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SEGIS and the SMART GRID

Ward Bower; SEGIS Project Manager
Sandia National Laboratories

for SEGIS Seminar, 2011

References:
http://www1.eere.energy.gov/solar/systems_integration_program.html
http://www.sandia.gov/solar/
http://www.sandia.gov/segis/

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Acknowledgements
SNL SEGIS Key Program Team Members

	Project Technical Specialty
Ward Bower	Project Lead and White Paper
Chris Cameron	White Paper and Economic Analysis
Sig Gonzalez	DETL Power Hardware Validations
Abbas Akhil	Energy Storage and Micro-grid
Scott Kuszmaul	Software, Firmware and Communications
Lisa Sena-Henderson	Web Sites, Webinars, Graphics, Follow-on Demonstration Monitoring/Communications
Carolyn King David	Contracts and Legal Communications

Specialties are listed but all participated in program logistics that included Request for Information, Request for Proposal, Selection Criteria, Proposal Reviews, Selection Committee, Critical Design Reviews, and many other logics, monitoring etc.

THE STAGE 3 SANDIA SEGIS TEAM

Introduction

- **SEGIS Project and Smart Grid Discussion**
- **What's Changed/Barriers**
- **SEGIS Awards/Advances**

  Added Value, Performance, Economics, Manufacturability, Lifetimes, Communications, Safety

- **Where We Are Today**
- **Public Aspects and Impacts of the SEGIS Projects**
- **Focus for the Future**

Smart What? Smart is Everywhere!

"Smart" Grid
"Smart" Car
"Smart" Phone
"Smart" Appliances
"Smart" Thermostat
"Smart" Windows
"Smart" Televisions
"Smart" Card
"Smart" Energy
"Smart" Goals
"Specific,Measurable,Attainable,Realistic,Timely
"Smart" >>>>> "YOU NAME IT"

"Smart" Barriers

Survey sees lag in interest for 'Smart' grid
By STEVE EVERLY
The Kansas City Star
Development of a "Smart" Electric Grid to distribute power more efficiently is facing a big obstacle: "Indifferent Utility Customers"

Report: Smart grid could cost **$476B**
Rick Merritt
5/24/2011 11:43 AM EDT
SAN JOSE, Calif. – Costs and benefits of building a smart electric grid have more than doubled as the vision of a digital, networked power utility has expanded, according to a new report from the Electric Power Research Institute.

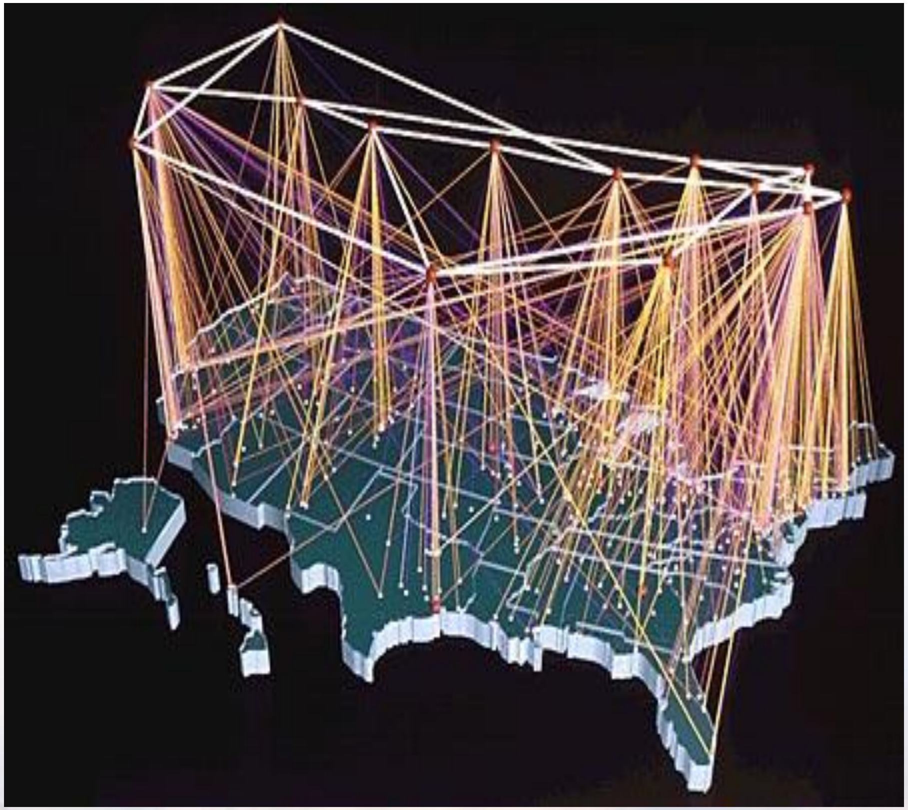
"….estimates did not include enabling plug-in electric and hybrid vehicles, renewable energy sources, grid-scale energy storage, distributed generation and demand response applications that let consumers adjust energy use based on changing energy prices."*

***Also didn't talk about "Energy Management and Conservation**

The Smart Grid Functionalities Apps Will Begin as Autonomous Capabilities

BUT LOOK AT WHAT IS COMING

- **Why – What – When?**
  - Communications Protocols
  - Communications Surety
  - Communications Costs
  - Communications Compatibility
  - Communications Reliability
  - Communications Speed
  - Communications Feedback
  - Communications Lifetimes



K.I.S.S.

Keep it Simple Stupid

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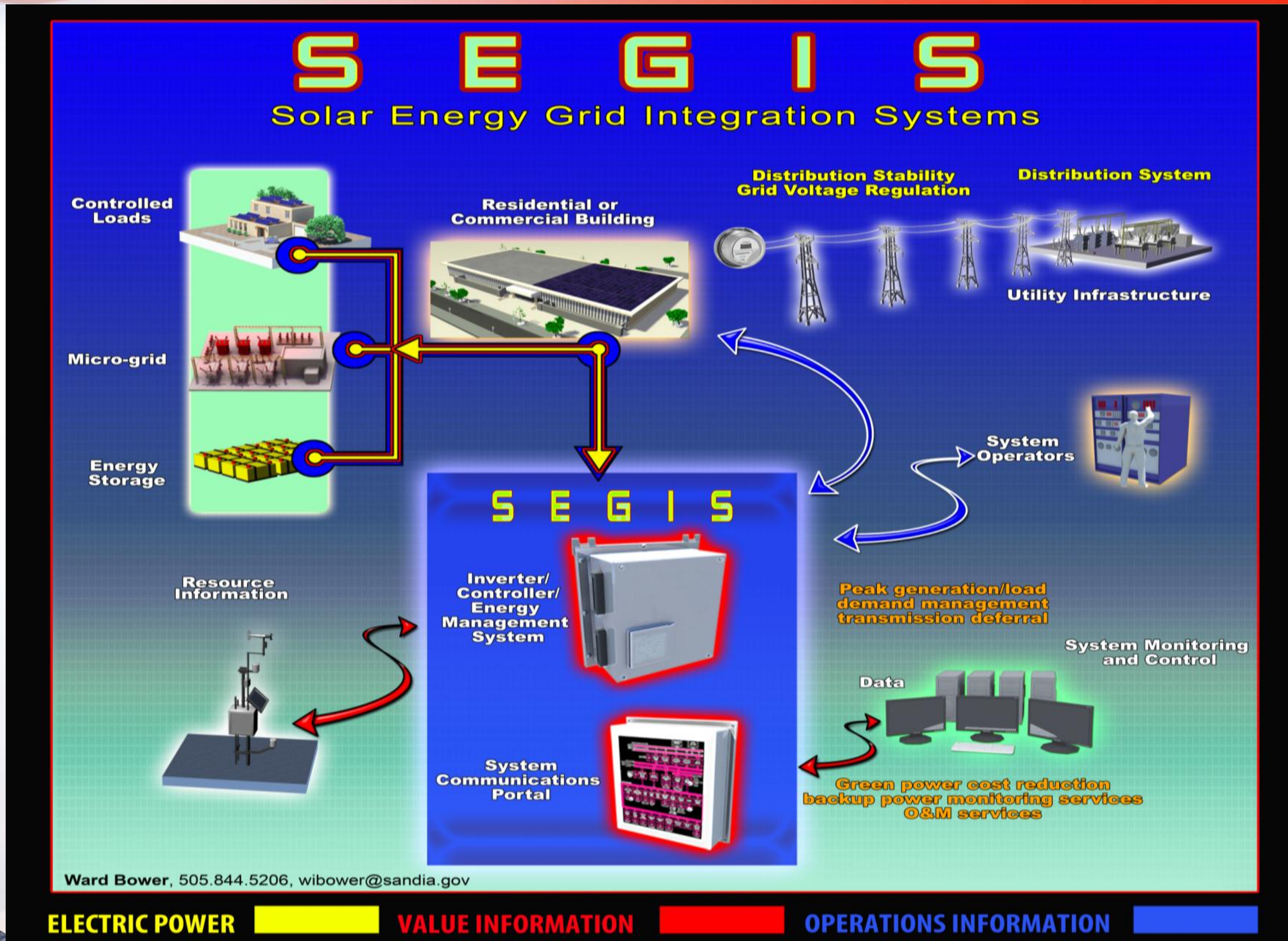
SEGIS is the First SETP Step Toward Intelligent PV Grid Integration



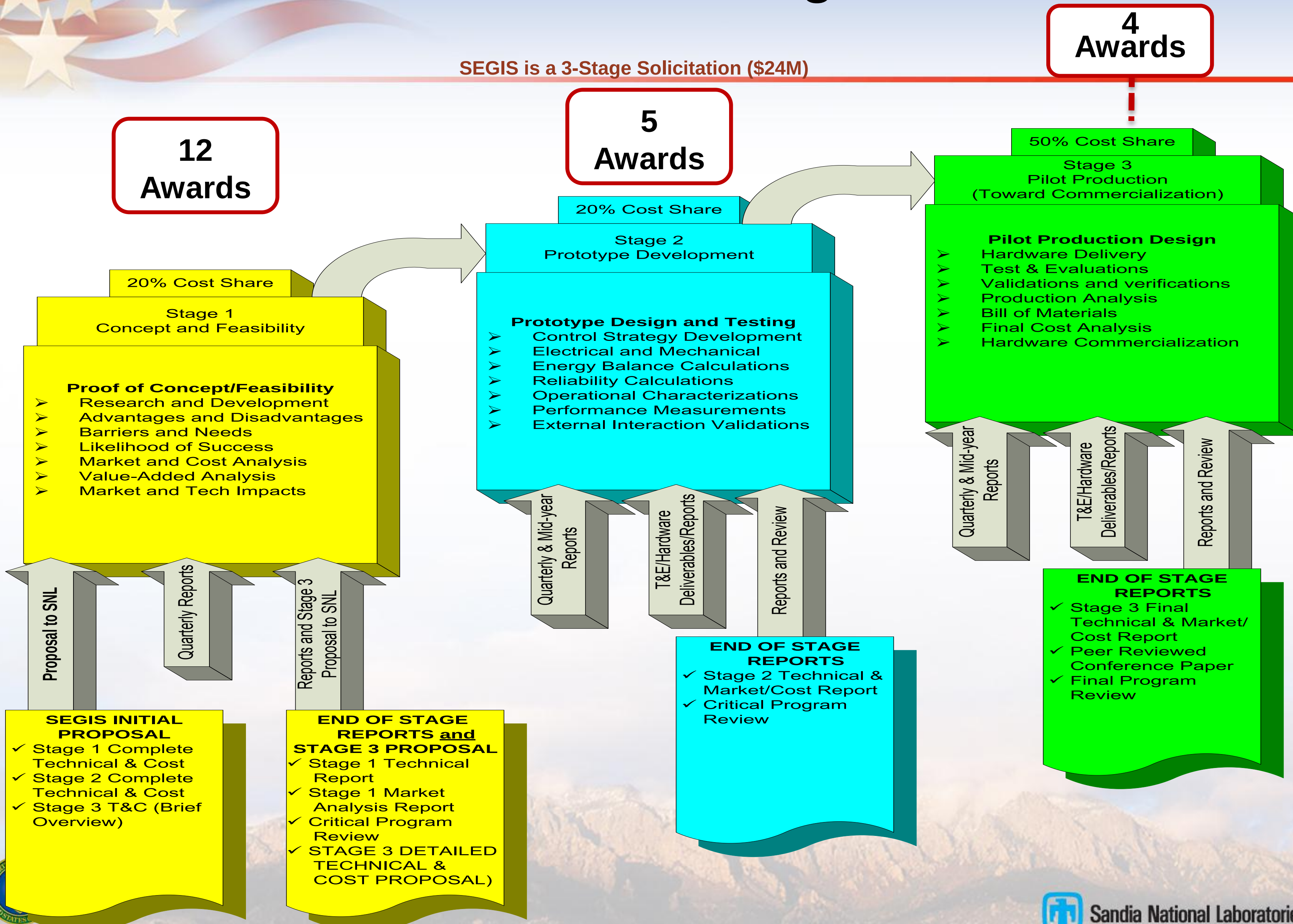
What is Changing?
Many Challenges and Barriers Remain

SEGIS –
SEGIS AC

SEGIS Challenges and Goals Set in 2008 for the SEGIS Solicitation

- ***SIGNIFICANTLY*** **Advance Inverters, Controllers & Energy Management Systems to maximize value to Utilities and Consumer**
- **Scope**
  - PV Systems for High-value Residential and Commercial Applications (100W – 250kW)
  - PV Systems using Advanced Energy Management, Utility Interaction, Technology Advances and Communications
  - Building Energy Management + PV Systems AND Hybrid/Micro-grid Applications that Utilize Energy Storage
  - Did NOT Include Development of PV Cell/ PV Module or Energy Storage Technology.

SEGIS Stages & Time Table



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Petra Solar: Economically Viable, Highly Integrated, Highly Modular SEGIS Architecture

Technologies Addressed

Smart Grid Interconnection, System Cost, Modularity, System Reliability, Safety, and Advanced Scalable Inverters. AC PV modules aimed at utility ownership and control.

Description

Smart Grid Interconnection, System Cost, Modularity, System Reliability, Safety, and Advanced Scalable Inverters. Low cost, easy-to-install, modular/scalable inverter architectures. Advances in multi-layer control, communications, monitoring and controlling a cluster of AC module inverters, and a strategic EMS switch junction box.

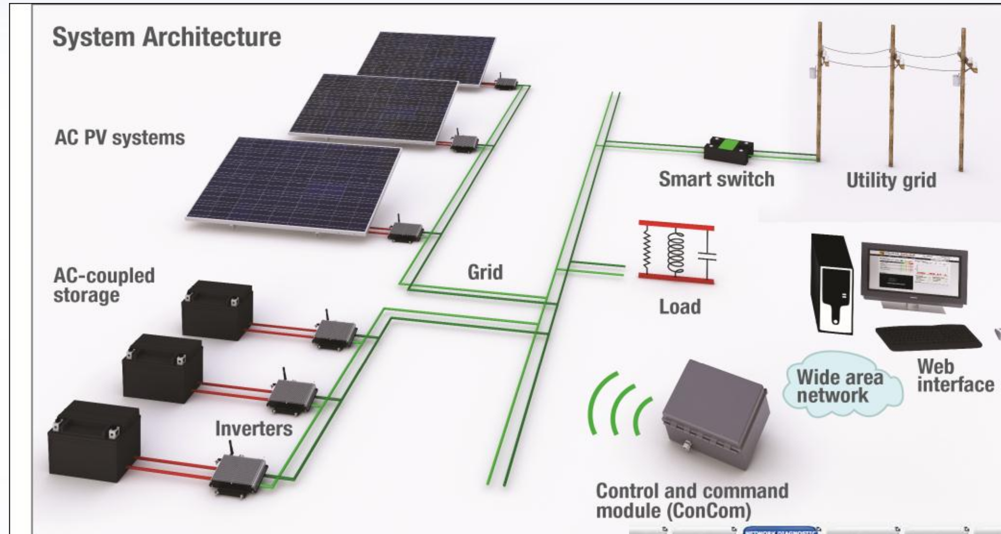
Advances

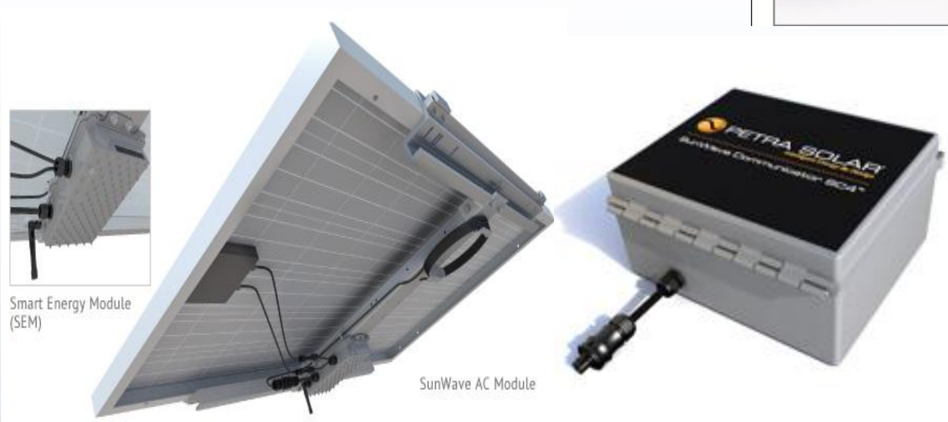
New circuits to add a new 240V SEGIS system to 120V models. All functionalities operated in prototype testing, communication advances progressive, meets UL today AND transitions from legacy to SEGIS mode. Potential to greatly improve cost and reliability with advanced integrated circuits. No thermal issues. Stated a utility marketing plan with partners ID'ed for demo. US manufacturing in place and expanding.

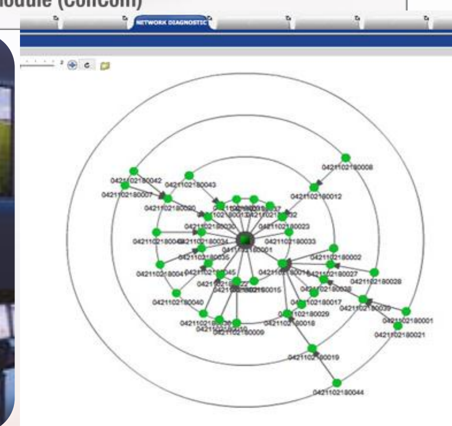
Participants

Petra Solar, Florida Power Electronics Center, Florida Solar Energy Center, Lakeland Electric, Echelon, PSE&G, First Energy, Pepco Holdings

Petra's Futuristic Role for PV and DG







Princeton Power: Demand Response Inverter

2011 R&D 100 Award Winner for the DRI

Technologies Addressed

Demand Response Inverter, Load Control, Energy Storage, High Efficiency Components, Grid Integration. Simultaneous multi-port operation for load and resource controls.

Description

Demand Response Inverter, Load Control, Energy Storage/Management, New High Efficiency Components, Grid Integration. Design a new 100-kW inverter based on Princeton's unique inverter technology. Optimize for low-cost, high-quality manufacture, integrated control capabilities with dynamic energy storage and demand response through generation and load control.

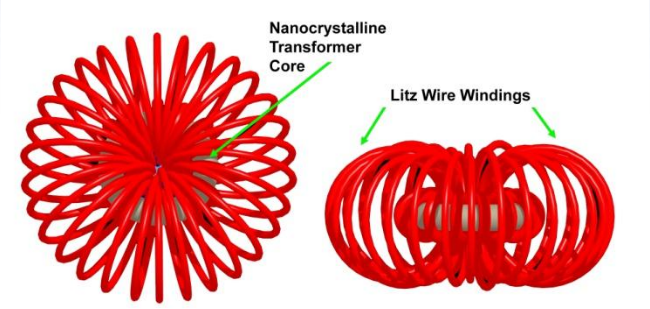
Advances

Innovative 4-port demand-response inverter topology w/smart functionality, central resonant link galvanic isolation alternative to transformers, nano-crystal magnetics & central capacitor long-lifetime self healing capacitors resulting in a smaller, much lighter inverter. Demonstrated simultaneous 4-port control of demand response/multi-generation inverter system w/galvanic isolation. System provides flexibility for energy management/micro-grids. ID'ed partners for demonstraton.

Participants

Princeton Power, TDI Power Corp., Gaia Power Technologies, PSE&G, Virginia Tech Center, International Battery, Inc., United Silicon Carbide, Inc., Process Automation.

Princeton Power Hardware Deliverables



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PV Powered: Maximum Power Point Tracking, Advanced EMS, Advanced Communication, Utility Integration

Technologies Addressed

Optimized Performance Algorithms, Advanced Data Collection, Communications/Energy Management Systems(EMS), Optimized MPPT, Advanced String Monitoring, BEMS.

Description

New maximum power point tracking (MPPT) algorithms to optimize energy harvest for all available and emerging PV technologies. Develop components, smart string combiner hardware, and BEMS to optimize system performance, value and safety. Integration of multilevel communications with facility energy management systems and utility grid management networks.

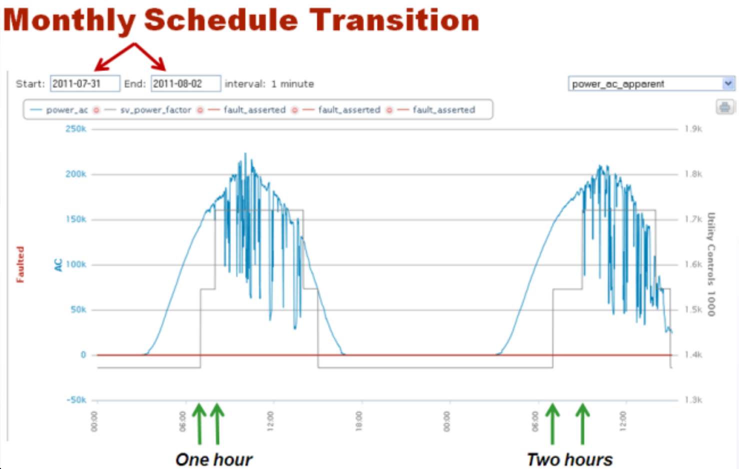
Advances

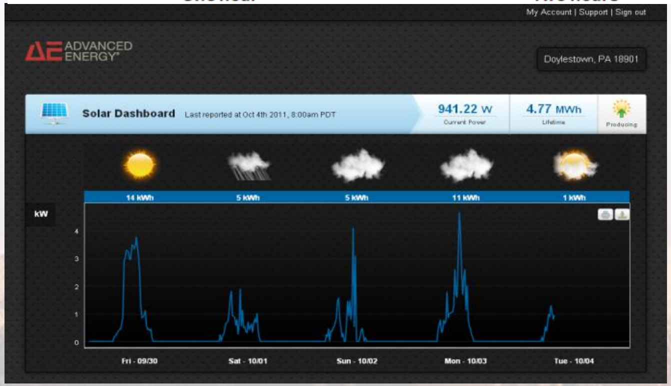
MPPT enhancements promise optimize energy delivery. Major commercially available EMS, string level monitoring-meter string currents and disconnect, advanced utility communication and unique use of synchro-phasors shown feasible, and a platform integration/database. Manufacturing/demo sites are ready & partners ID'ed. Plans for SEGIS in product line in progress.

Participants

PV Powered, Portland General Electric, Northern Plains Power Technologies,
Schweizer Engineering Laboratories (SEL), Sensus

AE/PV POWERED Hardware Deliverables





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Florida Solar Energy Center at UCF / Satcon: Development, Validation and Commercialization of Grid-Smart Inverters for Wider PV Technology Utilization

Technologies Addressed

Utility Control of Enhanced Inverter Features, Disturbance-tolerant Anti-Islanding, Shared Inverter, Energy Storage, Building Interaction

Description

Develop new concepts and enhance "Smart Grid" interconnections. Develop "Shared" inverter/controls that serve multiple PV arrays. Include battery storage, utility control, communication, monitoring, and building energy management systems (BEMS). Develop interactive "anti-islanding" strategy keeping PV on line during when necessary.

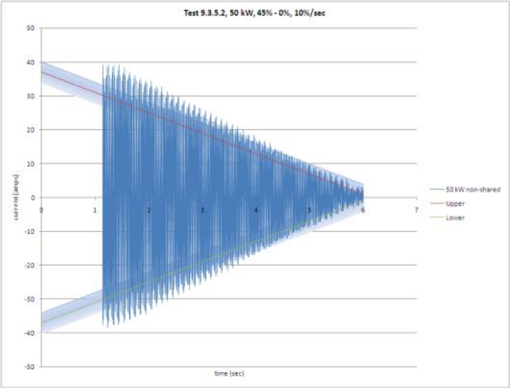
Advances

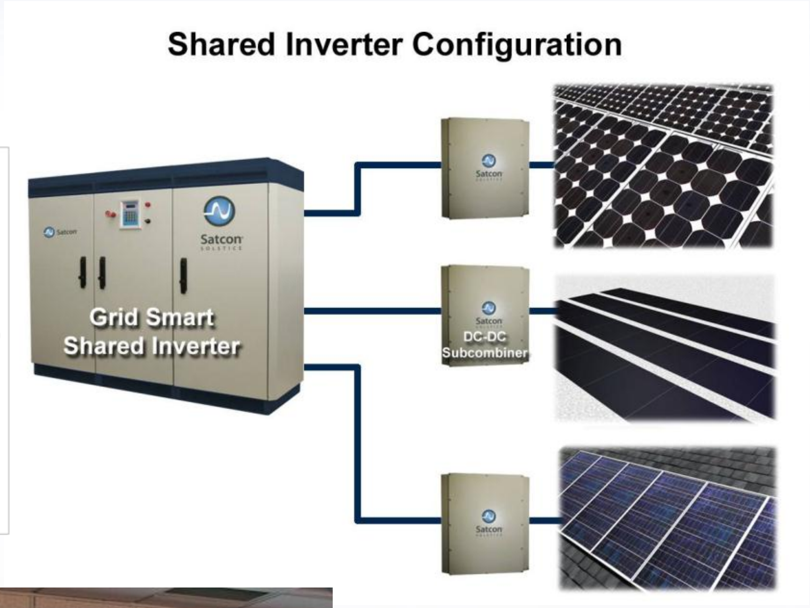
PV emerging into smart grids with utility controls of islanding and under voltage ride thru. Dc-dc conversion and dc bus adds flexibility for energy storage and micro-grid. The string combiner can improve performance, safety and reliability while enabling mixed PV technologies, optimal energy harvest, reduced BOS costs, and optimal inverter performance. Utility permissive control allows LVRT, VAR sourcing, constant PF control. Demo plans in place with ID'ed partners,

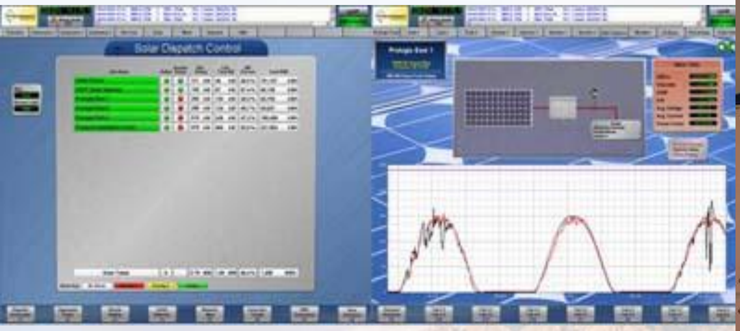
Participants

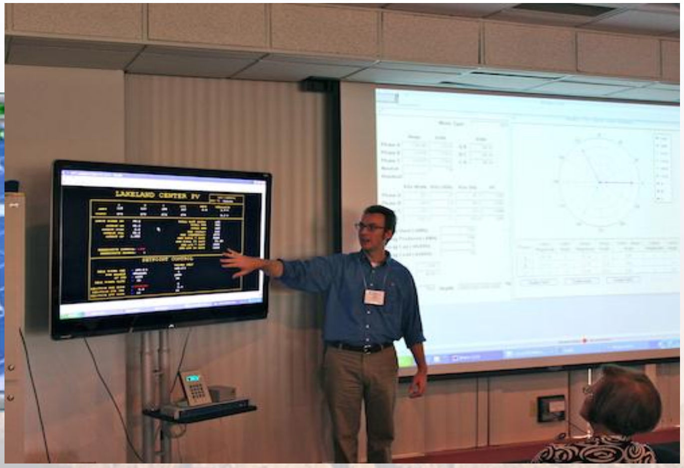
UCF/FSEC, SatCon, Sun Edison, Northern Plains Power Technologies, Lakeland Electric, Cooper Power Systems EAS, SENTECH Inc.,

FSEC/SATCON Deliverables

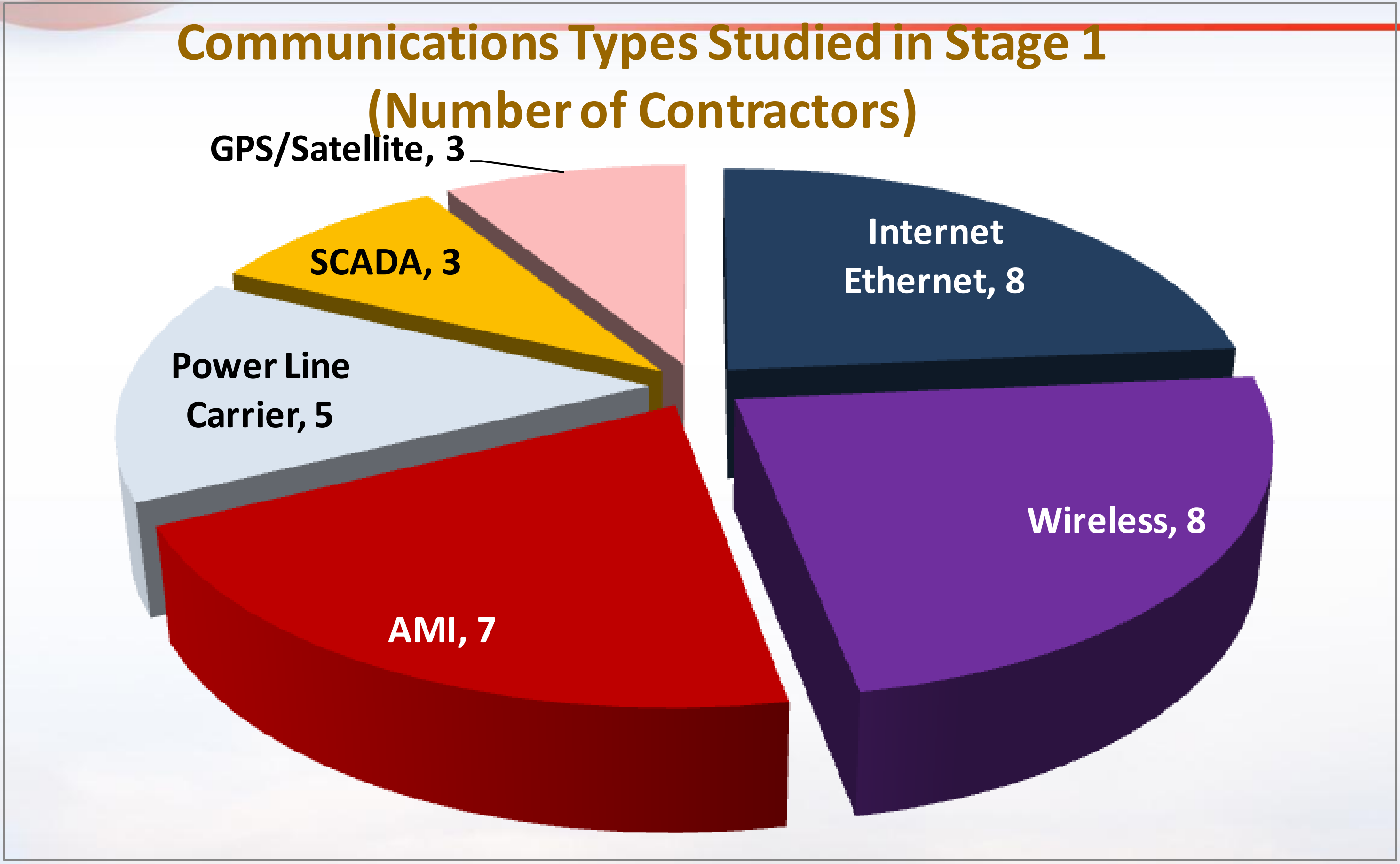








SEGIS Contractor's Communications Studies



Communications Method Studied Does NOT Mean It Was Selected as a Preferred Method
Numerous Communications Pitfalls and Incompatibilities were Uncovered
Communication Levels from Internal Controls to Utility Interactive Controls
Speed of Response and Communication Reliability Are the Main Issues

SEGIS is Addressing Maximum Power Point Tracking & Intermittent Power Production

Potential Issues for Intermittency, String Combiners, MPPT, System Stability
25MW DeSoto PV Pland, Arcadia, FL

SEGIS Advanced Component Developments and Applications

- Integrated Communications
- Micro-grid Controls & AMI
- MEMs & SiC Applications
- Diagnostics/Gateways
- Interactive Monitoring/Control
- Innovative Packaging
- Thermal Stress Management
- Internal Protection/Longevity
- Predictive/Adaptive Operation

Important "Smart Grid" SEGIS Advances

- **Systems Integrations**
- **Smart String Combiners**
- **DC Bus for Multi-source Energy**
- **VAR Support**
- **Maximum Power Point Tracking**
- **Low Voltage Ride-thru Functions**
- **Performance Predictions**
- **Intermittency Mitigation**
- **Component Utilization**
  - Nano-crystalline magnetics, Film Capacitors, Integrated Circuits, Custom ASICs, Smart Switches, Control Packages
- **Communications Integration**
  - Synchrophasors, Mesh Network, PLC, Wireless,
  - Data Collection and Advanced Analysis

Important “Smart Grid” SEGIS Advances

- **Power Output Curtailment**
- **Anti-Islanding and Intentional Islanding Controls**
- **Micro-Grid Enablement**
- **Energy Management/Storage**
- **Building Energy Management**
- **Performance/Economic Optimizations**
  - **Utility support (Value Added)**
  - **System Optimization (Economics)**
- **System Monitoring an d Data Analysis**

A CRITICAL WAKEUP CALL- New to SEGIS
Arc-Fault Detection and Interruption

690.11 Arc-Fault Circuit Protection (DC).

PV systems with dc source and/or output circuits on or penetrating a building operating at a PV system maximum system voltage of 80 volts or greater shall be protected by a listed (DC) arc fault circuit interrupter, PV type, or other system components listed to provide equivalent protection.

The PV arc-fault protection means shall comply with the following requirements:

(1) The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the dc PV source and output circuits.

(2) The system shall disable or disconnect one of the following:

- **a. Inverters or charge controllers connected to the fault circuit when the fault is detected**
- **b. The system components within the arcing circuit**

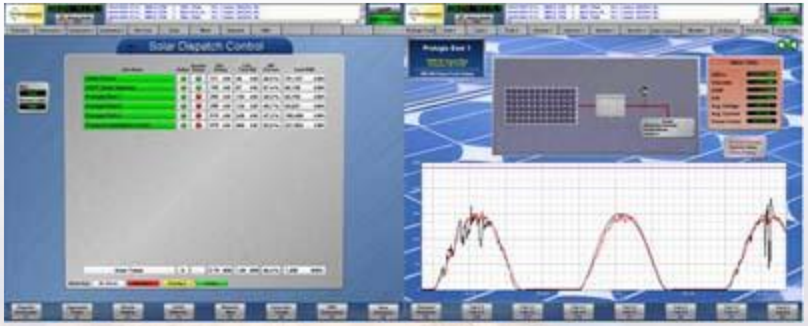
(3) The system shall require that the disabled or disconnected equipment be manually restarted.

(4) The system shall have an annunciator that must be manually disabled.

Impacts and Public Aspects of SEGIS

- New System Architectures Increase Types/Numbers of PV Applications
- Utility Dispatch Makes PV Look Like a Generator, NOT a Negative Load
- Utility Needs are Being Addressed
- Communications Add Value for Owner Economics and Utility Grid Stability
- Developments are Validating the Sanity of New Interconnect Standards
- System Integrations Improve Reliability and Functionality

Smart String Combiners



Dispatch and Monitoring Permissive links

Focus Points for the Future

- **Conduct Coordinated Teaming Projects that BRING the Collective Expertise of Utilities, PV Module Manufacturers, BOS Manufacturers, Academia and Communications Experts TOGETHER with a COMMON Goal.**
- **Enable Sustained Acceleration of PV Grid-tied Installations**
  - PV System Sizes Ranging from Micro-inverters - Large Commercial Installations with Expandability keeping $1/W as a new goal
  - Intelligent PV-Grid Interoperability (Higher Penetration) Advances
  - PV System Integration for:
    - PV System Performance Enhancement
    - Value Added for Improved Economics to Owners and the Utility
    - Features that Improve Manufacturability/Reliability/Lifetimes
    - Integration of Advanced Safety Features (i.e. Arc-fault Detection/Mitigation)
  - Micro-grid Controls and Functionality Integration that Optimize PV and Energy Management Values

Focus Points for the Future

- **System Topologies – (Low V to 1000V)**
  - Modularized/Compatible Components
  - Large Area PV Module System Optimization
  - International Functionalities
  - Intelligent Control and Power Interfaces
- **Longer System Lifetime (30y goal)**
  - Higher temperature components
  - Large-scale IC and Power IC applications
  - Vertically Integrated Manufacturing
  - New Power Semiconductors (Wide Band-gap devices)
  - Materials Corrosion/Wear-out Improvements (Optimize Costs/Lifetime)
- **Optimized Levelized Cost of Energy**
  - Model developments that include energy storage and alternative methodologies to optimize economics
  - Models that perform LCOE/Value comparisons to assess the metrics used for today's systems

Focus Points for the Future

- **Energy Management Optimizations**
  - Minimize Wear-out Mechanisms for Grid-tied PV systems (e.g. VAr generation can replace a LOT of energy storage)
  - Optimize Energy Storage Types in PV applications (economics/lifetime)
  - Integrate Energy Management (Load Controls) with Energy Storage
  - Address Safety when Energy Storage is in Accessible Locations
  - Integrate System Controllers (ties PV to utility needs)
- **System and Component Reliability**
  - Use of Advanced Technologies
    - More efficient and advanced magnetic materials
    - Self-healing capacitors and capacitor application improvements
    - Improved packaging and cooling
  - Component remaining lifetime indications
    - Improved sensing for damage to internal circuits
    - Thermal sensing and system profiling
    - Self-protection built into the power conversion hardware

Focus Points for the Future

- **Communications for PV Grid Interoperability**
  - Team with Communications experts to implement nested communications to:
    - Perform and report safety related conditions
    - Perform economic adjustments to optimize PV system values for owners and interconnected utilities
    - Perform resource predictions and adaptive functionality of PV systems
    - Perform performance monitoring and reporting
    - Participate in and implement best choices of methods, protocols, standards, speed, dependability, etc.
  - AMI/AMR Interaction Development
    - Determine best methodologies and system limitations
    - Interface with developed interface controllers/inverters for maximum benefits for the owner/utility
- **Safety**
    - Arc-fault Detection and Mitigation
    - Smart String Combiners

Made in The United States of America!

Thank You