Electric Distribution Grid Resilience R&D by the U.S. DOE

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Acting Deputy Assistant Secretary
Power Systems Engineering Research and Development

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Mission of the Office of Electricity Delivery and Energy Reliability (OE)

Drives electric grid modernization and resiliency in the energy infrastructure.

Leads DOE efforts to ensure a resilient, reliable, and flexible electricity system.

Accomplishes mission through research, partnerships, facilitation, modeling and analytics, and emergency preparedness.

Cost-Effective and Reliable + Clean and Efficient + Secure and Resilient

Accessible to New Technologies + Empowered Consumers with Options
OE Leading Transition to a Modern Grid

Current
- Monolithic
- Centralized generation
- Decisions driven by cost
- Vulnerable to catastrophic events
- Limited energy choices
- Vulnerable to new threats

Future
- Modular and agile
- Centralized, distributed generation
- Decisions driven by cost and environmental sustainability
- Contained events
- Personalized energy options
- Inherently secure to all threats
OE Supporting the DOE Implementation of the President’s Climate Action Plan

OE serving as lead or liaison in CAP categories for which DOE has primary role

- **Expanding and Modernizing the Electric Grid:** Upgrading country’s electric grid is critical to efforts to make electricity more reliable, save consumers money on energy bills, and promote clean energy sources.

- **Building Stronger and Safer Communities and Infrastructure:** Identify and remove barriers to making climate-resilient investments; identify and remove counterproductive policies that increase vulnerability; and encourage and support smarter, more resilient investments.

- **Supporting Communities as they Prepare for Climate Impacts:** Provide targeted support and assistance to communities.

- **Rebuilding and Learning from Hurricane Sandy:** Pilot new ways to support resilience in the Sandy-affected region.
Risks

Operational issues (2011 Blackout, 111(d)) → Climate/Weather (Hurricane Sandy) → Cyber Security (Shamoon, Stuxnet) → Physical Security (Metcalf, EMP as a future threat) → Infrastructure interdependencies (Natural Gas/Electric) → Pandemic

Resilience combined with modernization would define success
Every $1 on protection measurements can prevent $4 in repairs after a storm.

Trends indicate the situation will get worse, not better.
OE Areas of Support to Grid Resilience

- Microgrid
- Resilient Distribution Grid R&D
- Energy Storage
- ARRA Smart Grid Investments
- Other R&D: Cyber Security, wide area visualization (PMUs), advanced modeling, etc...
- Technical Assistance to States
Microgrid R&D to Enhance Energy Surety, Reliability, and Resiliency

- Small combustion and μ-turbines
- Fuel cells
- IC engines
- Small hydro and wind
- Solar electric and solar thermal
- Energy storage (batteries, flywheels,...)
- Plug in hybrid vehicles
- Modular energy sources

<table>
<thead>
<tr>
<th>Residential</th>
<th>Less than 10-kW, single-phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Commercial</td>
<td>From 10-kW to 50-kW, typically three phase</td>
</tr>
<tr>
<td>Commercial</td>
<td>Greater than 50-kW up to 10MW</td>
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Microgrids for Energy Surety
(safety, security, reliability, sustainability, and cost effectiveness)

Current Microgrid Projects/Test Center Landscape in the U.S. (as of Feb 2011)

SPIDERS: Smart Power Infrastructure Demonstration for Energy Reliability and Security

TRANSITION
- Template for DoD-wide implementation
- CONOPS
- TTPs
- Training plans
- DoD adds specs to GSA schedule
- Transition to commercial sector via DOE
- Transition cyber-security to federal sector and utilities

CAMP SMITH ENERGY ISLAND
- Entire installation Smart MicroGrid
- Islanded installation
- High penetration of renewables
- Demand-side management
- Redundant backup power
- Makana Pahili hurricane exercise

FT CARSON MICRO-GRID
- Large scale renewables
- Vehicle-to-Grid
- Large scale storage
- Critical assets
- Demonstration to tie in with COOP exercise

PEARL HARBOR / HICKAM AFB
- Renewables
- Storage
- Energy management

CYBER-SECURITY

(Source: Pike Research)
Microgrids as a Resiliency Resource

Combined heat and power (CHP) with microgrid technology provided the co-op building with critical electricity services during the week of utility outages caused by Superstorm Sandy.

Demonstrating the WSU-Pullman microgrid capable of reducing switching operations for faster restoration and picking up more interrupted load during outages.
Microgrids Help Communities as They Prepare for Climate Impacts

NJ TransitGrid Project
- Microgrid to enhance grid-rail resiliency to serve over 900,000 riders/day
- Key evacuation service for Manhattan & N. New Jersey
- MOU between DOE and State of NJ
- Completed the feasibility study; received the FTA award in Sept 2014 to build microgrid

Hoboken ESDM Project
- Provide electrical power to support critical functions up to 7 days for 52,000 residents in 1.2 sq. mi.
- Key evacuation route for Manhattan
- DOE-Hoboken-BPU-Sandia-PSEG Partnership
- Completed microgrid conceptual design for Hoboken, NJ, to enhance system resilience post-Sandy
Public/Private Partnerships through FY14 FOA on Microgrid R, D, & System Design

**FOA Objective:**
Advance microgrid system designs (<10MW) and control functionalities for implementation by communities to support achieving DOE program targets and Communities-defined resilience objectives

**FOA Partnered Projects:**
>$12M in total investment (OE: 59%; Indian Energy: 9%; private sector: 33%);
2-year project PoP, including 18-month R&D and 6-month testing, data collection, and analysis

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*Timeline*
- **FY14**
  - Issue date, 31 Jan
- **FY15**
  - Selection announcement, 8 Sept
  - Awards finalization
- **FY16**
  - Final test plan, 9 mos from award
- **FY17**
  - Testing completed for technical feasibility & economic performance
  - Downselection for field demo

*Partners*
- ALSTOM
- ComEd
- EPRI
- GE Global Research
- Microgrid Institute
- TSB power
- University of California, Irvine

*Dates*
- Selection announcement, 8 Sept
- Awards finalization
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Microgrid R&D
Progressing toward Meeting Program Targets

National Labs
• Foundational R&D
• Integrated tools for microgrid planning/design and operations/control

Industry-led
• Commercial viability
• Community-defined resiliency objectives
• Testing to be completed in FY16; field demo in FY17+

State/regional partnerships
• Microgrid deployment
• Individual states (NJ, VT, CT, NY) in FY 13-15
• Regional energy assurance in FY16+

DC Microgrids
• Scoping study in FY14-15
• New project starts in FY15 to achieve climate-neutral buildings

Networked Microgrids
• Scoping study in FY 15
• New FOA awards in FY16 for integrating a network of multiple microgrids with distribution systems
Resilient Distribution Grid R&D Roadmapping and Implementation

Diagram:
- Establish
  - Project Selection
  - Award Announcements
- Envision
  - Program conception (idea/vision)
  - Technical Deep Dive
  - Workshop
  - Internal Debate
- Evaluate
  - Full Proposal Panel Review
  - Contract Negotiation and Awards
- Engage
  - FOA Announced
  - Further Refinement & FOA Development
- R&D Implementation
## List of R&D Needs and Projects from 2014 Stakeholder Workshop

<table>
<thead>
<tr>
<th>Area</th>
<th>R&amp;D Needs</th>
<th>R&amp;D Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design, Preparedness, and Planning</td>
<td>1. Design of segmented and agile distributed system</td>
<td>– Emergency controls, segmentation, communications</td>
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<tr>
<td></td>
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<td>– Microgrid to feeder integration</td>
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<td></td>
<td>2. Big data &amp; analytics</td>
<td>– Multi scale modeling: Distribution &amp; Transmission</td>
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<td>– Real-time database with speed and accuracy</td>
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<td>3. Stochastic and uncertainty</td>
<td>– Robust control to uncertain data</td>
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<td>– Predictive models</td>
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# List of R&D Needs and Projects from 2014 Stakeholder Workshop (continued)

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<tr>
<td><strong>Operational Response and System Recovery</strong></td>
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<tr>
<td>1. Proactive assessment of damage (automated calls to customers, smart meters)</td>
<td>– Damage assessment,</td>
<td>– Development of architecture</td>
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<td></td>
<td>– UAVs to support real-time Google maps</td>
<td>– State estimation with new data and new devices</td>
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<td>– New devices to support degradation identification</td>
<td>– Cyber physical degradation, and the necessary understanding when it occurs to respond to it</td>
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<tr>
<td></td>
<td>– Hardening of communications</td>
<td>– 3-phase state estimation</td>
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<tr>
<td>2. Situational awareness</td>
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<tr>
<td>3. Decision support to determine restoration priorities</td>
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<td>– Development of technologies to find alternative restoration strategies</td>
<td>– Cost effective resilient control systems</td>
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<td></td>
<td>– Coupling of electric restoration models to other infrastructure models</td>
<td>– Integration of microgrids to Distribution Management System</td>
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<td></td>
<td>– Advancement of standardization of microgrid resources such as inverters, Distributed generation</td>
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Resilient Electric Distribution R&D

Develop Resilient Grid Roadmap in 2015 toward accomplishing 20% reduction in systemic impact (calculated from outage duration, frequency, and avoided lost load value) under extreme weather scenarios.

<table>
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<th>Enhanced System Design</th>
<th>Preparation &amp; Planning</th>
<th>Operational Response</th>
<th>System Repair and Recovery</th>
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</thead>
<tbody>
<tr>
<td>• Design tools that integrate existing modeling modules for use by distribution utility designers for rebuilding &amp; upgrades</td>
<td>• Geospatial power system modeling tools with weather forecasting for damage prediction and response</td>
<td>• Advanced analytics for operational decisions</td>
<td>• Integration of grid modeling with optimization algorithms to promote evaluation of options for repair and recovery in near real-time</td>
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<tr>
<td></td>
<td>• Cost-effective hardening measures</td>
<td>• Novel control algorithms driven by all-hazards impact assessments</td>
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A second stakeholder workshop is planned in June-July 2015 to incorporate QER recommendations and finalize the program plan.
Resilient Electricity Delivery Infrastructure (REDI) Funding Opportunity Announcement

- Implement and deploy smart grid technologies and tools (inc. ES and cybersecurity) to improve climate preparedness and resiliency of electricity delivery infrastructure
  - Best pre-commercial and commercial technologies from industry
  - National Laboratory technologies with readiness for community applications
  - FOA in support of another DOE initiative on Climate Action Champions (16 communities announced as the 1st group of CACs)
- FOA issued on 3 December 2014
  - $3.5M DOE funding for 4-8 awards for a PoP of 2 years (50% applicant cost share required)
- FOA open to local and tribal governments experienced a Presidentially Declared Major Disaster

Application due: 4 May 2015
Framework for Developing Resilience Metrics

Resilience Analysis Process:
How metrics should be defined and used

Resilience Metric:
Used to compare performance of improved system vs. baseline

Resilience Analysis Process:
- Define System & Resilience Metrics
- Define Resilience Goals
- Characterize Threats
- Determine Level of Disruption
- Define & Apply System Models
- Calculate Consequence
- Evaluate Resilience Improvements

Resilience Metric:
- Distribution of Consequence
- Extreme Values: Base System vs. Improved System

Probability of Consequence

Mean

Consequence

19
Framework for Developing Resilience Metrics

Performance Indicators

Load Not Served, Hurricane

Decreased Labor, Hurricane

Added Operating Cost, Hurricane

An exemplar consequence distribution is created to account for uncertainty
(Threat intensity, Available resources, System response, Interdependencies, Disruption impacts, etc.)

Consequence, Hurricane

Distribution of Consequence, Hurricanes

Alternative units:
Safety, Economics, Population affected, etc...

This distribution is the RESILIENCE METRIC.
Electric Resilience Assessment Program-Distribution (ERAP-D) Tool for Distribution Utilities to Assess Resilience

Building on Infrastructure Survey Tool (IST) development under DHS Regional Resiliency Assessment Program:

- Developing the proof-of-concept tool in FY15
- Transitioning the tool for use by distribution utilities in FY16

A notional IST RMI dashboard for transportation facilities
Enable distribution grid designers to prioritize cost-effective system upgrades and expansions to minimize future damage to their grid and outages to customers.

**Leverage modules developed under DHS National Infrastructure Simulation and Analysis Center (NISAC):**

- Developing a prototype resilience design tool for multiple hazards (ice and flooding) in FY15
- Begin developing “recovery” modules in FY16

Resilient Distribution Grid Design Tool
Looking Forward

Developing a Smarter, More Resilient Grid by Employing ADMS and Transactive Controls and Integrating Network of Microgrids

Picture courtesy of: Smart Grid 2030
Program Resources

Office of Electricity Delivery
and Energy Reliability
http://www.oe.energy.gov

Smart Grid
http://energy.gov/oe/services/technology-development-smart-grid

Recovery Act Smart Grid Investments
https://smartgrid.gov

Microgrids