SAND2012-0600P

SANDIA NATIONAL LABORATORIES

Distributed Energy Technologies Laboratory (DETL)

APEC-ISGAN Workshop

Smart Grid International Research Facility Network (SIRFN)

January 26, 2012

Albuquerque, NM

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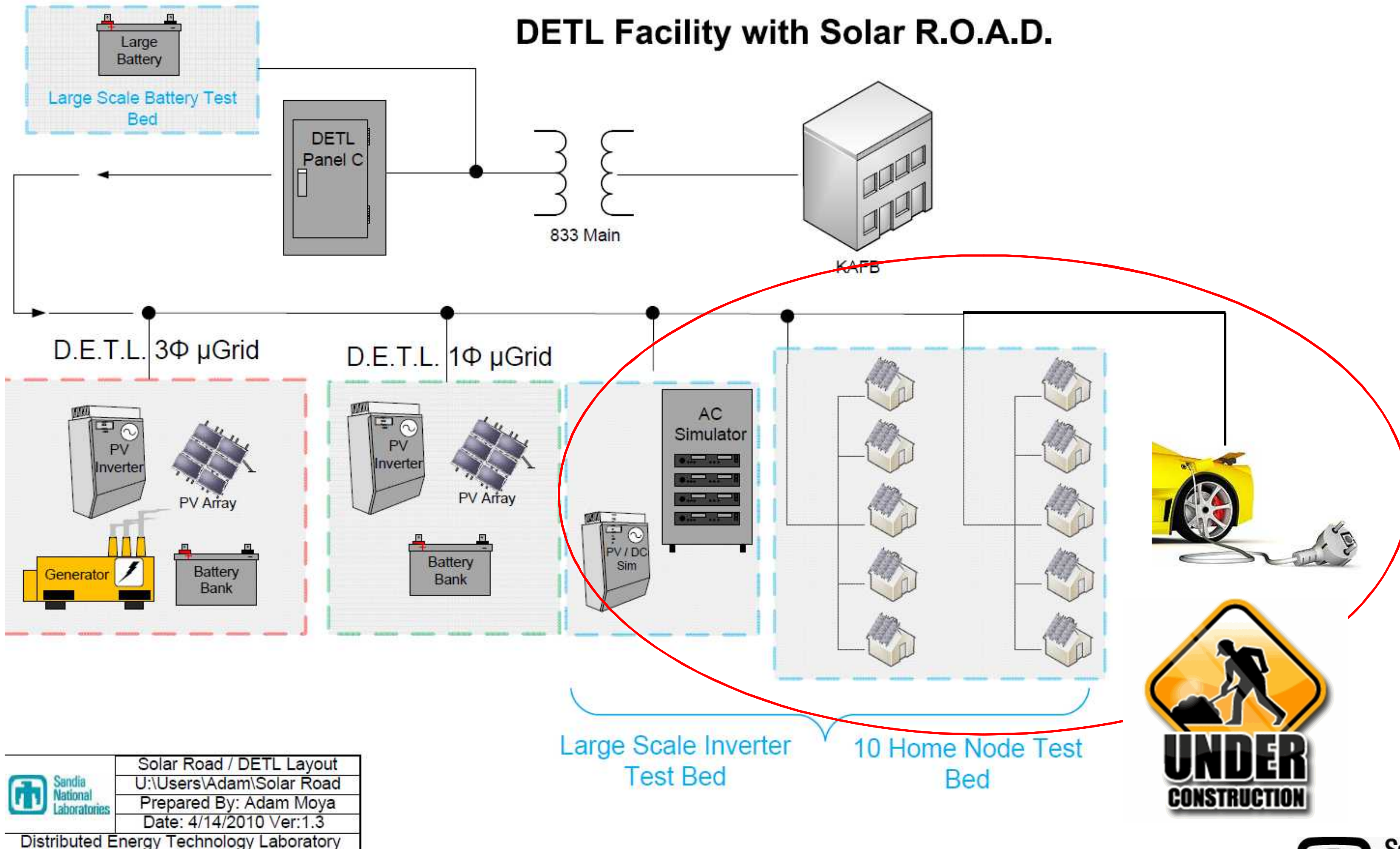
Country/Economy Smart Grid Needs (Testbed Perspective)

Easily reconfigurable infrastructure for a variety of experiments



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High Penetration of Grid Connected Photovoltaics Issues and Concerns

Smart Grid functionality and high penetration of utility interconnected PV systems has invoked concerns about operating within the ranges listed below. Under smart grid, expanded ranges raise concerns about responsiveness to loss of utility.

- IEEE 1547 Voltage and Frequency Tolerance

Voltage Range (% Nominal)	Max. Clearing Time (sec) *
V < 50%	0.16
50% ≤ V < 88%	2.0
110% < V < 120%	1.0
V ≥ 120%	0.16

(*) Maximum clearing times for DER ≤ 30 kW; Default clearing times for DER > 30 kW

Frequency Range (Hz)	Max. Clearing Time (sec)
f > 60.5	0.16
f < 57.0 *	0.16
59.8 < f < 57.0 **	Adjustable (0.16 and 300)

(*) 59.3 Hz if DER ≤ 30 kW

(**) For DER > 30 KW

- Additional disconnection requirements
  - Cease to energize for faults on the Area EPS circuit
  - Cease to energize prior to circuit reclosure
  - Detect island condition and cease to energize within 2 seconds of the formation of an island ("anti-islanding")

Except from IEEE 1547: "The DR shall not actively regulate the voltage at the PCC. The DR shall not cause the Area EPS service voltage at other Local EPSs to go outside the requirements of ANSI C84.1-1995, Range A."

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High Penetration of Grid Connected Photovoltaics

Utility Interconnection standards are finding ways to address the high penetration of a varying ac source.

- 1547.8 Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies For Expanded Use of IEEE Standard 1547
- 1547.4 Guide for Design, Operation, and Integration of DR Island Systems with EPS (Microgrids)

Smart Grid functionality

- Implementation of functionality
  - VRT, autonomous voltage control, scheduled power factor
- Standardization of communication
  - DNP3 ⟶ 61850 ⟶ Hardware
    - Modes of operation
    - Loss of utility
    - Economics

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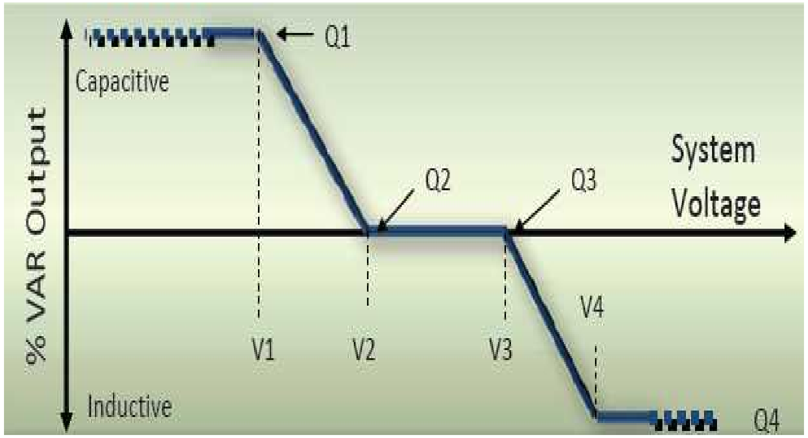
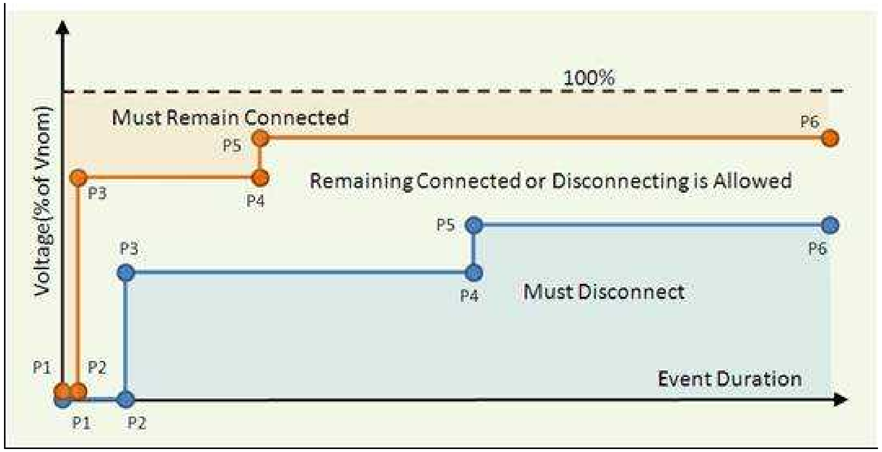
Smart Grid Needs
(Testbed Perspective)

Ability to exercise Smart Grid functionality and evaluate communications necessary for the implementation of the functionality *(DER prespective).*

Volt/Var Compensation



LVRT DER Connectivity



Example: Proposed EPRI/SNL Volt/Var and LVRT Management Functions

Source: B. Seal, "Smart Inverter Communication Initiative Project Overview and Status, 4th International Conference on Integration of RE and DER", Albuquerque, NM Dec 2010

capability under development at the SNL DETL.

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High Penetration of Grid Connected Photovoltaics

Utility interconnection and Smart Inverter evaluations require using equipment that create conditions to exercise "hardware innovations"

Specifications:
Power: 180kVA
Voltage: 0-300 $V_{L\text{-}N}$
Frequency: 16-819Hz
Current: 200A

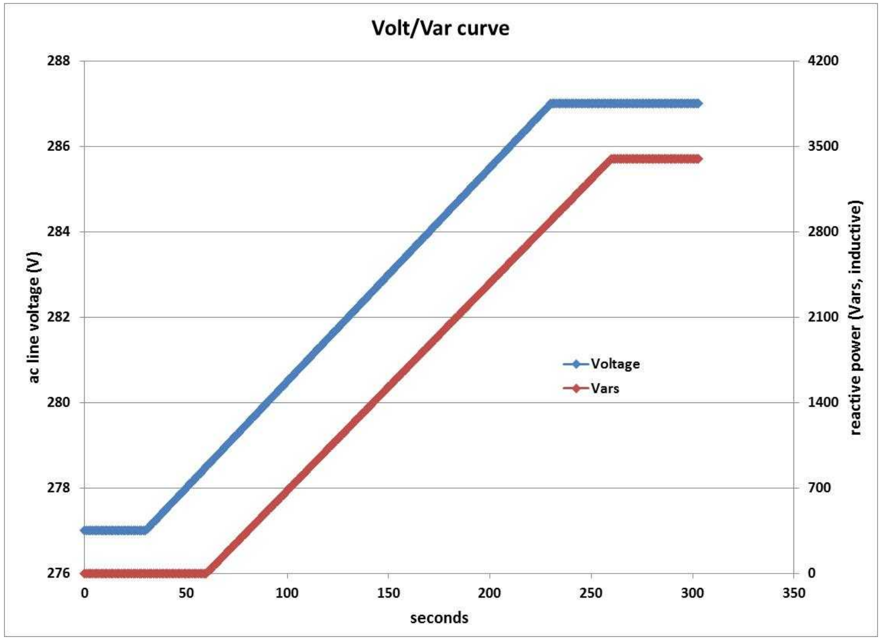
Characteristics:
Crest Factor: up to 3.6
Regenerative Current Sink:

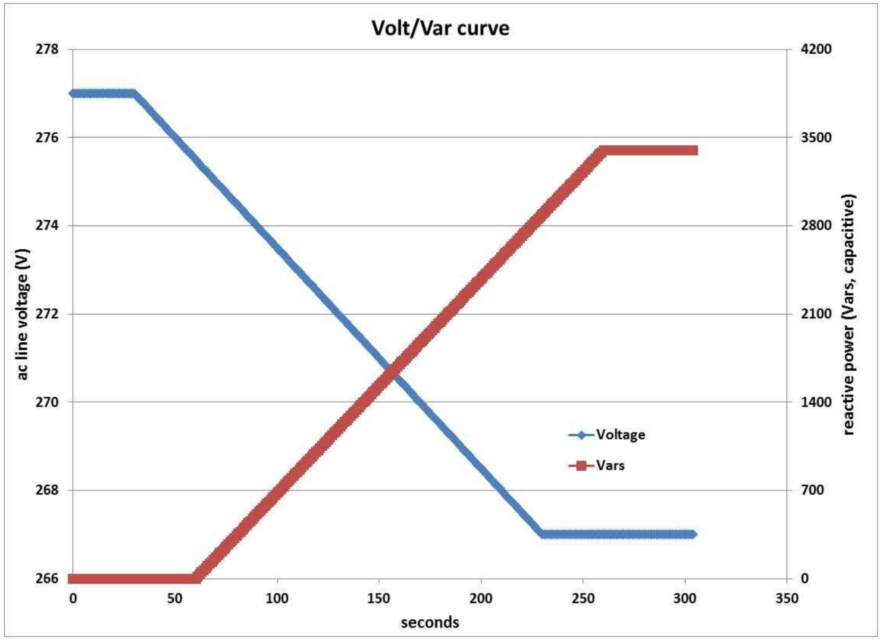
- The –SNK or current sink option enables the RS power source to sink current from the unit under test.

On-board monitoring with high level of accuracy

High Penetration of Grid Connected Photovoltaics

Programmable-regenerative utility simulator allows for voltage sags and surges to be implemented and for monitoring the real and reactive power at the PCC.





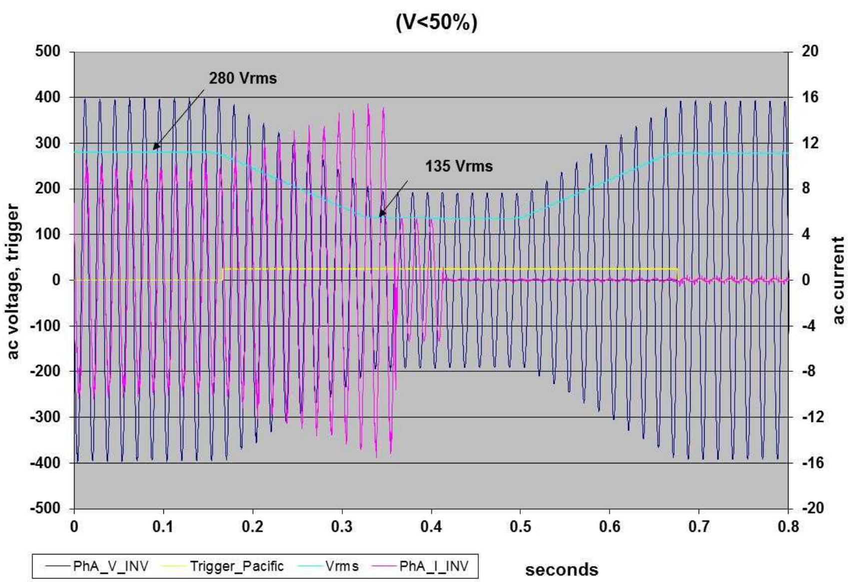
**The voltages (shown in blue) can be programmed and the reactive power (red trace) is the *expected* response.

High Penetration of Grid Connected Photovoltaics

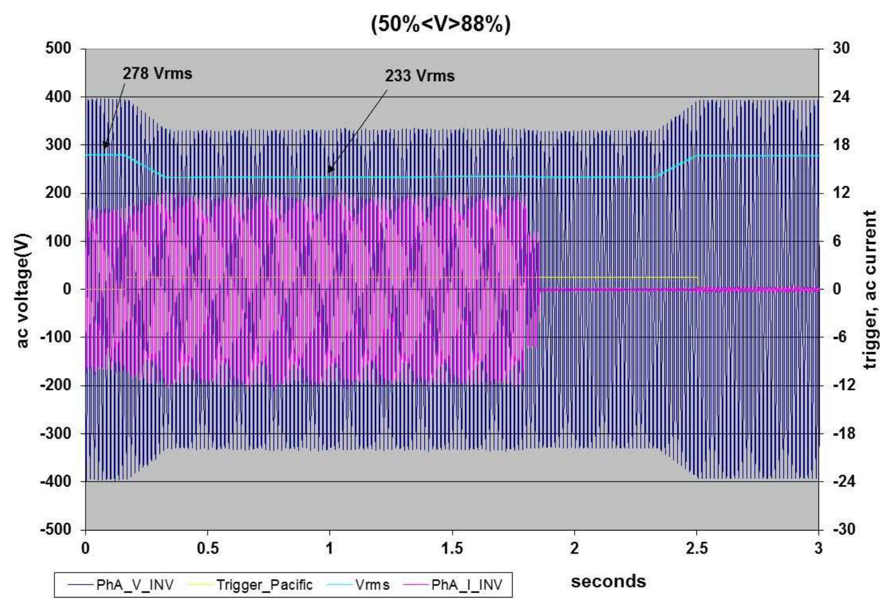
Programmable utility simulator allows for voltage sags and surges to be implemented and document adherence to interconnection requirements.

Below are two test conditions:

- **V<50% of nominal, required response time is 10 cycles (167mS)**
- **50% < V > 88% of nominal, required response is 120 cycles (2 seconds)**



For a voltage sag of V<50% of nominal, the required response time is 167mS. Proposed LVRT curve does not violate this requirement.



For a voltage sag of 50%<V>88% of nominal, the response time is 2sec. Example shows good utilization of disconnect time to minimize nuisance trips.

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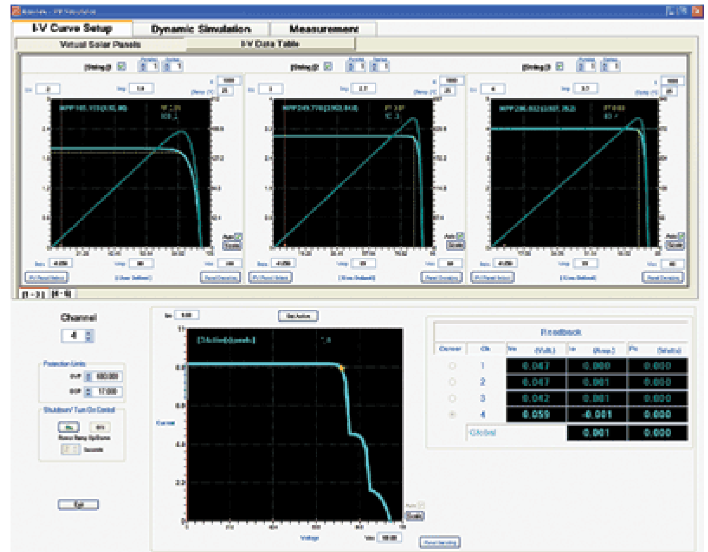
High Penetration of Grid Connected Photovoltaics

Utility interconnection and Smart Inverter evaluations require using equipment that create the conditions that have lead to "hardware innovations" and exercise these enhancements .



Specifications:
Power: 200kW (20 outputs, 10kW each)
Voltage: 0-1000 Vdc/output
Current: 10A/output

Characteristics:
Individual I-V curve characteristics per output.
Outputs can be combined to mimic poor performing string.
Ideal MPPT evaluating source

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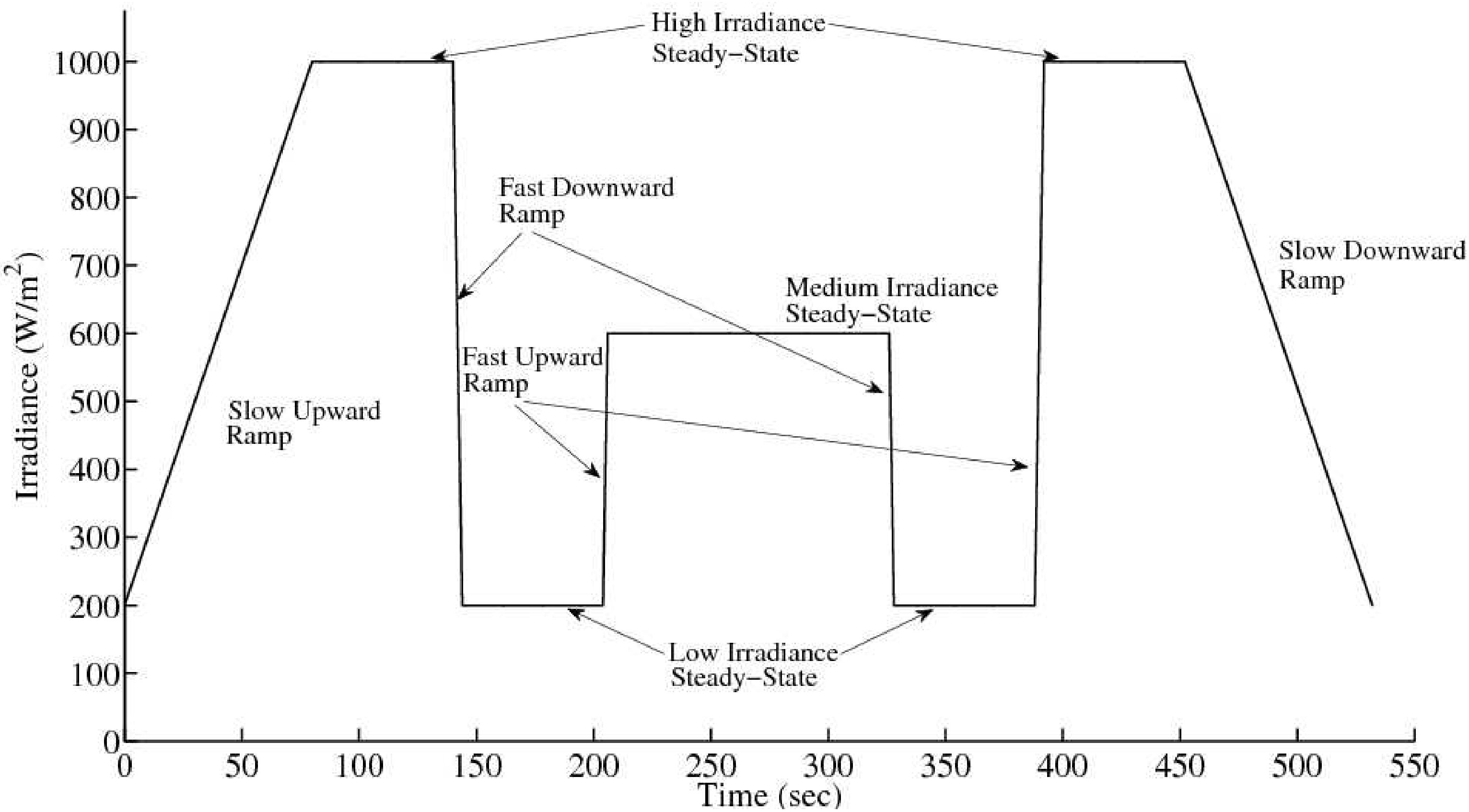
High Penetration of Grid Connected Photovoltaics

Inverter energy harvest capabilities can be quantified by documenting the response to dynamic irradiance conditions as shown below..



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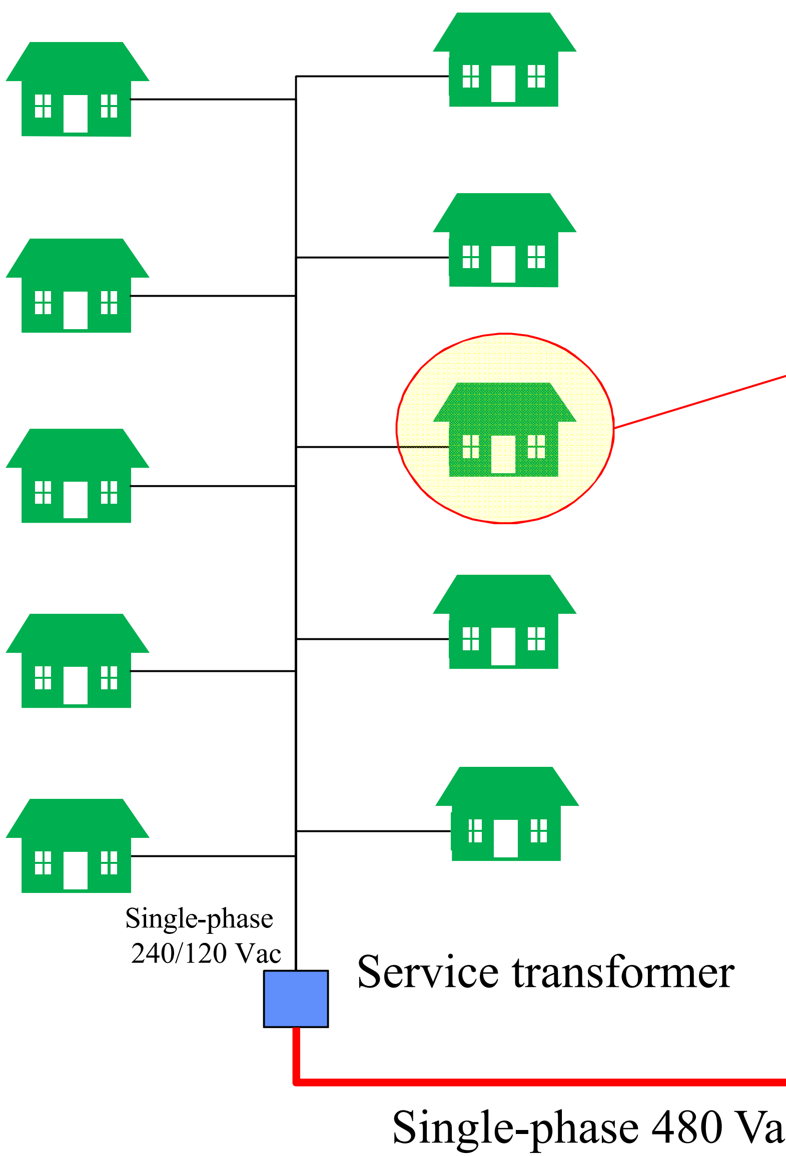
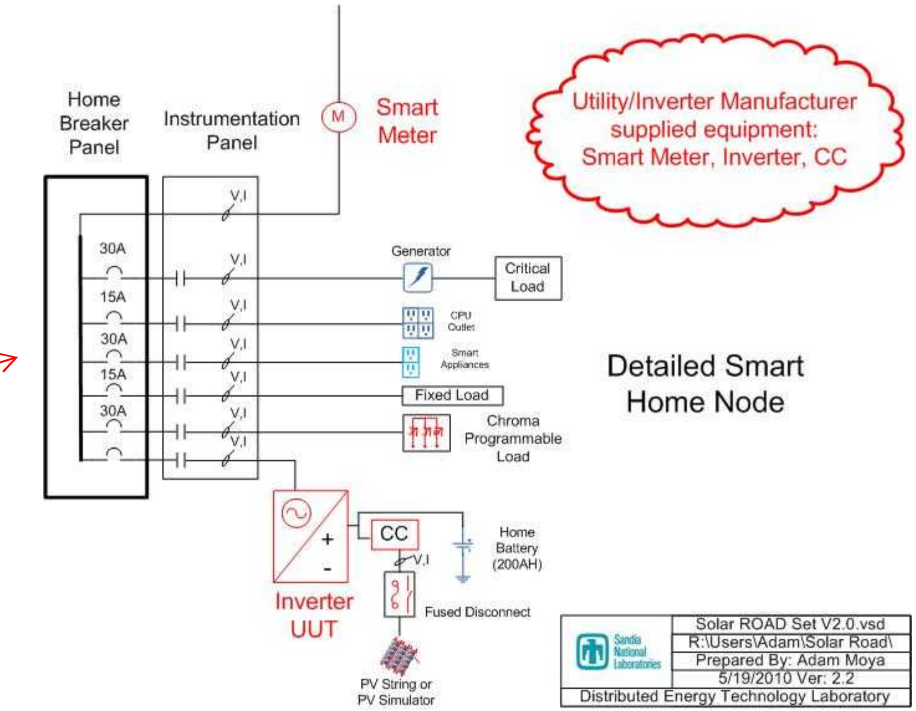
Solar Reconfigurable Open Architecture Design (ROAD)





- Replicate high PV penetration at residential scale
- Full flexibility at each node
    - PV system
    - Energy storage
    - Programmable loads
    - Smart Meter
    - Utility/Home EMS

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Slide 11

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s4 Single-phase lateral is 480 Vac
There are two 5-home circuits and each circuit has 4 PV grid tied homes and 1 PV/battery grid tied home.

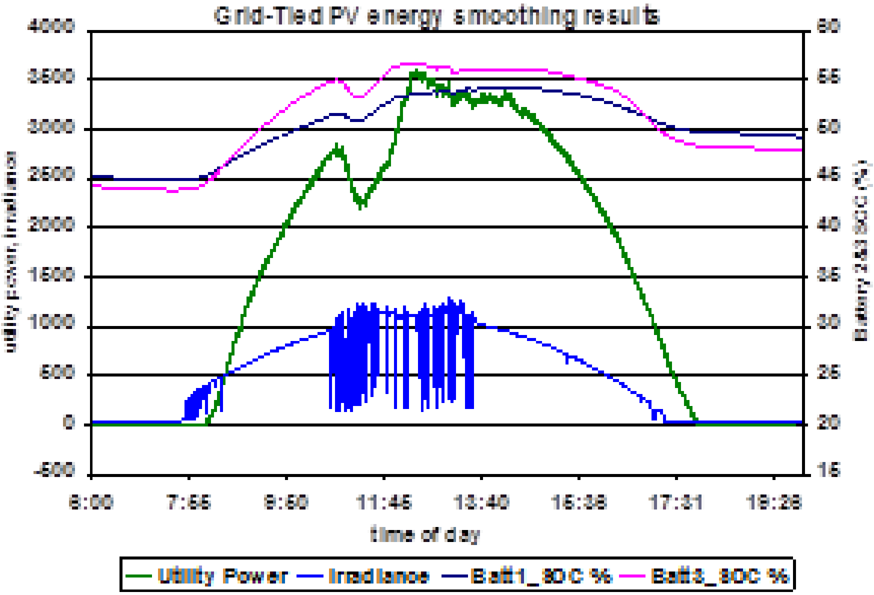
Both circuits have there own Xfmers but can be tied together as shown below. Service transformer is 100kVA 480:240/120 (FYI)

sgonza, 1/11/2012

Smart Grid Needs

High Penetration of Photovoltaic utility interconnected systems has led to requirements beyond the traditional mode of operation.

***Shown here is the hardware used to implement a power smoothing algorithm designed to address the intermittency of the power that is prevalent during cloudy conditions.**



The battery smoothing technique requires a battery technology suited for partial state of charge operations. This allows energy to flow into and out of the battery as needed to optimize the smoothing function. Peak shifting is a attribute of this method of power smoothing.

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Conclusion

International Collaboration needs for Global Markets

- DETL works with many industry partners interested in global markets
- Advances in power electronics are taking place across the globe – access to latest in new developments
- Greater knowledge/understanding of standards and protocols from other parts of world can facilitate in-country development
- Development and operations of test facilities can benefit from knowledge of testbed innovations in other countries