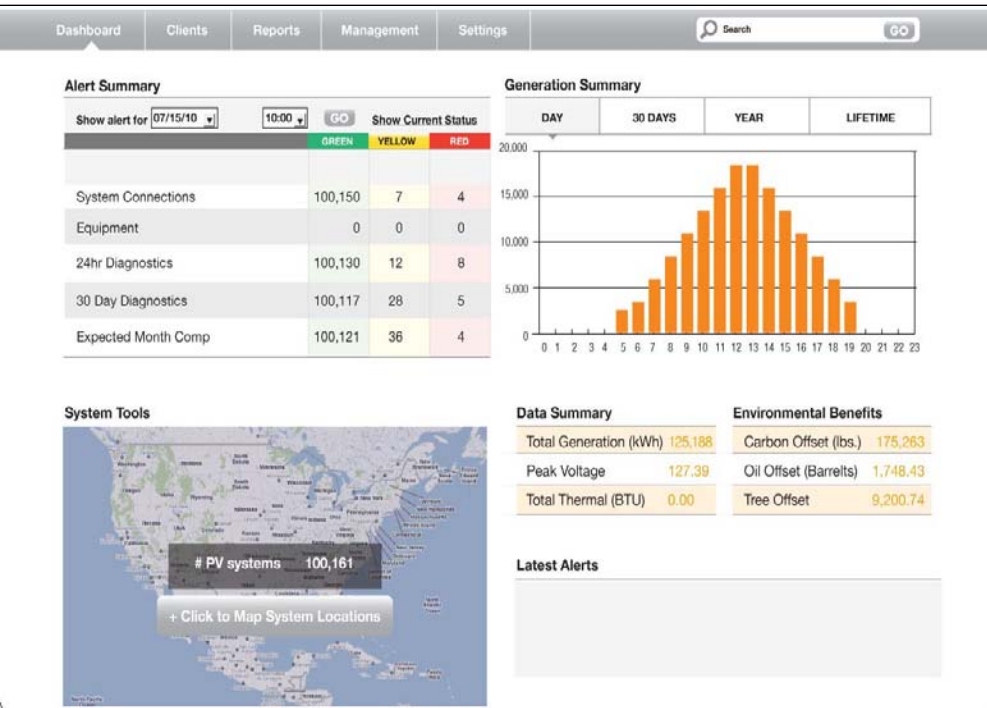
- **Disruptive Technology**
  - The SunWave™ AC Solar Module: Integrated solar panel & power management electronics
- **Modular Architecture**
  - Diagnostics and functionality on an individual panel level
- **Utility Grade Design**
  - Industrial Temperature Range:  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$
  - Extended reliability profiles beyond standard requirements
  - Other Utility specific features



**Petra Solar  
Smart Energy Module**



# Smart Grid - Monitoring and Control



- Two-way Smart Grid Communications System
- Cost-effective centralized monitoring and control of large scale distributed solar deployments
- Visibility into each Solar unit for optimizing energy harvest and data reporting requirements
- Command capability for active control and configuration of remote Solar Systems
- Expandability/compatibility for Demand Response, AMI, Lighting Control, and PHEV management

# Grid Reliability

- Real-time outage data to support Smart Grid Outage Management Systems.
- Line loss reduction and voltage optimization through dynamic distributed VAR generation.
- Outage and Low Voltage Ride Through
- Generation Ramp Rate Control
- Communications and Controls Platform to Plug-in Electric Vehicle Charging
- Power Quality improvements through non-linear power mitigation
- Storage Integration to avoid impact of renewable intermittency



# Proven Utility Grade Solution



# PSEG

- 200,000 SunWave™ systems to be deployed over 3.5 years
- First shipment Sept 1, 2009
- ~60,000 units (12MW) have shipped and been commissioned to date
- Reliable and schedulable platform for solar deployment

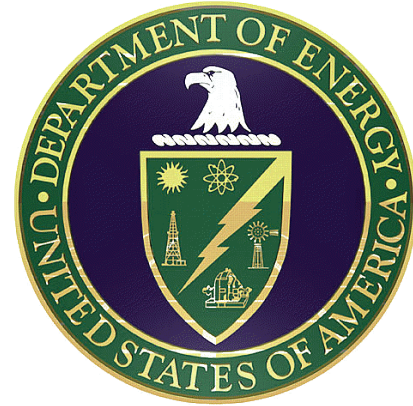


Wall Street Journal, Friday July 31<sup>st</sup>, 2009

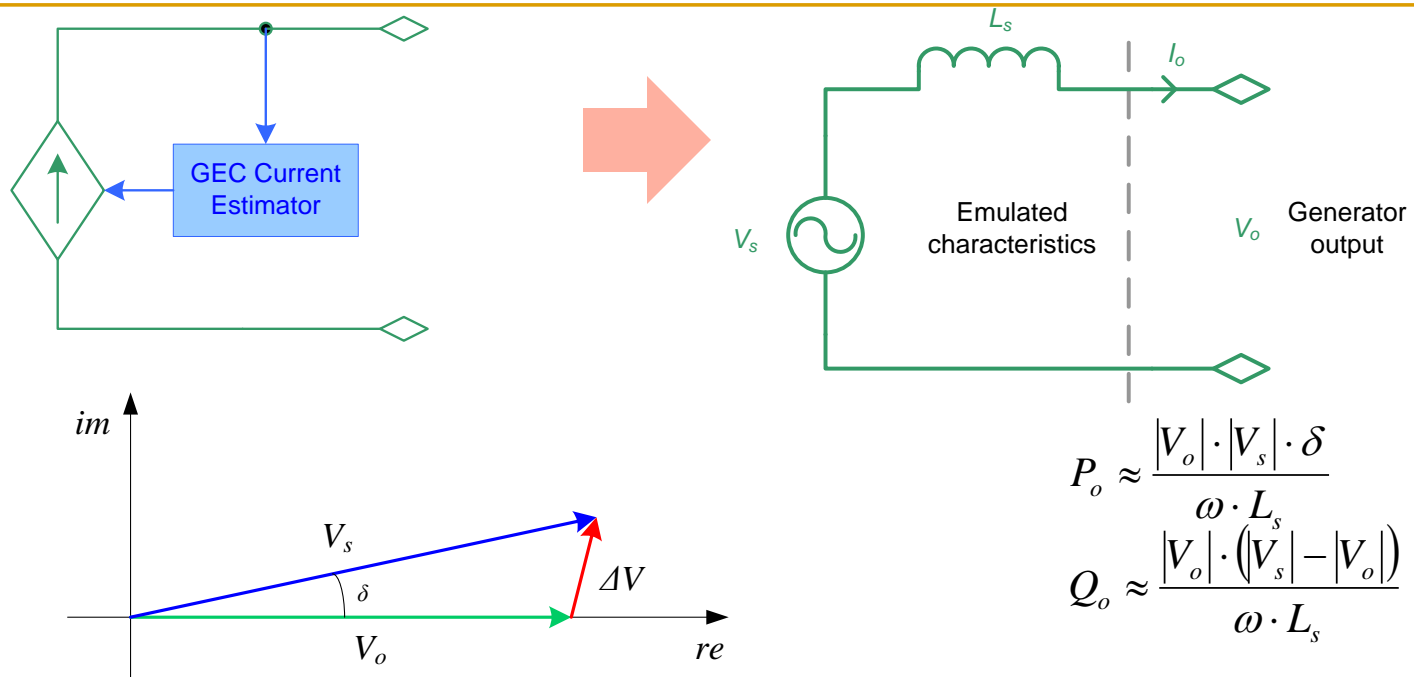
# Department of Energy Collaboration

## *Solar Electric Grid Integration Systems (SEGIS)*

- Focused on funding technology development to enable the preservation of **Grid Stability as the penetration of Solar increases**
- **Grid support** functions achieved through an advanced energy platform with algorithms for Reactive Power compensation
- **Grid stability** maintained through over-generation detection and power cutback
- \$5.8M in funding for Stage 1, 2, and 3
- **Generator Emulator Controls (GEC):** Patents pending for advanced platform and control algorithms developed under SEGIS program



# GEC Concept



- DG inverters should behave similar to traditional generators, which have moderate output impedance
- GEC emulates the output impedance of traditional generation
  - Large series inductance, inverse proportional to size
  - Frequency/Watt droop, and amplitude/VAr droop

# Inverter Multi-Mode Operation

- **Legacy Tie**

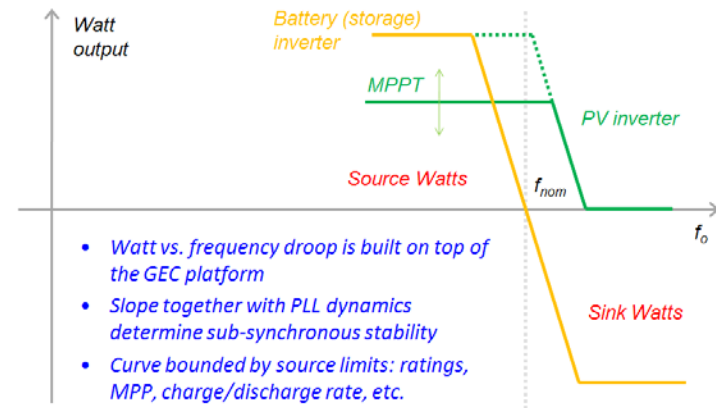
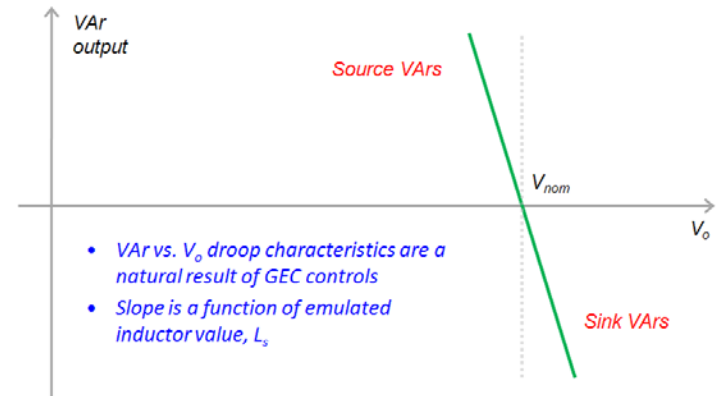
- UL1741-compliant grid-tie operation

- **Smart Tie**

- Voltage Regulation Support
- Programmable voltage/frequency windows
- Low-voltage ride-through (LVRT)
  - Down to zero-voltage, exceeds WECC standards
- Reactive power injection (VARs)
- Power de-rating

- **Islanded**

- Voltage & Frequency Regulation
- Automatic load sharing
- Black Start Support
- Seamless transition to and from grid-tie



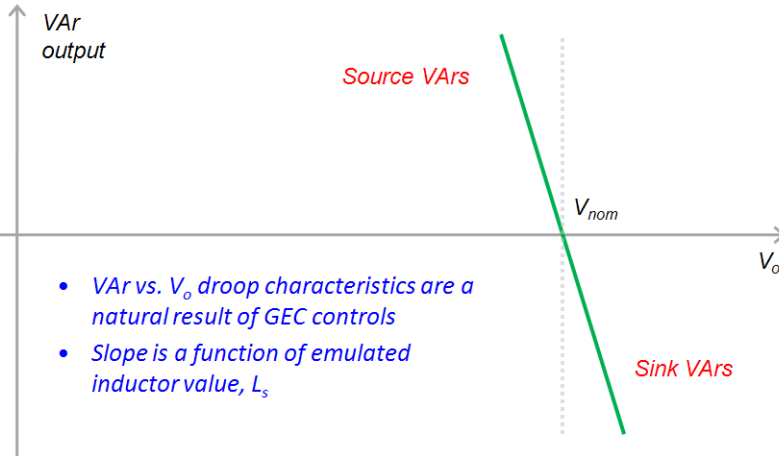
# Power Management Features

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- **Solar Power Conversion**
  - Modular, Scalable Architecture – AC Modules
  - Generator Emulated Controls (GEC) Platform
  - Output Voltages at 120V & 240V; 200W – 240W Power Ratings
- **Ancillary Functions**
  - Automatic (Volt/VARs Droop) and On-Command VAR injection
  - Automatic (Power/Frequency Droop) and On-Command Power Derating
  - Outage Ride Through per Utility Command
  - Electric Vehicle & Storage Integration via AC Coupling Architecture
  - Microgrid Support
- **Communications & Monitoring**
  - Remote Monitoring, Control, and Configuration of Solar PV systems
  - Complete Network Management of Distributed Solar PV and other DER
  - Integration into Smart Grid Communications Networks

# Drop Characteristics

## VAr-Voltage Droop

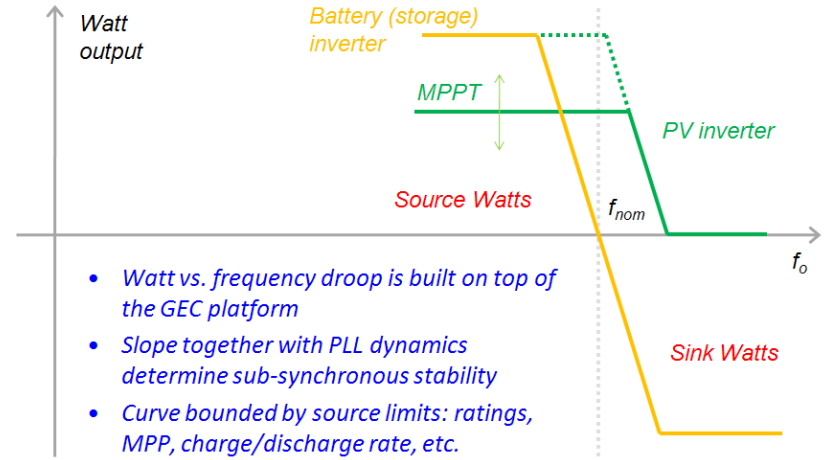


- VAr vs.  $V_o$  droop characteristics are a natural result of GEC controls
- Slope is a function of emulated inductor value,  $L_s$

Output Voltage (V)	Q Expected (VAr)	Q Measured (VAr)
240	-15	-15
245	-30	-26
250	-45	-43
255	-60	-59.4
260	-75	-72
240	-15	-15
235	0	0
230	15	13.6
225	30	24
220	45	39

Vars/Volt: 3VAr's/Volt

## Watt-Frequency Droop

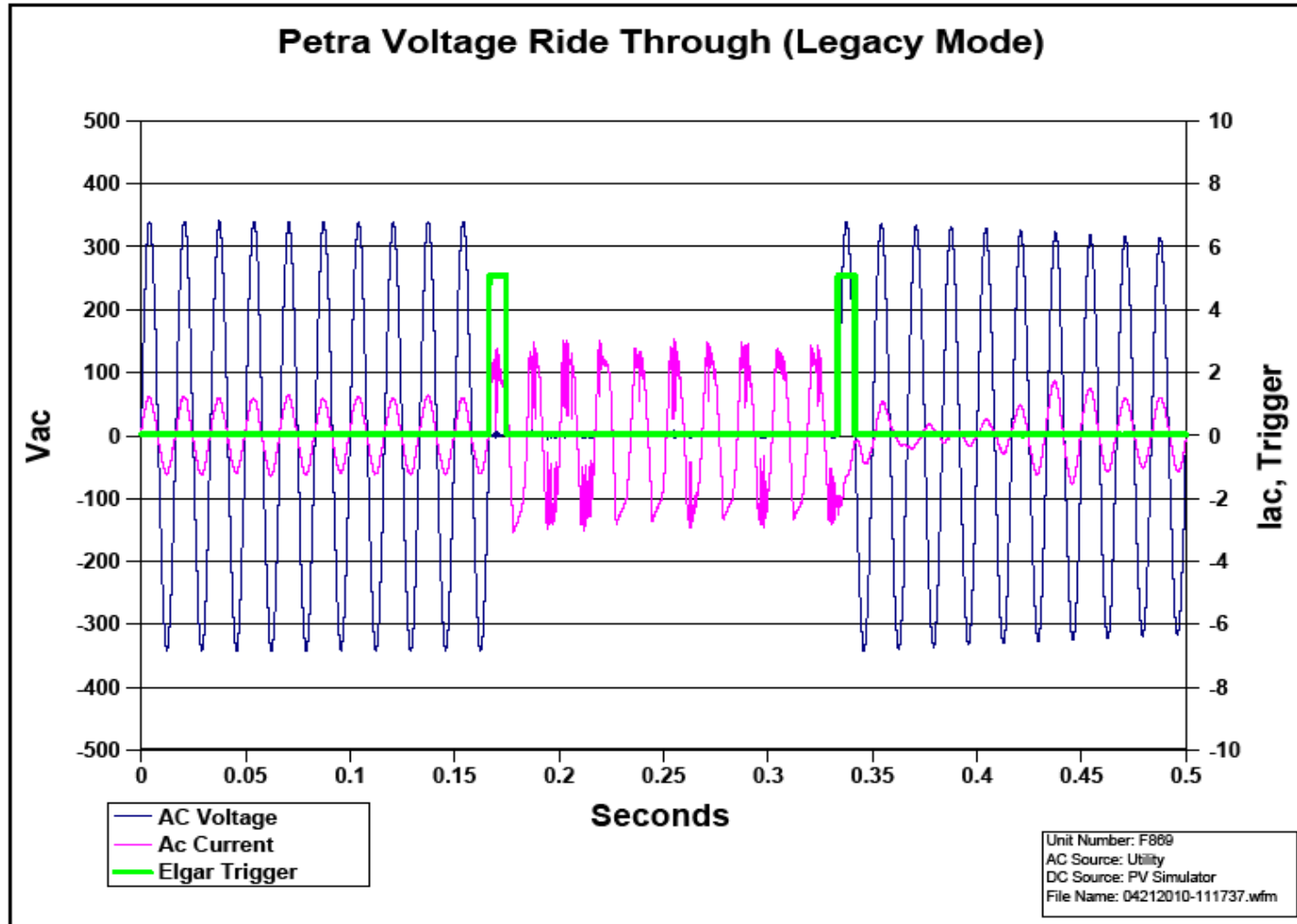


- Watt vs. frequency droop is built on top of the GEC platform
- Slope together with PLL dynamics determine sub-synchronous stability
- Curve bounded by source limits: ratings, MPP, charge/discharge rate, etc.

Output Frequency (Hz)	Power Expected (W)	Power Measured(W)
60.2	200	205
60.4	160	162
60.6	120	123
60.8	80	83
61	40	43
61.2	0	3

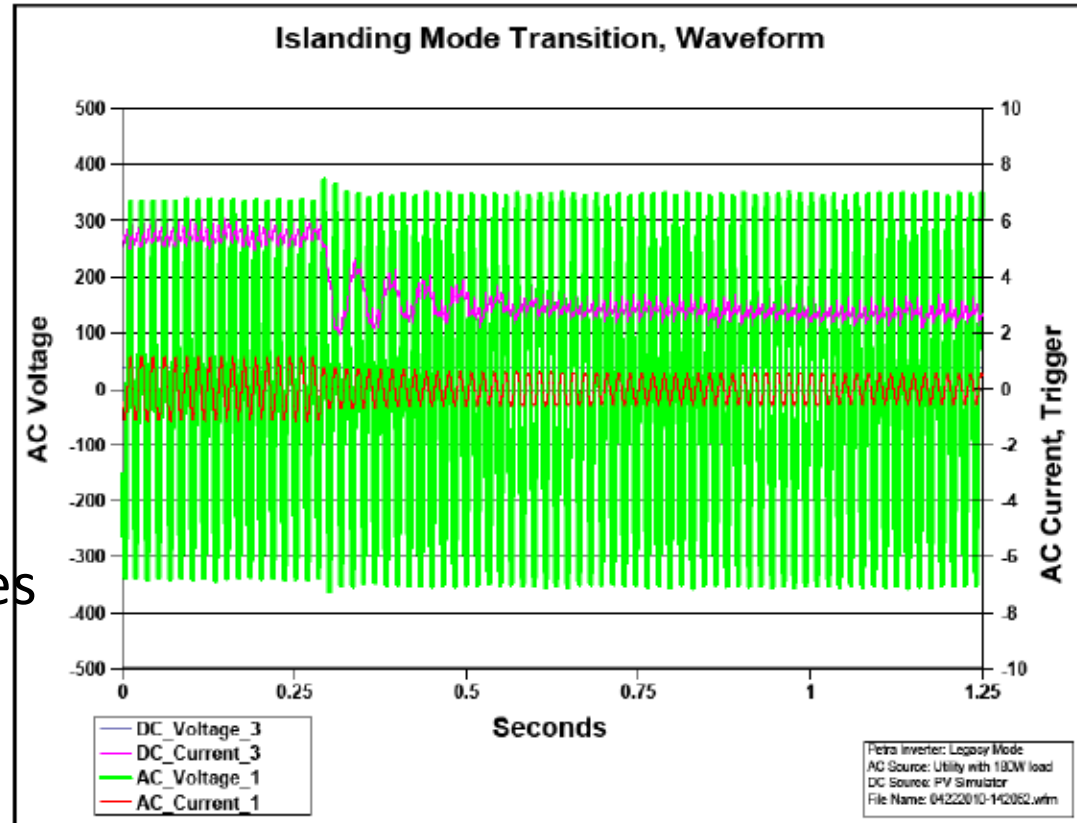
Watt-Frequency: 200Watts/Hz

# 0V ride-through Capabilities

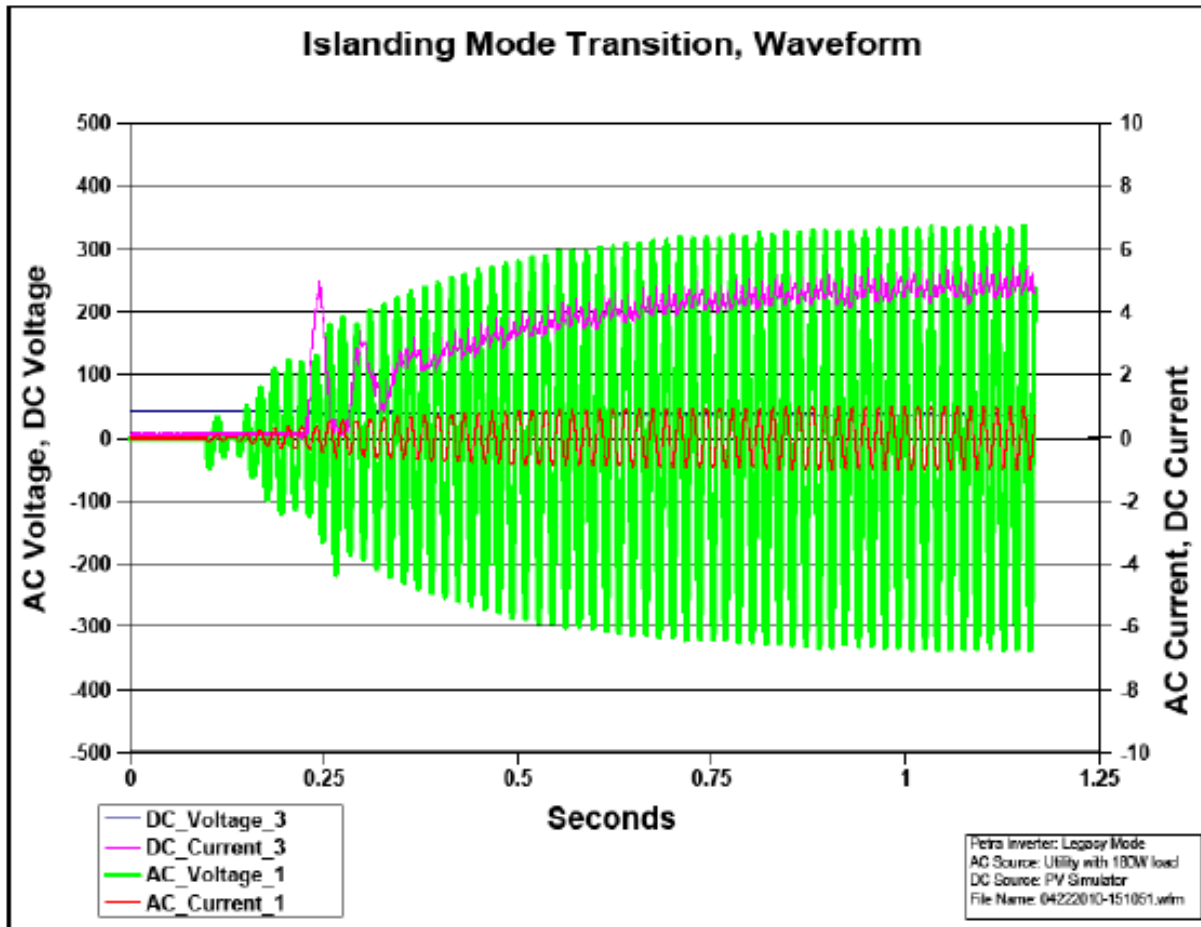


# Transition to Islanded Mode

- 180W Load supported by the combination of the inverter and Grid
- Inverter commanded to enable Smart-Tie mode
- Grid is removed and the Inverter seamless continues to support the load



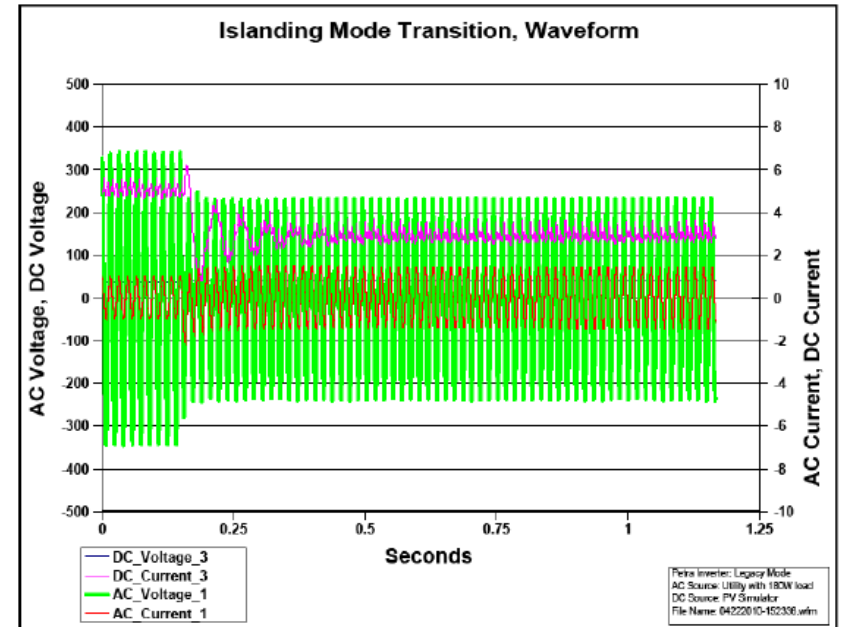
# Black Start



Ability to initiate in a deenergized micro-grid

# VArS Support in Islanded Mode

- 160W Load supported by the inverter in Islanded mode
- Inductive load of 130 VArS instantaneously added
- Inverter support Real & Reactive load without disruption





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**Thank You**



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