Montreal 2006
Symposium on Microgrids

Overview of DOE Microgrid Activities

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Office of Electricity Delivery and Energy Reliability

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Mission

Lead national efforts to modernize the electric grid, enhance security and reliability of the energy infrastructure, and facilitate recovery from disruptions to energy supply.

Research & Development (R&D)

Permitting, Siting, & Analysis (PSA)

Infrastructure Security & Emergency Response (ISER)

Grid Modernization and Power System Transformation is Essential in the US and Globally

Power Infrastructure not Keeping Up with Increasing Energy Demand

- Increased incidence of blackouts and demand for enhanced reliability
- Increased number of disturbances and outages costing an estimated $80BN/year
- Increased transmission congestion resulting in higher electricity costs for consumers
- Renewables penetration limited by dispatchability concerns
- Increased vulnerability to external threats and natural disasters

Increase in World Population is Driving:

- Increased electric power demand
- Increased pollution and global warming
- Increasingly inadequate fresh water supplies
- Increased demand for fuel sources

Technology Development Priorities to Address the Needs and Challenges

- **Visualization and Controls**
  - **Real-time monitoring**
  - **Secure control systems**
- **Distributed Systems**
  - **Phase out activities on single technology development**
  - **Systems integration and Interoperability**
- **High Temperature Superconductivity**
  - **Wires**
  - **Cables**
  - **Devices**
- **Power Electronics (Switches) and Advanced Materials**



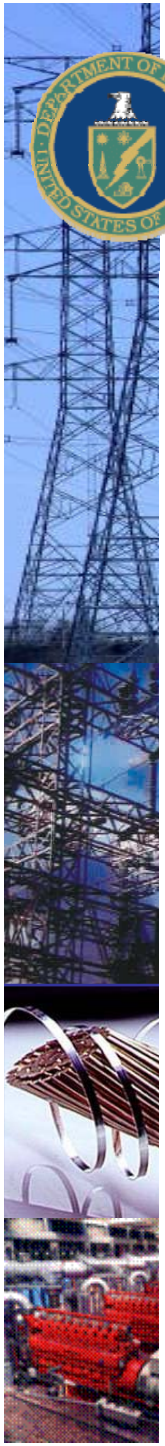






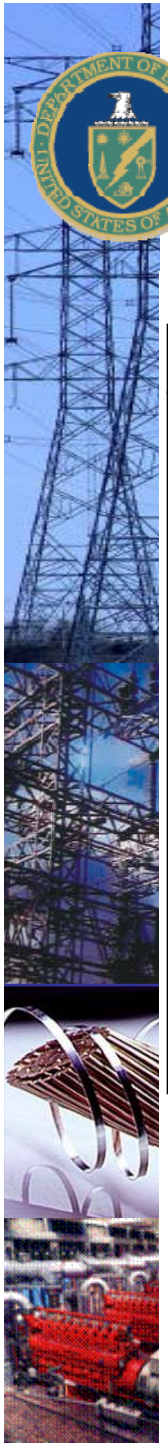

DOE Microgrid Activities

- Background
- Snapshot
- Definition, Diagram and Scope of Service
- Drivers
- Value Proposition
- Vision and Roadmap
- Market Assessment and Benefits
- Functional Areas and Technology Platforms
- Recent Awards



Microgrid Background

- DOE and CEC collaboration since 2004
- Jointly funded the Microgrid Research Assessment based on a broad stakeholder process



To meet the 2020 vision, microgrids must prove they can meet functional requirements for a scope of service beyond a single facility and for value propositions beyond reduced cost

Today's Capabilities

- Limited experience meeting performance standards for a wide range of configurations beyond single-facility applications
- Limited ability to deliver complex value propositions
  - Operate in islanded mode
  - Coordinate physical, financial, or operational elements

Microgrids must focus on meeting the technology challenges in the following areas:

Scope of Service/Business Model

Single and Multi - Facility
- Design
- Performance Requirements
- Operations

Feeder, Sub-station
- Protection
- Design
- Infrastructure

Value Propositions

Reduced Cost, Security, Reliability
- Performance Requirements / Interconnection requirements
- Protection / Auto-synchronization

Service Differentiation, Power System, Green Power
- Internal Controls
- Coordination of physical, financial, and operational elements

Technology Platforms

- Fast Switch
- Control Systems
- Energy Storage
- Others
- Standards

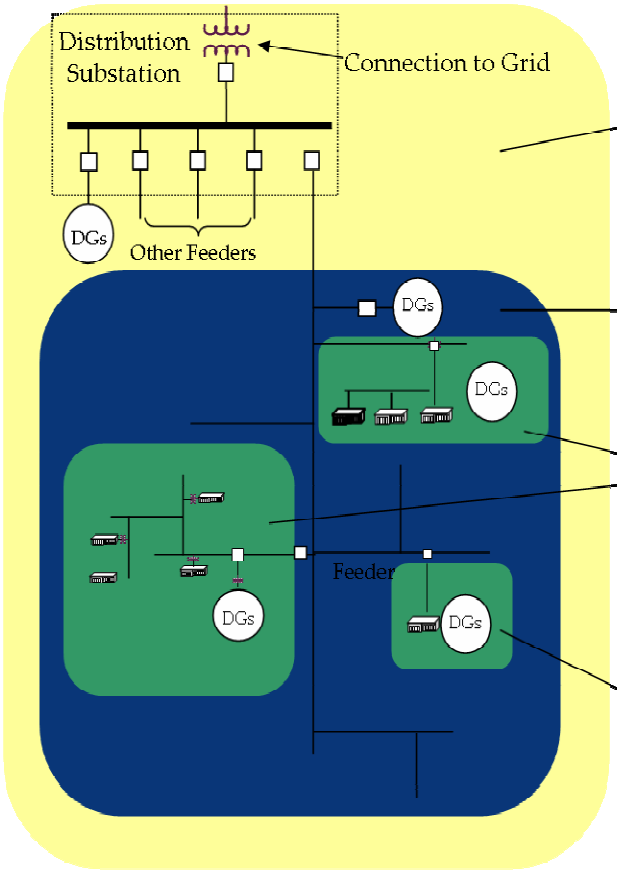
2020 Vision

- Operate to provide transition between grid parallel and islanded operation modes.
- Operate under appropriate interconnection and interoperability standards.
- Rely on monitoring, information exchange (including price signals), control technologies, open architecture, and interoperability.
- Fully coordinate financial, physical, and operational elements with the larger power system
- Integrate demand response, renewables, CHP, storage, power conversion, metering and other DER.

Microgrid: Definition and Scope of Service

A microgrid is an integrated energy system consisting of interconnected loads and distributed energy resources which as an integrated system can operate in parallel with the grid or in an intentional island mode

Microgrid Schematic



Scope of Service Definitions and Insights

Size	
Sub - Station (20+MW)	Smaller individual facilities with multiple loads, e.g. hospitals, schools. Lack of a cost advantage over DG will limit market penetration
Feeder (5 – 20 MW)	Small to larger traditional CHP facilities plus a few neighboring loads, exclusively C&I. Increased scale provides cost advantages of DG/CHP.
Multi-facility (<5MW)	Small to larger traditional CHP facilities plus many or large neighboring loads, typically C&I. Increased scale provides further cost advantages.
Single-facility (1kW - 2MW)	Traditional CHP plus many neighboring loads. Will include C&I plus residential. Poorer economics due to load factor, decreased thermal loads, and increased infrastructure costs.

Microgrids: Drivers

- **Deregulation driving system operation close to capacity limits**
- **Transmission constraints driving generation sources closer to loads**
- **Demand for improved power availability and power quality**
- **Industry interest in DER potential for clean & efficient energy (electrical and thermal)**
- **DG required to shut down during a disturbance on the grid**

Microgrids could provide six complementary value propositions.

Value Proposition	Description
Reduced Cost	Reducing the cost of energy and managing price volatility
Reliability	Improving reliability and power quality
Security	Increasing the resiliency and security of the power delivery system by promoting the dispersal of power resources
Green Power	Helping to manage the intermittency of renewables and promoting the deployment and integration of energy-efficient and environmentally friendly technologies
Power System	Assisting in optimizing the power delivery system, including the provision of services
Service Differentiation	Providing different levels of service quality and value to customers segments at different price points

Note: Remote power systems can primarily provide the Reduced Cost, Reliability and Green Power value propositions.

CEC-DOE Microgrid Vision

Microgrid Vision[1] – One GW of Microgrids was installed during the year 2020

Value Proposition

Microgrids are providing added value to society, the grid, and to customers by:
- Improving reliability,
- Reducing the cost of energy and managing price volatility,
- Assisting in optimizing the power delivery system, including the provision of services,
- Providing different levels of service quality and value to customers segments at different price points,
- Helping to manage the intermittency of renewables.
- Promoting the deployment and integration of energy-efficient and environmentally friendly technologies, and
- Increasing the resiliency and security of the power delivery system by promoting the dispersal of power resources.

Technology

Technologies exist to support these microgrid value propositions, and can:
- Operate to provide transition between grid-parallel and islanded-operation modes,
- Rely on monitoring, information exchange (including price signals), control technologies, open architecture, and interoperability,
- Fully coordinate financial, physical, and operational elements with the larger power system,
- Integrate demand response, renewables, CHP, storage, power conversion, metering, and other DER, and
- Operate under appropriate interconnection and interoperability standards.

Regulation

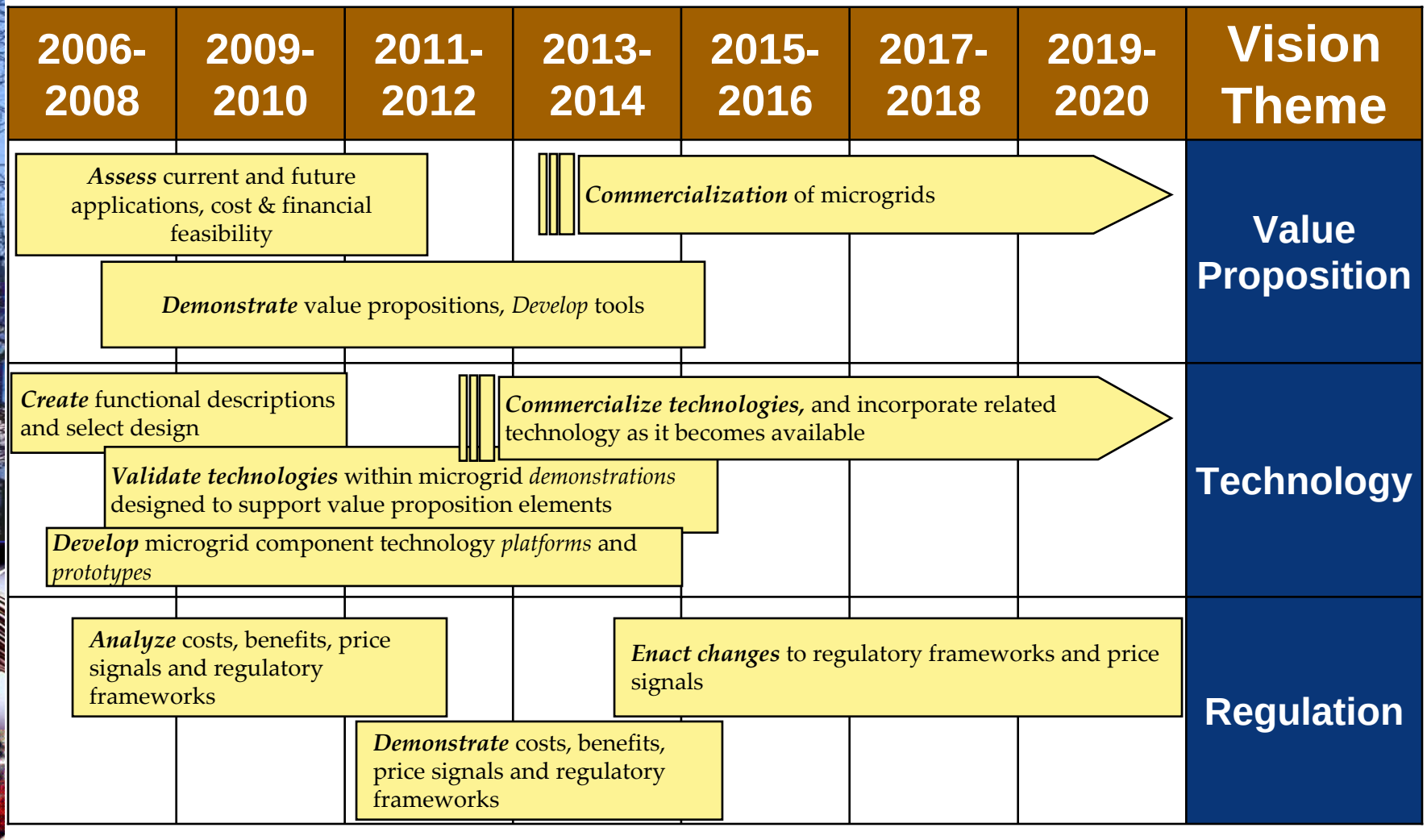
Regulations have changed to:
- Allow competition, while maintaining an obligation to serve,
- Fairly compensate utilities for services provided and investments made,
- Provide transparent compensation for environmental, system reliability, and homeland security benefits,
- Permit customers to see the real cost of electricity, including real-time, locational and environmental attributes
- Remove barriers for utility deployment of DER, and
- Adopt nationally recognized interconnection standards.

Utilities, new investors, and customers own and operate microgrids, under arrangements which allow:
- Utility-owned generation and wires,
- Privately owned generation and wires,
- Hybrid ownership and operational structures.

1. Vision was developed at the Microgrids Visioning Workshop (June 22-24, 2005)

CEC-DOE Microgrid Roadmap

Microgrids Roadmap[1]



1. Roadmap was developed at the Microgrids Visioning Workshop (June 22-24, 2005)

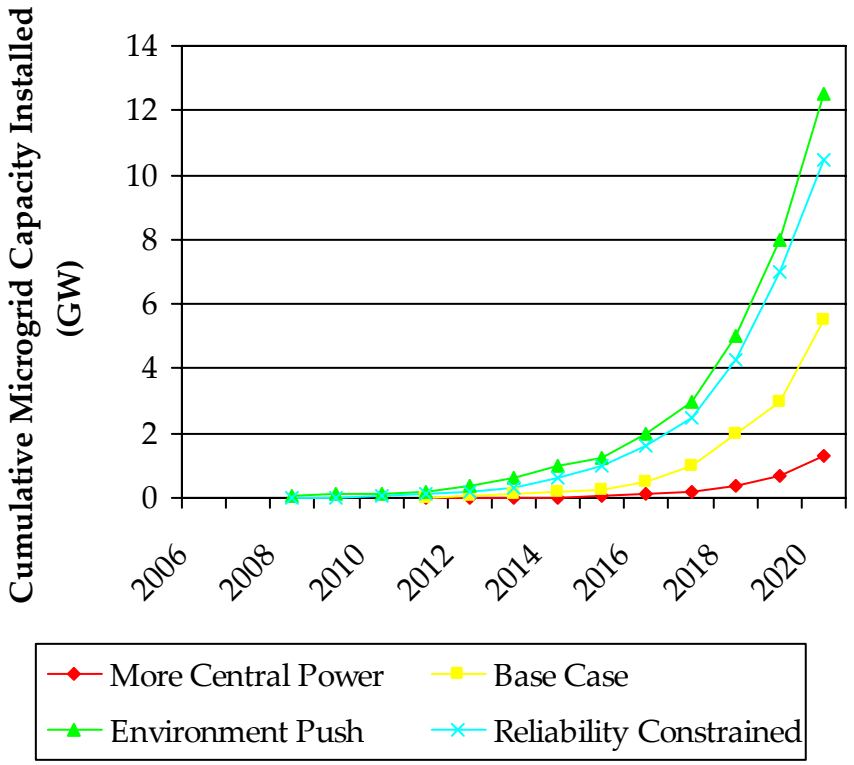
Microgrid: Challenges

Drivers of Gaps (X denotes a significant factor in meeting a requirement)

Functional Area	Functional Requirements	System Integration	Standards / Certification	Technology Platforms							
				Control System			Fast Switch	Energy Storage	Demand Response	Power Electronics	Sensors, processing
				Asset	Internal	External					
Performance Requirements	▪Meet IEEE 1547 requirements	X	X								
	▪Power quality	X	X	X	X			X	X		
	▪Steady-state and dynamic performance	X	X	X	X			X	X		
Design	▪NEC/NESC code requirements	X	X								
	▪Switching (Generation and Load isolation)	X		X	X		X		X	X	
	▪Load transfer	X		X	X	X	X	X	X		
	▪Line and equipment ratings	X									
	▪Regulation (voltage and power factor)	X		X	X	X	X	X	X	X	X
	▪Critical loads	X									
Monitoring and Control	▪Control system algorithm	X		X	X	X	X	X			X
	▪Frequency (load following)	X		X			X	X			
	▪Voltage (load following)	X		X	X		X	X		X	
	▪Power Factor	X		X	X		X	X		X	
	▪Load	X		X			X	X		X	
	▪Generation	X		X	X		X	X			X
	▪Communications infrastructure	X		X	X	X				X	X
Protection	▪Fault current interruption	X								X	X
	▪Coordination (normal vs. reconfigured)	X			X					X	X
	▪Under/Over voltage	X									X
	▪Fault isolation (voltage and current)	X								X	X
	▪Auto synchronization with the grid	X	X	X	X	X	X				X
	▪Black start capability	X		X	X	X					
Operations	▪Safety	X									
	▪Plan and protocol (O&M plan)	X									
	▪Spare parts and inventory	X									
	▪Labor	X									
Infrastructure	▪Utility system and equipment upgrades	X	X								
	▪Interconnection requirements	X	X								
	▪Communication Infrastructure & Controls	X		X	X	X					

Microgrid: Market and Benefits Assessment

Microgrids could capture a market size in 2020 between 1 GW and 13 GW



Actual deployment in 2020 is highly dependent on market conditions

- If conditions are similar to today, deployment could be 5.5 GW as represented in the Base Case scenario
- If conditions are less favorable for microgrids (e.g. spark spreads deteriorate, there are minimal advances in DG technologies), microgrids could capture approximately 1 GW.
- If conditions for microgrids improve either, for example through higher environmental constraints or though higher reliability needs, the market could be 10 GW to 13GW as represented in the Environmental Push and Reliability Constrained scenarios

Microgrid: Market and Benefits Assessment

Annual Microgrid Benefits – Base Case Scenario ($Billion)

Category	2015	2016	2017	2018	2019	2020
Energy Efficiency	$0.02	$0.03	$0.07	$0.13	$0.2	$0.36
System Efficiency	$0.00	$0.00	$0.01	$0.01	$0.02	$0.04
Reliability	$0.00	$0.00	$0.01	$0.01	$0.02	$0.04
Security	$0.00	$0.00	$0.00	$0.01	$0.01	$0.01
Emissions(1)	$0.02	$0.05	$0.10	$0.20	$0.29	$0.55
Total	$0.04	$0.09	$0.18	$0.36	$0.54	$1.0

Annual Emission Reductions – Base Case Scenario (tons)

Emission	2015	2016	2017	2018	2019	2020
CO_2	793,000	1,590,000	3,170,000	6,340,000	9,510,000	17,400,000
SOx	4,000	9,800	19,700	39,400	59,100	108,000
NOx	821	1,640	3,290	6,570	9,850	18,000

Recent RD&D Awards Related to Distributed Systems Integration

- Advanced Integration of Distributed Energy Resources into the Utility Distribution System
- 3G System of the Future: Advanced Distribution Operation with DER Integration
- Southern Company Integrated Distribution Management System
- **Microgrid Design, Development, and Demonstration**
- **Value and Technology Assessment to Enhance the Business Case for the CERTS Microgrid**

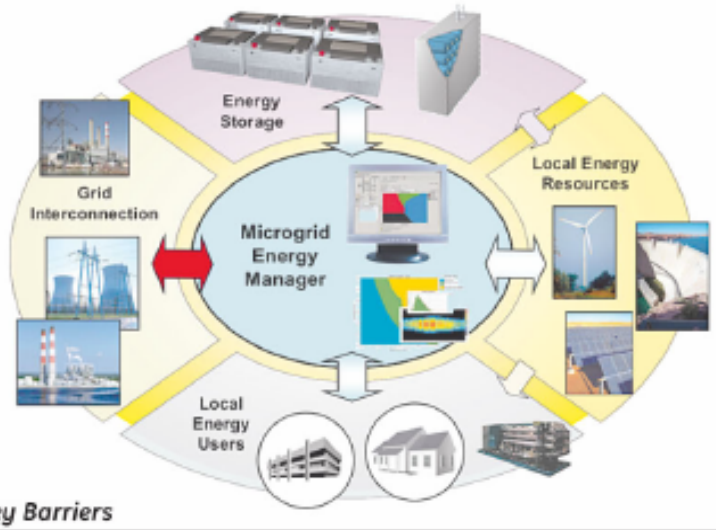
GE Project Objectives

Project Team

- **GE Global Research** — *Advanced Energy Management Algorithms*
- **GE Energy (NRPS)** — *Energy Management Software and Hardware Platform*
- **GE Consumer & Industrial (Multilin)** — *Distribution Protection Equipment*
- **Rocky Research** — *Thermal Energy Storage to Improve Engine Efficiency*
- **NREL** — **National Renewable Energy Laboratory**

24 month, $4.2 MM Program to Develop a Microgrid Energy Management System and Demonstrate at the City of Wayne, NJ

Program Objective: *To develop microgrid specifications, investigate business models, develop advanced local and supervisory control algorithms, and demonstrate and validate at the city of Wayne, NJ*



Key Barriers

- Lack of unified energy management strategies
- Microgrid system-level integration and controls are still a research area
- Incomplete understanding of potential microgrid architectures and generalized control systems solutions

Program Deliverables

- Advanced local controls, energy management and protection algorithms for microgrid systems
- Demonstration of downselected controls, energy management, and protection functionality in a multi-building campus microgrid

Potential Benefits

- Minimization of application engineering through simpler integration and operation procedures
- Reduction in cost of energy and cost of ownership
- Flexibility to allow easy expansion of generation, storage, and loads
- Demonstration of renewables friendliness
- Aggregated behavior of the microgrid entity, with potential for dispatchability

Develop and demonstrate advanced controls, energy management and protection technologies that are needed to make microgrids technically and economically viable.

GE Project Technical Approach

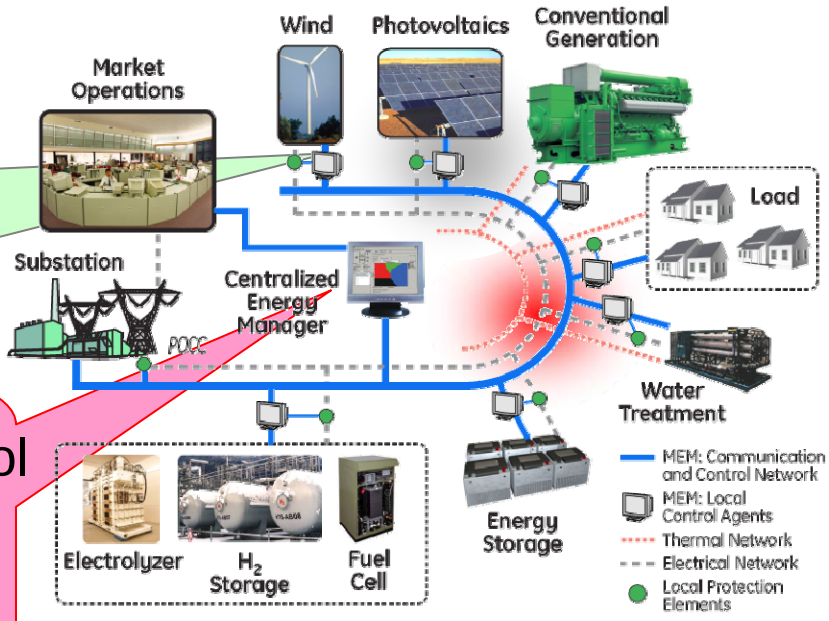
- Evaluate advanced asset controls and protection strategies through simulation
- Develop and implement supervisory controls to optimize customer benefits, e.g., performance, operating cost, emissions, etc.
- Evaluate (macro) grid independent and dispatchable grid interactive operation
- Incorporate maximum level of commonality among various microgrid applications.

Local Controls & Protection

- VAR management / voltage control
- Frequency control
- Energy storage
- Power quality
- Asset protection and fault isolation
- System modeling

Energy Mgmt & Supervisory Control

- Dispatch controls
- Supervisory control optimization
- DMS / real time pricing
- Physical systems for control and communication



GE Project Benefits Summary

- Development of control algorithms and hardware that will promote…
- Energy efficiency and optimal energy utilization
- Reduction in cost of energy and total cost of ownership
- Flexibility to integrate a diverse set of controllable assets
- Demonstration of renewable energy integration
- Aggregation and algorithms to enable dispatchable Microgrids
- Concepts to improve power quality and availability in islanded operation

Next Steps

- Regular communication and information exchange between research teams, program managers, industry
- Integrated and complimentary R&D planning and activities

For More Information...

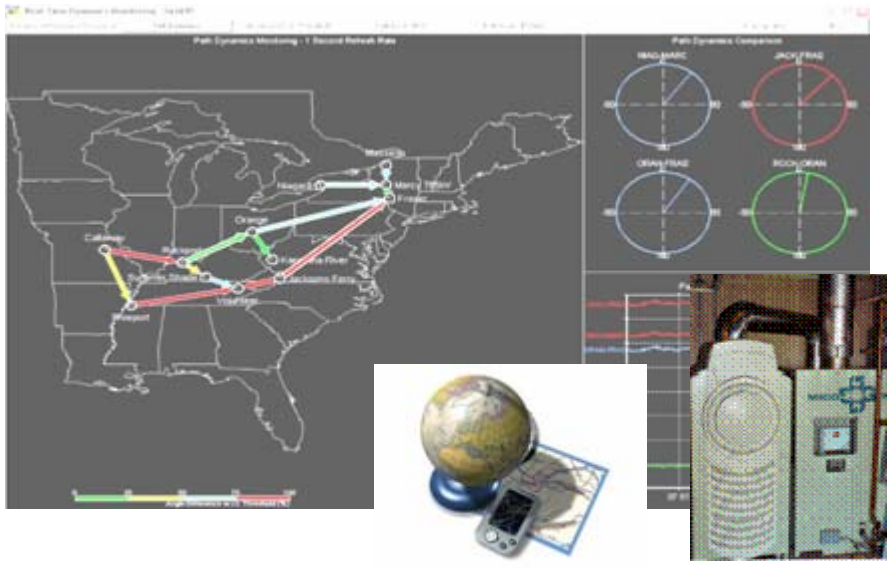
Office of Electricity Delivery and Energy Reliability's website www.oe.energy.gov

OE Background Slides

- R&D Priority Areas
- Select Energy Policy Act of 2005 R&D Provisions

Visualization and Controls R&D

- **Includes developing next generation system control and data acquisition system with:**
  - **GPS-synchronized grid monitoring**
  - **Secure data communications**
  - **Custom visualization and operating cuing**
  - **Advanced control algorithms**
- **Helps detect disturbances and prevent widespread outages**
- **Provides real-time information during energy emergencies**



Benefits

- ✓ **Improves reliability**
- ✓ **Improves system efficiency and energy efficiency**
- ✓ **Increases utilization of assets**
- ✓ **Reduces vulnerabilities**

High Temperature Superconductivity (HTS)

- Develop HTS wire with 100 times the power capacity of conventional copper wires at a comparable cost ($/kiloamp-meter).
- Develop HTS electric power equipment with one-half the energy losses and one-half the size of conventional units.

Benefits

- ✓ **Congestion relief – transmit more power through a smaller footprint**
- ✓ **Efficiency – T&D system, large motors**
- ✓ **New capabilities – Fault current limiters, low impedance power lines control regional electricity flow**
- ✓ **Military – smaller motors enable improved naval ship design, smaller generators enable airborne non-lethal air force electromagnetic weapons**




Power Electronics (Switches) and Advanced Materials

- High voltage power electronics allow precise and rapid switching of electric power to support long distance transmission. This speed and precision will allow the system to more rapidly respond to system disturbances and allow the system to operate with lower margins and fewer constraints, thereby reducing the need for additional infrastructure.

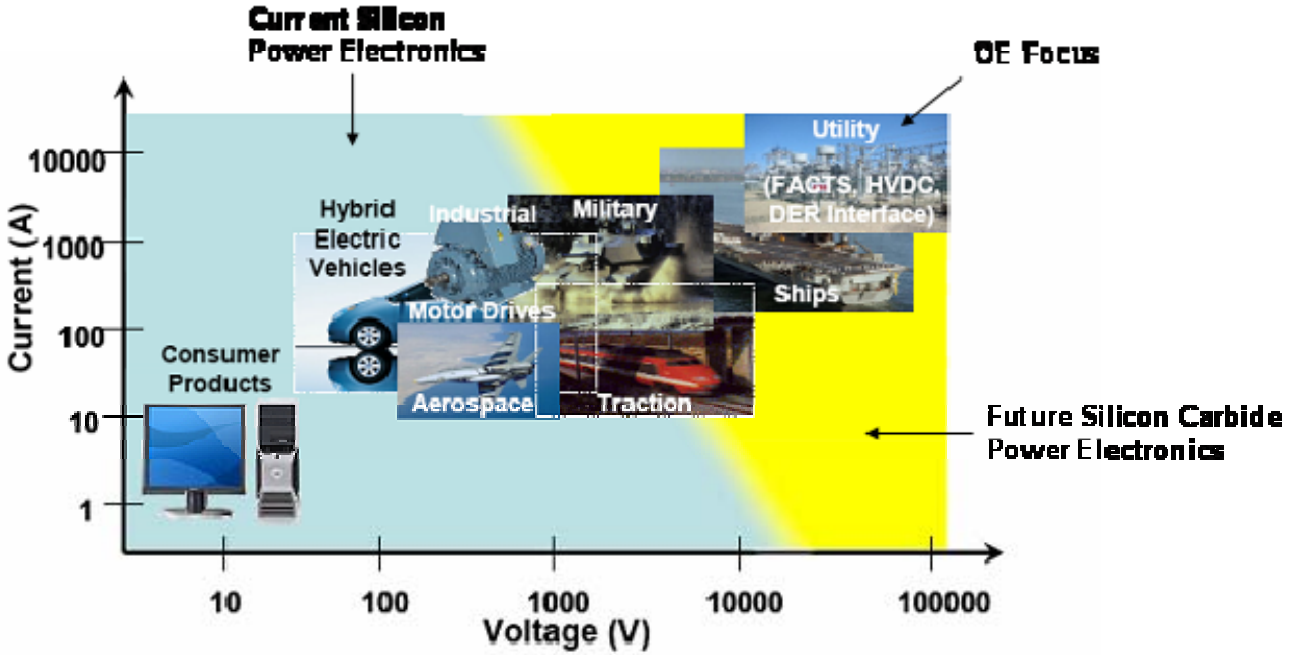


Fig. 1.2. Voltage and current rating for different power electronics application areas.

Distributed Systems Integration

- Involves development of advanced operational controls for greater interoperability and the seamless integration of distributed systems (generation and storage) with electric grid planning and operations
- Includes research, development, field testing, and demonstration of distributed systems for demand response and ancillary services
- Provides energy solutions for utilities, customers, and local energy systems such as district energy, power parks, and microgrids

Benefits

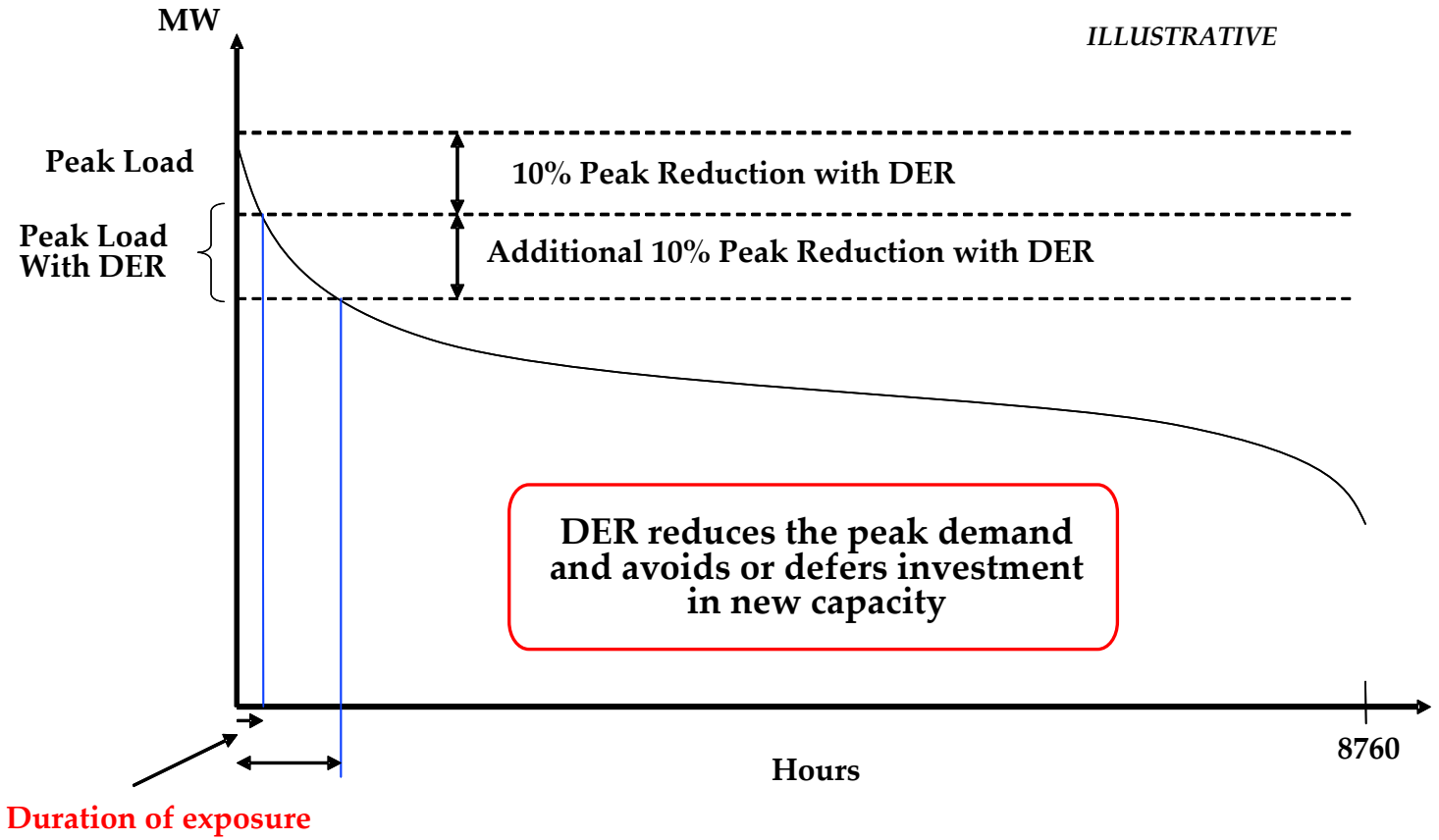
- ✓ Increases grid reliability
- ✓ Addresses vulnerability of critical infrastructure
- ✓ Helps manage peak loads and defers T&D investment
- ✓ Lowers emissions and utilizes fuel resources more efficiently
- ✓ Helps customers manage energy costs






DER Reduces Peak Demand on Grid

Eliminates or defers new transmission and distribution capacity, reduces congestion and decrease electricity prices and volatility



Grid Modernization is a Presidential Priority...

"...We have modern interstate grids for our phone lines and our highways. It's time for America to build a modern electricity grid."

President George W. Bush

April 27, 2005

...and now also a Congressional priority due to the Energy Policy Act of 2005

Key EPACT 2005 Provisions for Grid Modernization

Title IX – Research and Development

- Subtitle B – Distributed Energy and Electric Energy Systems
  - *Section 925 Electric T&D Programs RD&D*

Title XII - Electricity

- Subtitle A – Reliability Standards: Electric Reliability Organization
- Subtitle B – Transmission Infrastructure Modernization
  - *Section 1221 – Designation of National Interest Electric Transmission Corridors*
- Subtitle E – Amendments to PURPA
  - *Section 1252 – Smart Metering and Demand Response*

Title XVIII – Studies

- *Section 1817 – Study of Distributed Generation*

Section 925 Multi-Year R&D Plan

- **Develop a comprehensive five-year plan for research, development and demonstration program to ensure the reliability, efficiency, and environmental integrity of the electrical transmission and distribution system**
  - **Transmission and Distribution Grid Planning and Operations Initiative**
  - **Power Delivery Research Initiative**
  - **High-Voltage Transmission Lines (testing optimization techniques for power flow)**
  - **Distributed Generation**
- Workshop at Florida State University February 1-2, 2006
  - Obtain public/expert inputs
  - Draft due Spring 2006

Section 1252 (f)

Federal Encouragement of Demand Response

"It is the policy of the United States that time-based pricing and other forms of demand response….shall be encouraged, the deployment of such technology and devices….shall be facilitated, and unnecessary barriers to demand response participation in energy, capacity and ancillary service markets shall be eliminated."

Section 1817 Report on DG Benefits

- **Covers potential benefits to:**
  - **Increased system reliability**
  - **Improved power quality**
  - **The provision of ancillary services**
  - **Reductions in peak power requirements**
  - **Provision of reactive power**
  - **Offset investments in G,T, D**
  - **Diminished land use**
  - **Reduced vulnerability to terrorist attack**
- **Federal Register Notice to gather information and materials**
  - **Thanks to EPRI for submitted reports!**
- **Draft report for public comment due Summer 2006**