NIST Smart Grid Program

# Smart Grid And CPS Testbed Update

## Smart Grid Federal Advisory Committee Meeting
## June 3, 2014

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Smart Grid and Cyber-Physical Systems Office
National Institute of Standards and Technology
U.S. Department of Commerce

## Smart Grid and Cyber-Physical Systems Testbeds Layout

CPS Testbed | Smart Grid Testbed

| A047-053 | A045 | Stairwell | A031-A029 | A027 | A023-A025 | A021 | A019 | A017 | A015 | A013 |
|---|---|---|---|---|---|---|---|---|---|---|
| Workspace | Server Room | | Cyber Security<br>V. Pillitteri | Smart µ-grid Interconnect Inverter/PCS<br>A. Hefner | Smart Microgrid Control and Intelligent Device | Smart Storage<br>A. Hefner | Networking and Communication<br>N. Golmie | Smart Sensors<br>K. Lee | | Smart Meters<br>T. Nelson |

Note: Precision timing lab (PI Ya-Shian Li-Baboud) will remain in Bldg 222, with fiber optic connection to other labs.

← Future expansion → ← Under renovation Phase 1 →← Future expansion Phase 2 →

- Outside Testbeds
- Outside Testbeds
- NIST SCADA Lab — K. Stoufer
- NIST Net Zero House
- Other NIST Testbeds and Laboratories

2

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## Smart Grid and CPS Testbeds

- Smart Grid Testbed Phase  Smart Grid Technology Integration
  - Smart grid testbed “user facility” organized around microgrid concept
  - Modular and flexible, working on several projects at once
  - Testbed Phase 1 focus on microgrids, smart inverters/PCS
  - Testbed Phase 2 project areas include:
    - Sensors, Smart Meters, Timing, Network and Communications, Cybersecurity
  - Phase 2 construction will begin FY2015, expected to be operational by 4Q
  - Interactions with different parts of the testbed, with other NIST testbeds and laboratories, and testbeds external to NIST
- Cyber-Physical Systems Testbed
  - Cross-cutting over architectural layers—computational /simulation /analytics
  - Workshop to be held early next year to help finalize research goals.
  - Construction will begin FY2015
  - Interconnected to SG testbed, other NIST testbeds and laboratories, and testbeds external to NIST



## Smart Grid Testbed Workshop Key Findings

- Coordination and awareness among testbeds and central understanding of priorities for R&D are significantly lacking.
- Significant measurement, characterization, performance, and other challenges remain that will benefit greatly from testbed analysis and demonstration. A range of testbed scenarios are needed, including
  - targeted testbeds for unique problems
  - modular/composable testbeds
  - interconnected testbeds – across domains, with multiple interconnected smart grid technologies, and those that connect the different capabilities of R&D laboratories or organizations.
- There is a compelling need for the creation of an accessible inventory of testbed entities and capabilities across the nation



## Smart Grid Testbed Workshop Key Findings

- Priorities for developing/expanding testbeds include:
  - Hardware and device development and integration
  - Testing of data security and compatibility of Advanced Metering Infrastructure (AMI) and Home Area Network (HAN) devices
  - Support systems for viable renewable power sources, including storage, demand response, communications, and infrastructure.
  - Integration of renewables across multiple smart grid domains, including distribution, demand responses, markets, and validated in federated testbeds
  - Data analytics for actionable information from large volumes of utility data and a wide range of datasets
  - Architectures for federation of interconnected testbeds, including frameworks for applications and interoperability
  - Multi-level control architectures needed to support changes in conventional grid control paradigms



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# Smart Grid Testbed, Phase1

## NIST Smart Grid Federal Advisory Committee June 3, 2014

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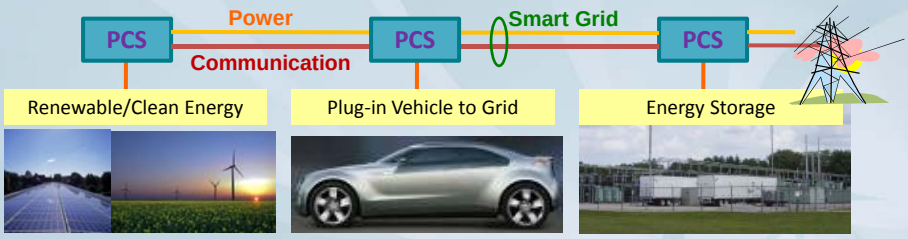
NIST National Institute of Standards and Technology U.S. Department of Commerce

engineering laboratory

## High Penetration of Distributed Energy Resources




- Power Conditioning Systems (PCS) convert to/from 60 Hz AC for interconnection of renewable energy, electric storage, and PEVs
- "Smart Grid Interconnection Standards" required for devices to be utility-controlled operational asset and enable high penetration:
  - **Dispatchable real and reactive power**
  - **Acceptable ramp-rates to mitigate renewable intermittency**
  - **Accommodate faults without cascading/common-mode events**
  - **Voltage regulation and utility-controlled islanding**

http://www.nist.gov/pml/high_megawatt/2008_workshop.cfm

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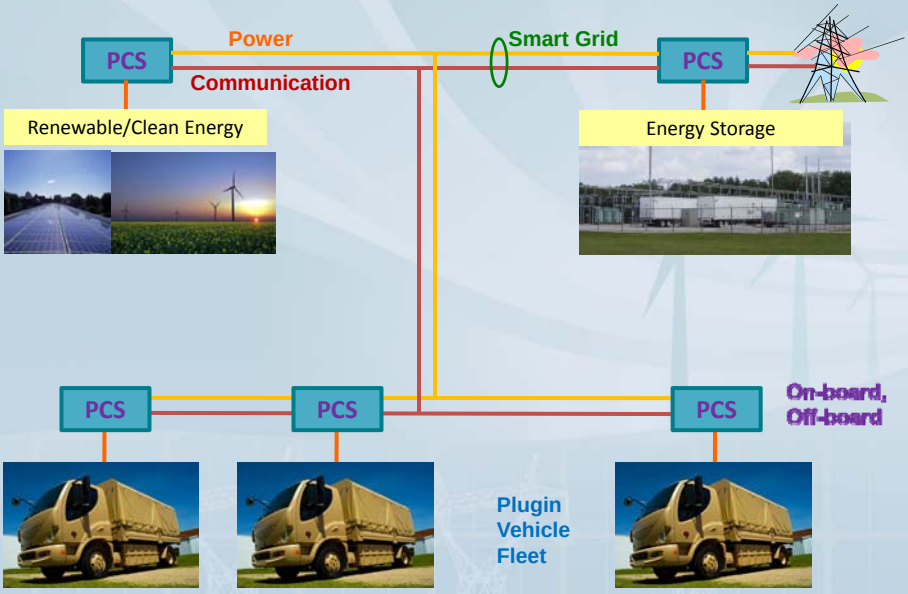
## PCS Architectures for PEV Fleet as Grid Storage




http://www.whitehouse.gov/blog/2011/09/09/air-force-jumpstarts-electric-vehicle-program

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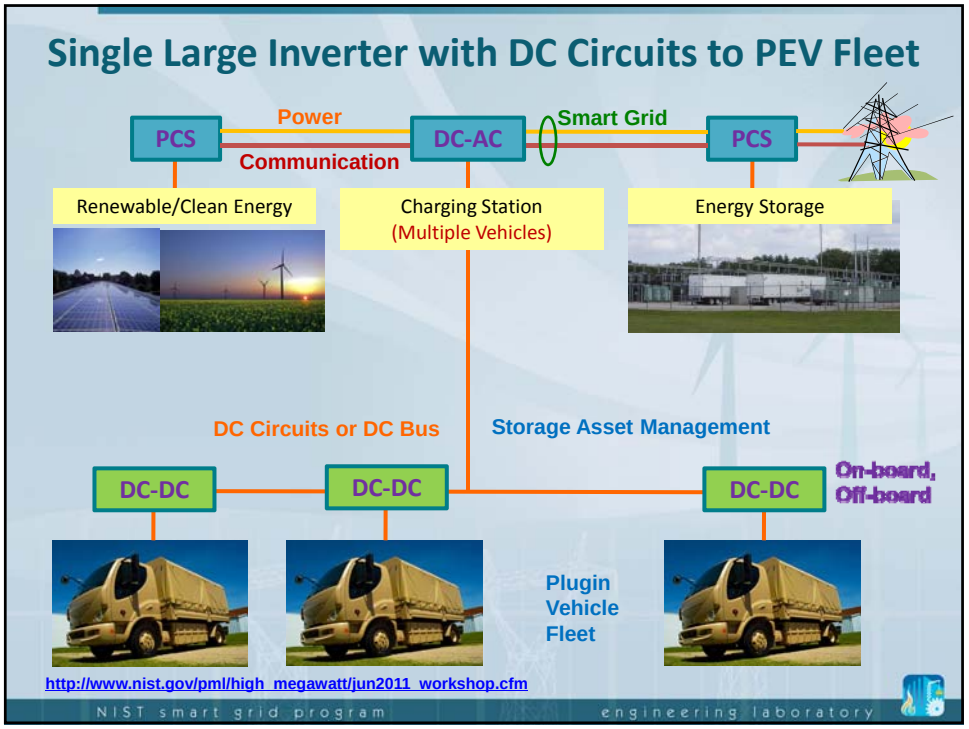
Single Large Inverter with DC Circuits to PEV Fleet
PCS
Power
Communication
DC-AC
Smart Grid
PCS
Renewable/Clean Energy
Charging Station
(Multiple Vehicles)
Energy Storage
DC Circuits or DC Bus
Storage Asset Management
DC-DC
DC-DC
DC-DC
On-board,
Off-board
Plugin
Vehicle
Fleet
http://www.nist.gov/pml/high_megawatt/jun2011_workshop.cfm
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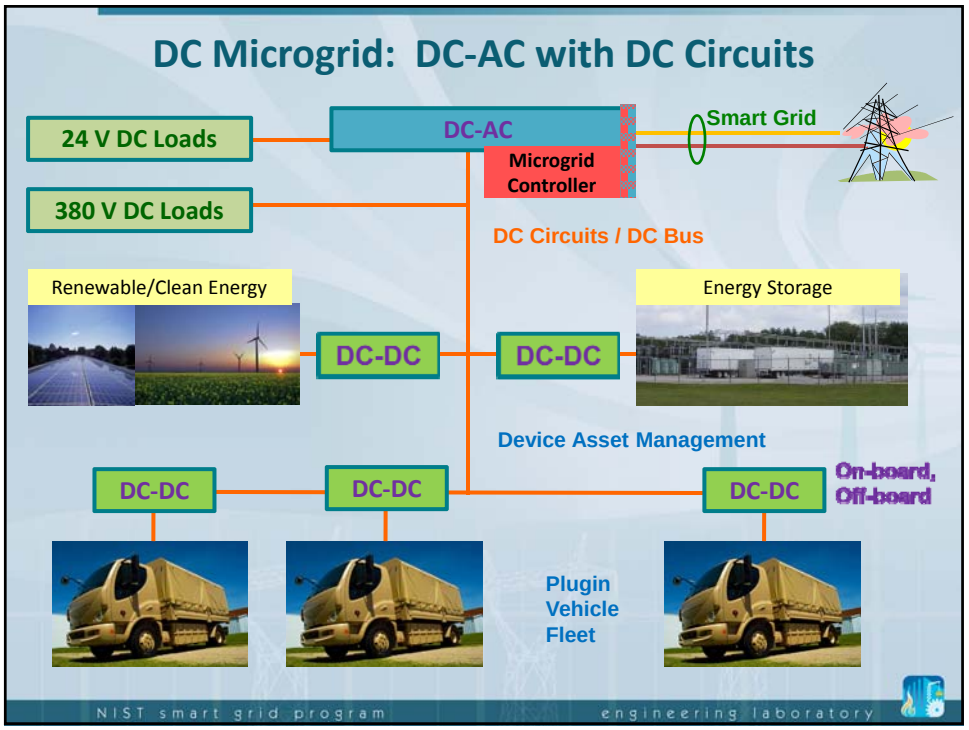
DC Microgrid: DC-AC with DC Circuits
24 V DC Loads
380 V DC Loads
DC-AC
Microgrid
Controller
Smart Grid
DC Circuits / DC Bus
Renewable/Clean Energy
Energy Storage
DC-DC
DC-DC
Device Asset Management
DC-DC
DC-DC
DC-DC
On-board,
Off-board
Plugin
Vehicle
Fleet
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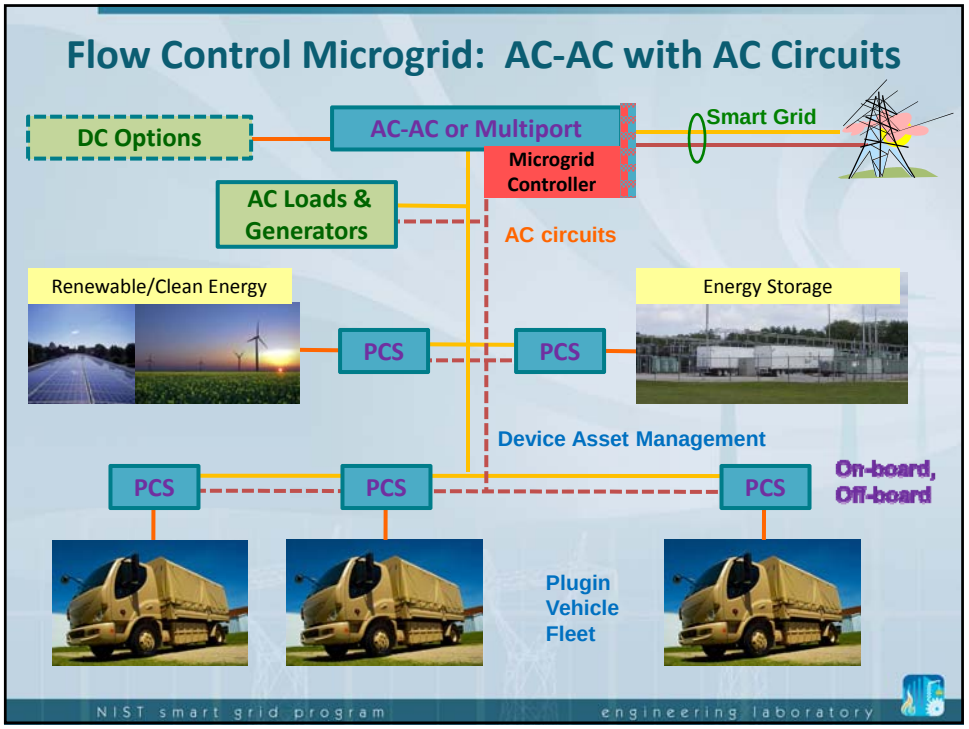
Flow Control Microgrid: AC-AC with AC Circuits
DC Options
AC-AC or Multiport
Microgrid Controller
Smart Grid
AC Loads & Generators
AC circuits
Renewable/Clean Energy
Energy Storage
PCS
PCS
Device Asset Management
PCS
PCS
PCS
On-board, Off-board
Plugin Vehicle Fleet
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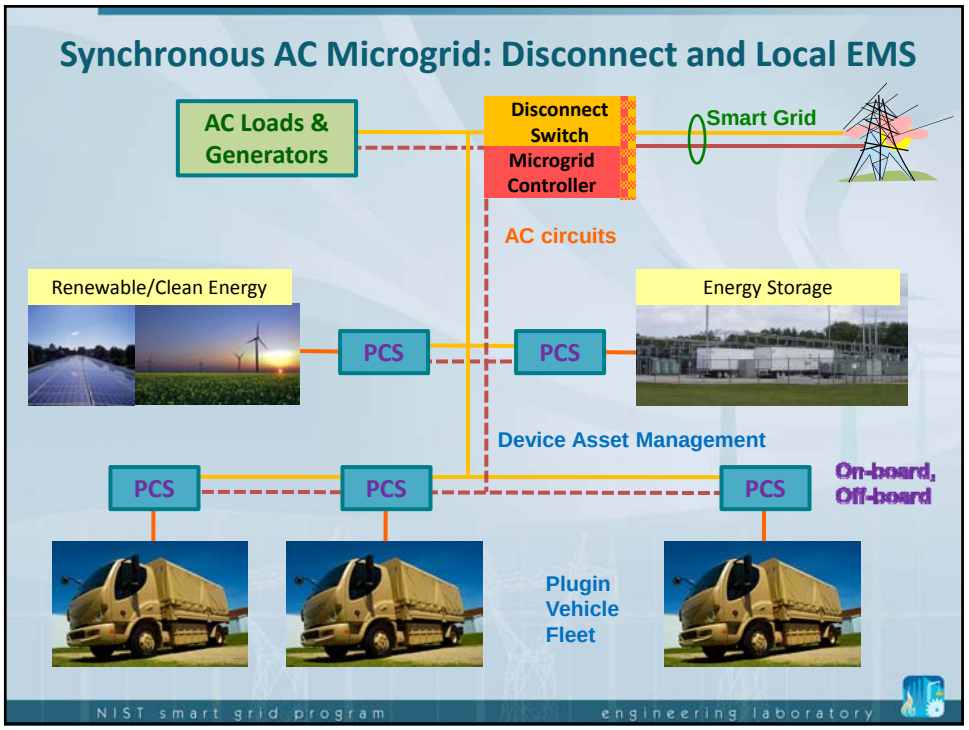
Synchronous AC Microgrid: Disconnect and Local EMS
AC Loads & Generators
Disconnect Switch
Microgrid Controller
Smart Grid
AC circuits
Renewable/Clean Energy
Energy Storage
PCS
PCS
Device Asset Management
PCS
PCS
PCS
On-board, Off-board
Plugin Vehicle Fleet
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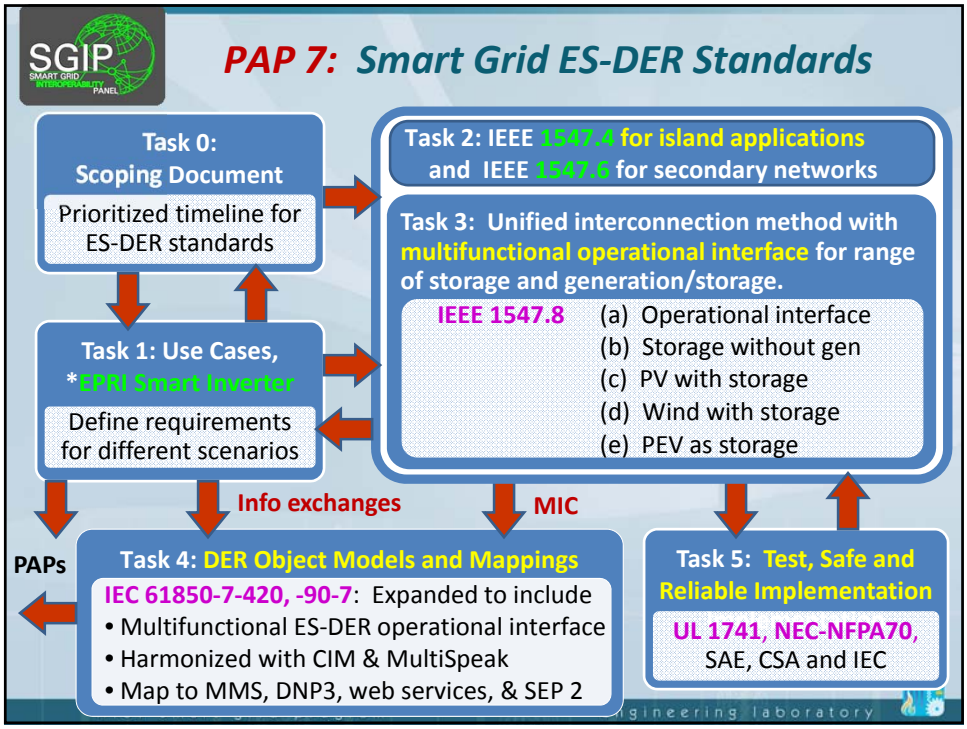
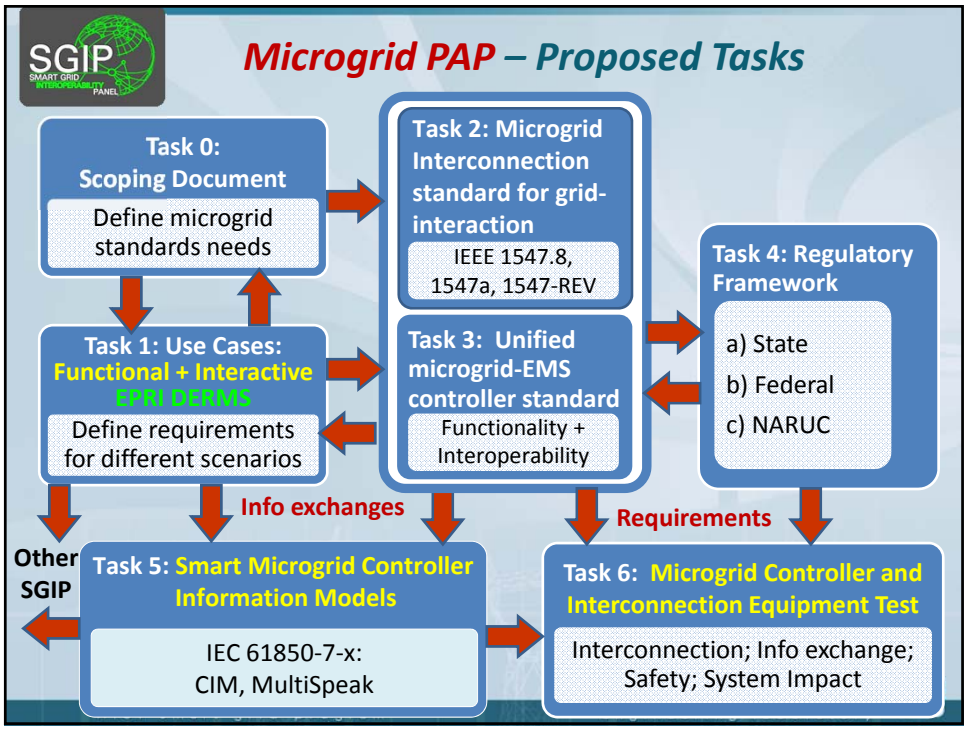

SGIP
SMART GRID INTEROPERABILITY PANEL
PAP 7: Smart Grid ES-DER Standards
Task 0:
Scoping Document
Prioritized timeline for ES-DER standards
Task 1: Use Cases,
*EPRI Smart Inverter
Define requirements for different scenarios
Task 2: IEEE 1547.4 for island applications and IEEE 1547.6 for secondary networks
Task 3: Unified interconnection method with multifunctional operational interface for range of storage and generation/storage.
IEEE 1547.8
(a) Operational interface
(b) Storage without gen
(c) PV with storage
(d) Wind with storage
(e) PEV as storage
Info exchanges
MIC
PAPs
Task 4: DER Object Models and Mappings
IEC 61850-7-420, -90-7: Expanded to include
• Multifunctional ES-DER operational interface
• Harmonized with CIM & MultiSpeak
• Map to MMS, DNP3, web services, & SEP 2
Task 5: Test, Safe and Reliable Implementation
UL 1741, NEC-NFPA70, SAE, CSA and IEC


SGIP
SMART GRID INTEROPERABILITY PANEL
Microgrid PAP – Proposed Tasks
Task 0:
Scoping Document
Define microgrid standards needs
Task 1: Use Cases:
Functional + Interactive
EPRI DERMS
Define requirements for different scenarios
Task 2: Microgrid Interconnection standard for grid-interaction
IEEE 1547.8, 1547a, 1547-REV
Task 3: Unified microgrid-EMS controller standard
Functionality + Interoperability
Task 4: Regulatory Framework
a) State
b) Federal
c) NARUC
Info exchanges
Requirements
Other SGIP
Task 5: Smart Microgrid Controller Information Models
IEC 61850-7-x:
CIM, MultiSpeak
Task 6: Microgrid Controller and Interconnection Equipment Test
Interconnection; Info exchange; Safety; System Impact

# Testing of Microgrid System Design with Controller for DOE Program Activities on Microgrids (Dan Ton)

**Preliminary test plan for technical feasibility and economic performance of the system design/controller, due with each application submission**
Test plan to cover test methodology and scenarios, and technique for data gathering and analysis (FOA evaluation criterion)

**Full and detailed test plan for submission for DOE review, due 9 months after the start of an award**

**Review by DOE Technical Advisory Group (TAG) to ensure consistency in testing and analyzing performance of microgrid design/controller**

**Six months of testing and data analysis, per the DOE-approved test plan**

**Final technical report including test data and analysis of test results, due 90 days after expiration of the award**

**Will work jointly with NIST in reviewing and implementing final test plans to consistently test all microgrid system designs and controller functions from FOA projects**

http://www.nist.gov/smartgrid/upload/SGTB-Panel-Ton.pdf

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# NIST Smart Grid Interoperability Testbed

SGIP Smart Grid Interoperability

NIST Measurement Science

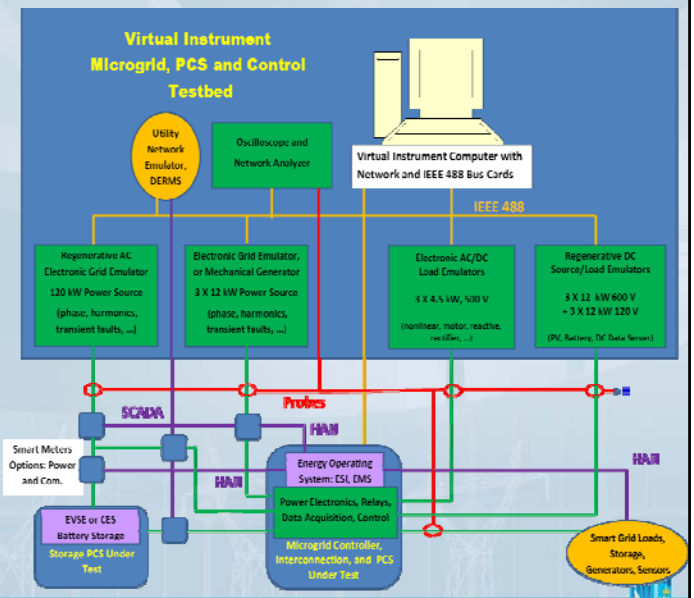
DOE/DOD Labs, Test & Certification

ESI, EMS, Microgrid & Storage functions

IT Networks, Cyber Security, Sensors & Smart Meter

NIST Power Electronics Technologies

Grid-Interactive DER functions & Energy appliances

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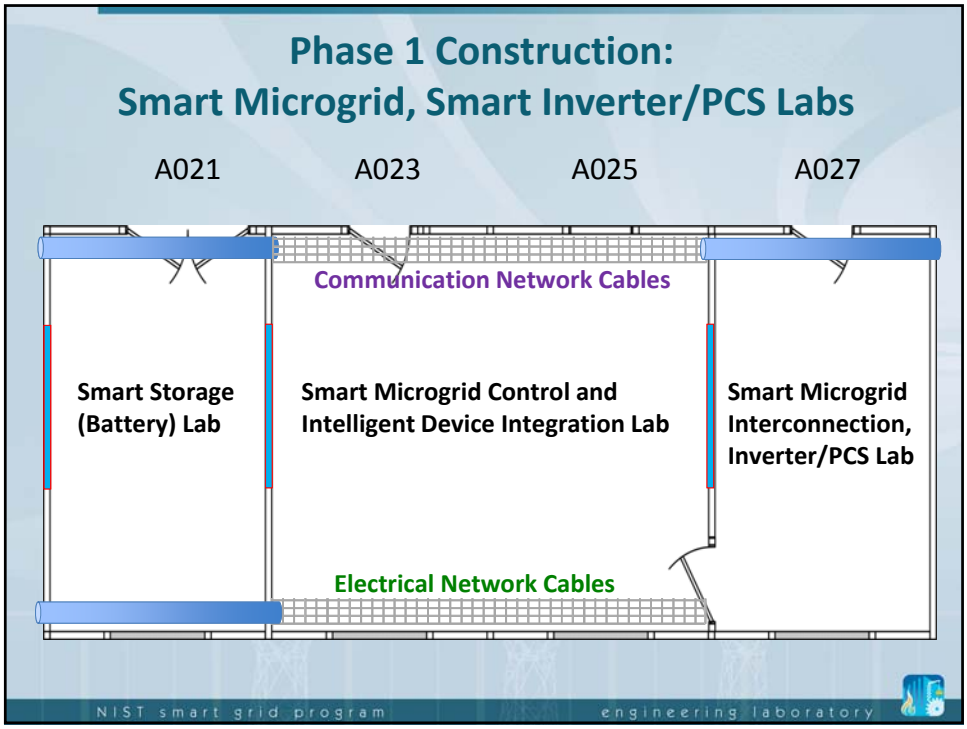
Phase 1 Construction:
Smart Microgrid, Smart Inverter/PCS Labs
A021
A023
A025
A027
Communication Network Cables
Smart Storage (Battery) Lab
Smart Microgrid Control and Intelligent Device Integration Lab
Smart Microgrid Interconnection, Inverter/PCS Lab
Electrical Network Cables
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