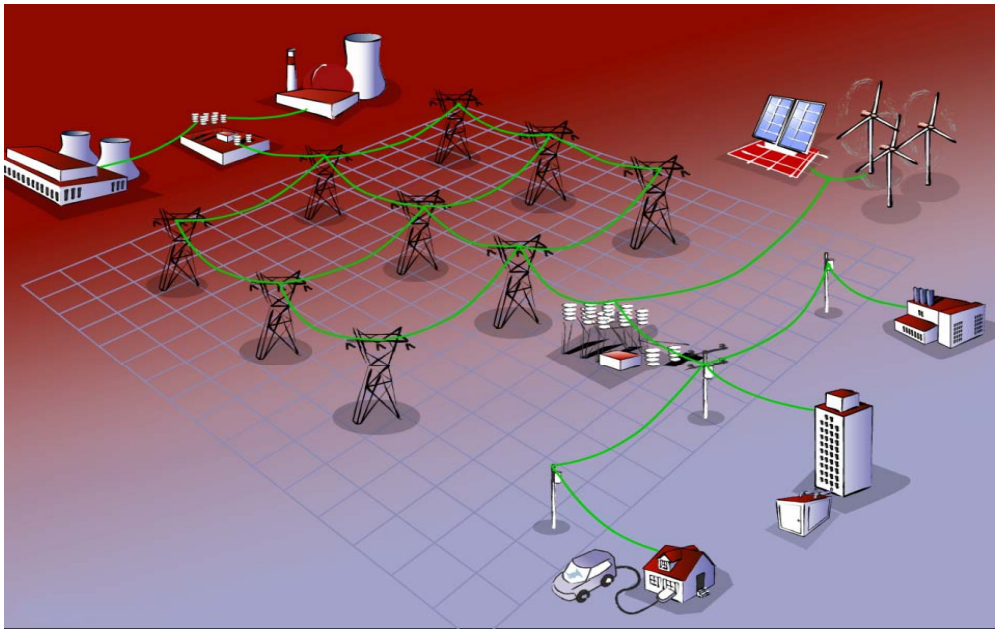
NATIONAL ENERGY TECHNOLOGY LABORATORY



Smart Grid Overview

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Topics

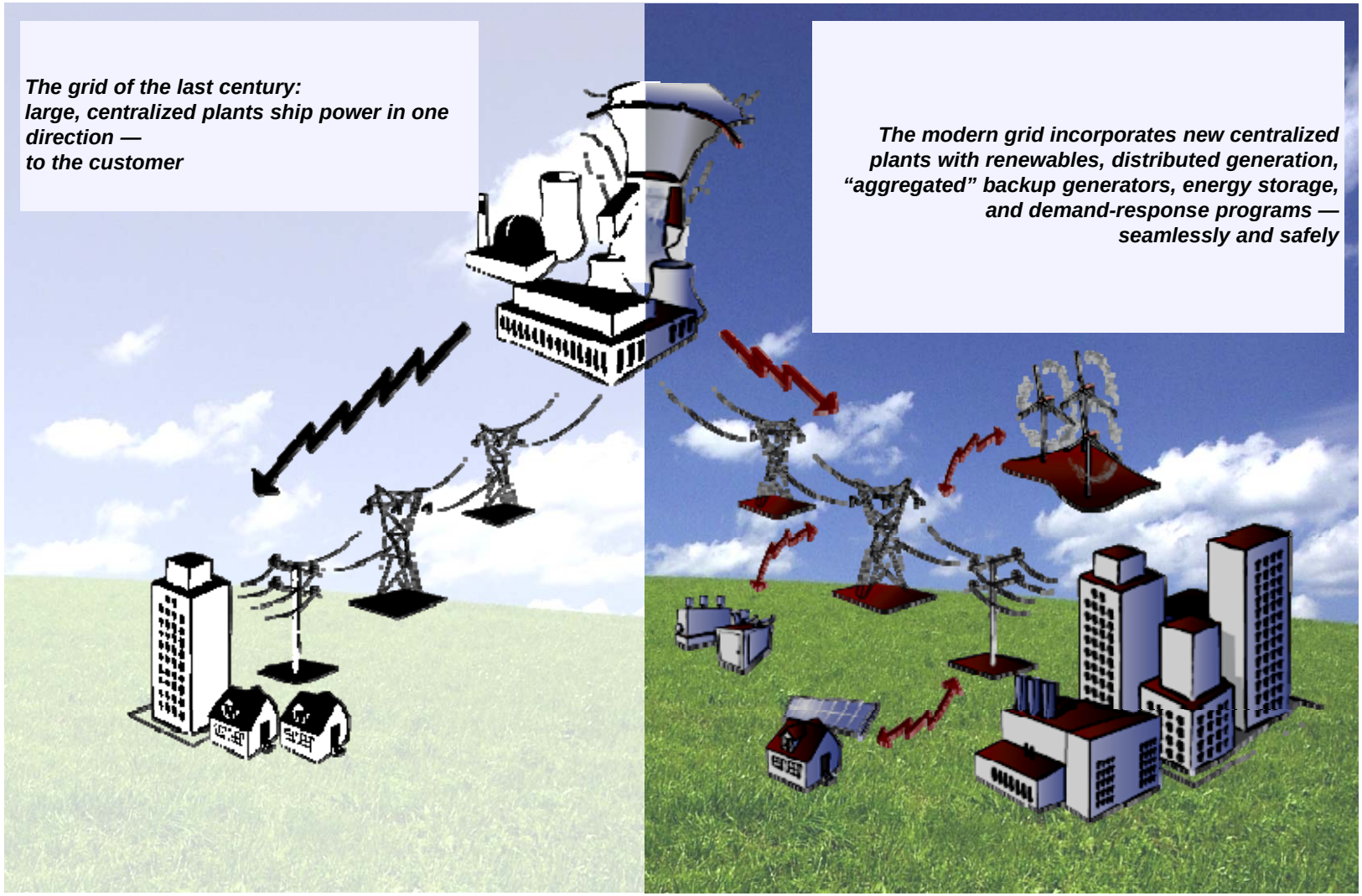
- The "Case for Action”
- What is the Smart Grid?
- The Systems View
- Performance Modes
- Principal Characteristics
- Key Technology Areas
- Metrics

Case for Action

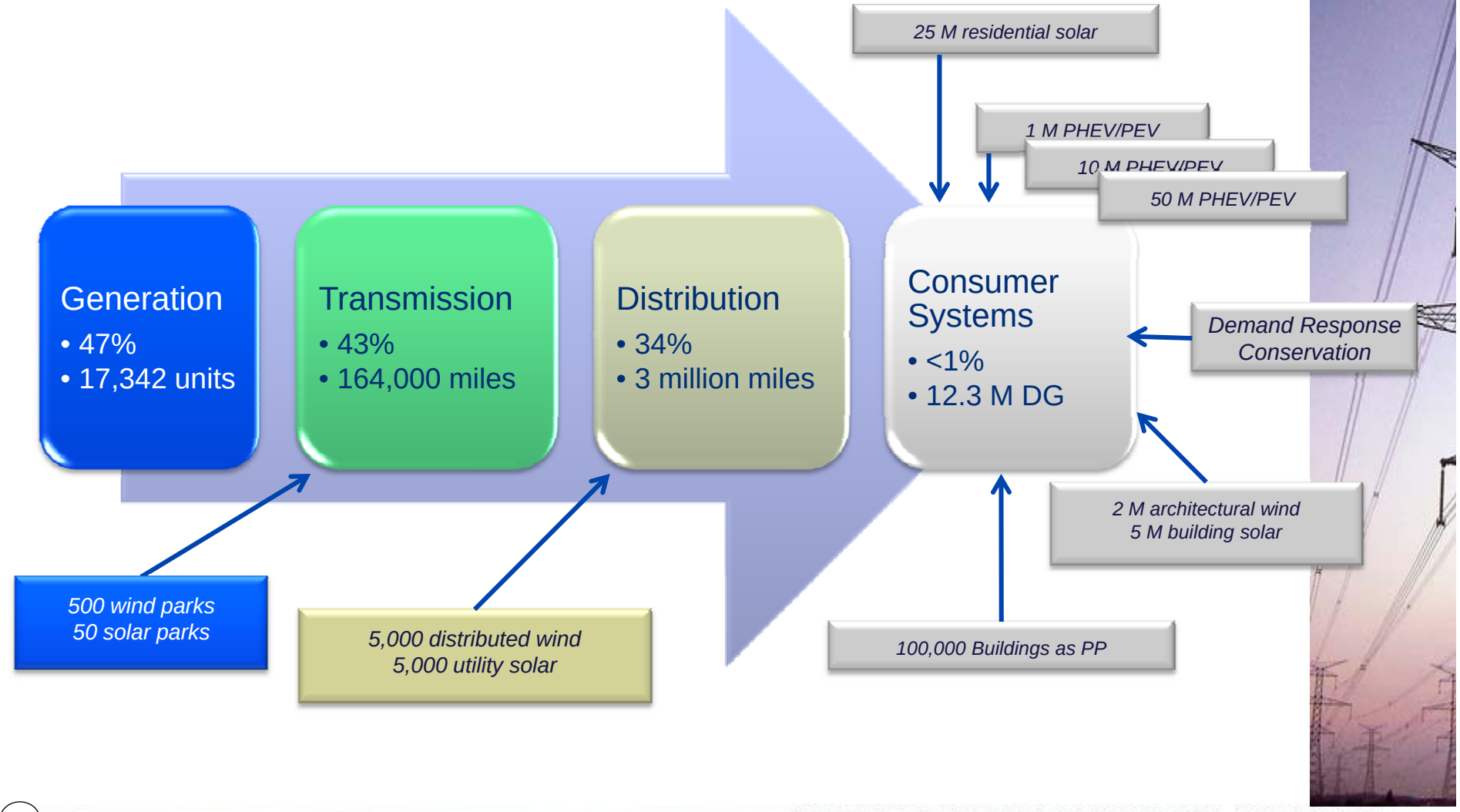
- Today's grid is aging and outmoded
- Unreliability is costing consumers billions of dollars
- Today's grid is vulnerable to attack and natural disaster
- An extended loss of today's grid could be catastrophic to our security, economy and quality of life
- Today's grid does not address the 21st century power supply challenges
- Missed opportunity to enjoy the benefits of a Smart Grid
- Disturbing trends in prices, reliability, peak loads, transmission congestion, & asset utilization

But is it worth it?

Smart Grid Supports 21st-Century Demand



The “Market” will create new stresses

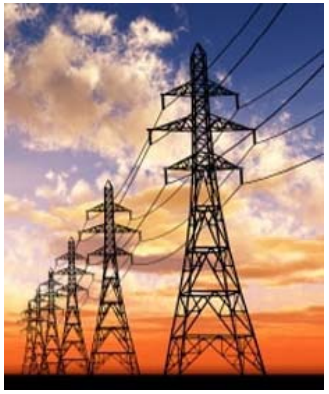


Electric Power System

Markets, System Operators and Communications

Generation and Storage

Transmission



Substations

Distribution & DER

Consumers & DER

The Systems View

Smart Grid Key Success Factors

The Smart Grid is MORE:

- Reliable
- Secure
- Economic
- Efficient
- Environmentally friendly
- Safe

Smart Grid Performance Modes

Some of the performance modes include:

- Emergency Response
- Restoration
- Routine Operations
- Optimization
- System Planning

Smart Grid Characteristics

Principal Characteristics of a Modern Grid:

- *Enable* active participation by consumers
- *Accommodate* all generation and storage options
- *Enable* new products, services, and markets
- *Provide* power quality for the digital economy
- *Optimize* asset utilization and operate efficiently
- *Anticipate & respond* to system disturbances (self-heal)
- *Operate* resiliently against attack and natural disaster

…the enabler

It will "Enable active participation by consumers"

- **Consumers have access to new information, control and options to engage in electricity markets**
  - Reduce consumption and energy bill
  - Enable new technologies (PHEV, HAN, EMS, smart appliances, etc.)
  - Sell resources for revenue or environmental stewardship
  - Incentives to participate (i.e. smart rates)
- **Grid operators have new resource options**
  - Reduce peak load and prices through demand response
  - Improve grid reliability
  - Ancillary services

Today	*Tomorrow*
Little or no info, limited use of smart pricing, few choices	**Full price info, choose from many plans, prices and options, buy and sell, "E-Bay"**

It will "Accommodate all generation and storage options"

- **Seamlessly integrates all types and sizes of electrical generation and storage systems**
- **"Plug-and-play" convenience**
  - Simplified interconnection processes
  - Universal interoperability standards
- **"Moves the needle"– shifts to a more decentralized model**
- **Large central power plants will continue to play a major role.**

Today	*Tomorrow*
Dominated by central generation. Little DG, DR, storage, or renewables	**Many "plug and play" distributed energy resources complement central generation**

It will "Enable new products, services and markets"

- **Links buyers and sellers – consumer to RTO**
- **Supports the creation of new electricity markets**
  - Demand Response
  - Energy, Capacity, Ancillary Services
  - Brokers, integrators, aggregators, etc.
  - In-home devices and applications
- **Provides for consistent market operation across regions**

Today	*Tomorrow*
Near-zero market interaction at distribution level	**Distribution assets and consumers act as resources for transmission, growth of new secondary markets**

It will "Provide power quality for the digital economy"

- **Monitors, diagnoses and responds to PQ issues**
- **Supplies various grades of power quality at different pricing levels**
- **Greatly reduces consumer losses due to PQ (~$25B/year)**
- **Quality Control for the grid**

Today	*Tomorrow*
Focus on outages not power quality	**PQ a priority with variety of price/quality options based on needs**

It will "Optimize asset utilization and operate efficiently"

- **Operational improvements**
  - Improved load factors and lower system losses
  - Integrated outage management
  - Risk assessment
- **Asset Management improvements**
  - The knowledge to build only what we need
  - Improved maintenance processes
  - Improved resource management processes
  - More power through existing assets
- **Reduction in utility costs (O&M and Capital)**

Today	*Tomorrow*
Limited grid information & minimal integration with asset management	**Deep integration of grid intelligence enabling reduction in O&M and CapEx**

It will "Anticipate & respond to system disturbances"

- **Performs continuous self-assessments**
- **Detects, analyzes, responds to, and restores grid components or network sections**
- **Handles problems too large or too fast-moving for human intervention**
- **Self heals - acts as the grid's "immune system"**
- **Supports grid reliability, security, and power quality**

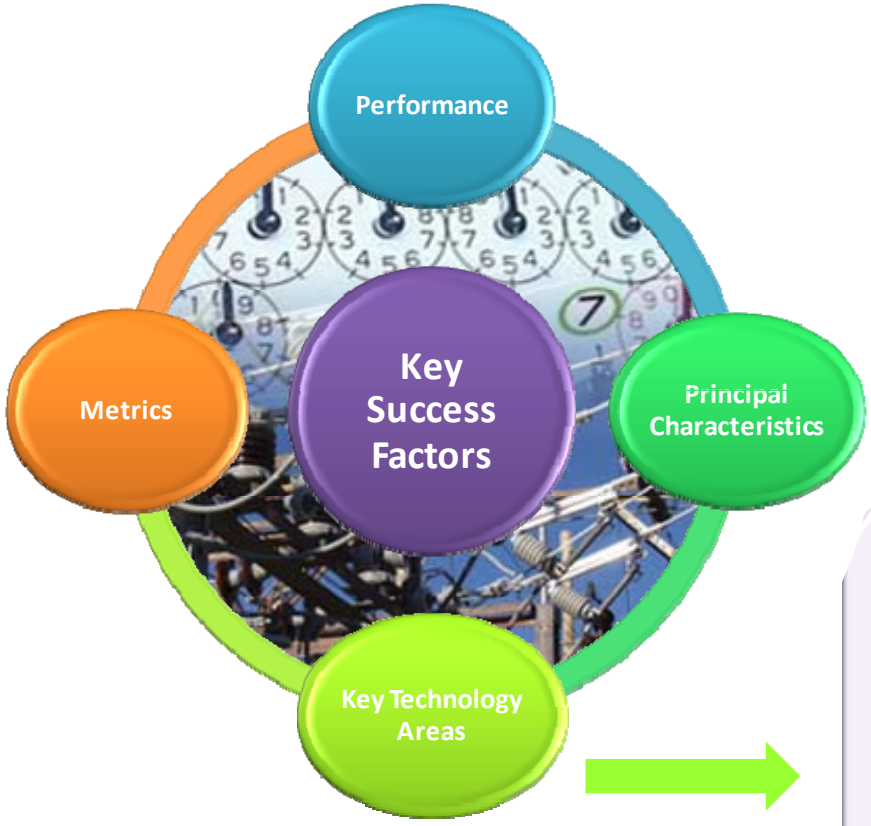
Today	*Tomorrow*
Protects assets following disruption (e.g., trip relay)	**Prevents disruptions, minimizes impact, restores rapidly**

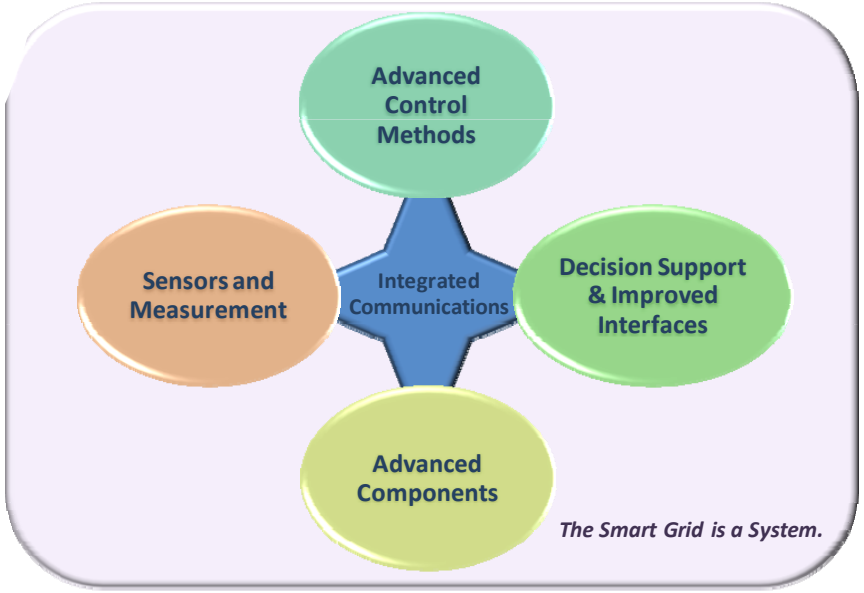
It will "Operate resiliently against attack and natural disaster"

- **System-wide solution to physical and cyber security**
- **Reduces threat, vulnerability, consequences**
- **Deters, detects, mitigates, responds, and restores**
- **"Fort Knox" image**
- **Decentralization and self-healing enabled**

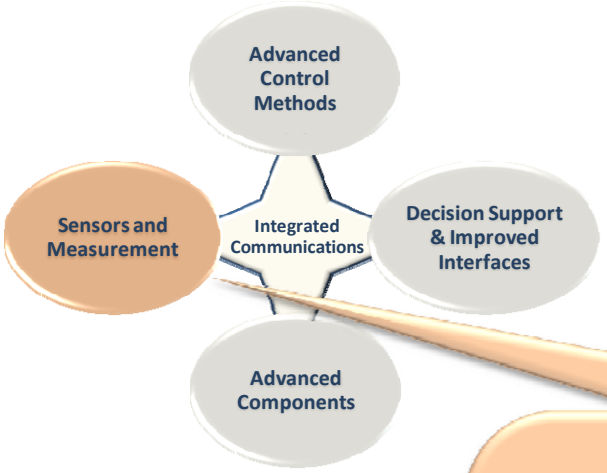
Today	*Tomorrow*
Vulnerable to terrorists and natural disasters	**Deters, detects, mitigates, and restores rapidly and efficiently—"cyber proof"**

Key Technology Areas





Sensors and Measurement



Smart meters

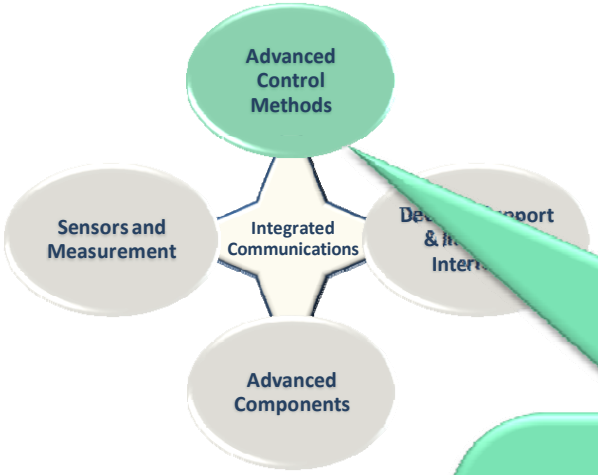
Smart sensors

- *Operating parameters*
- *Asset Condition*

Wide area monitoring systems (WAMS)

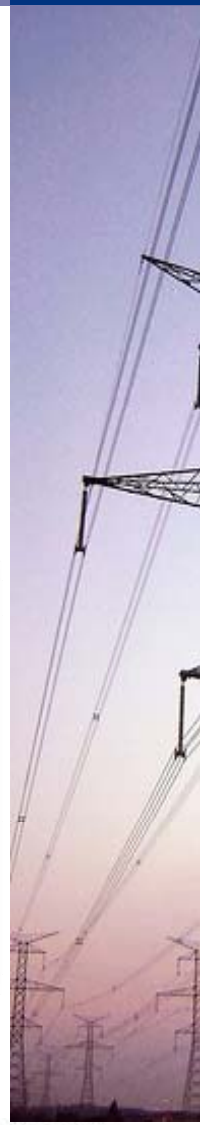
Dynamic rating of transmission lines

Advanced Control Methods

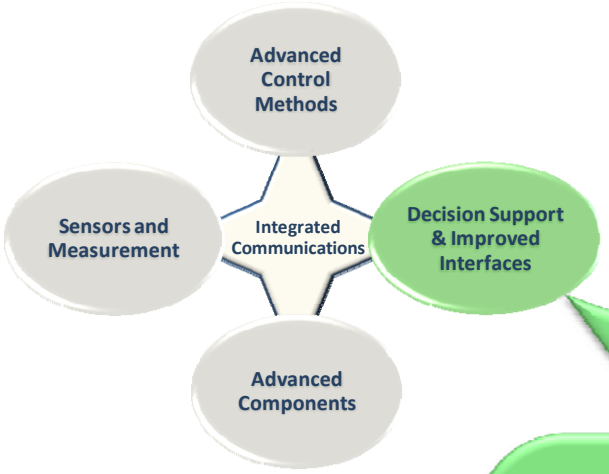


Applications that:

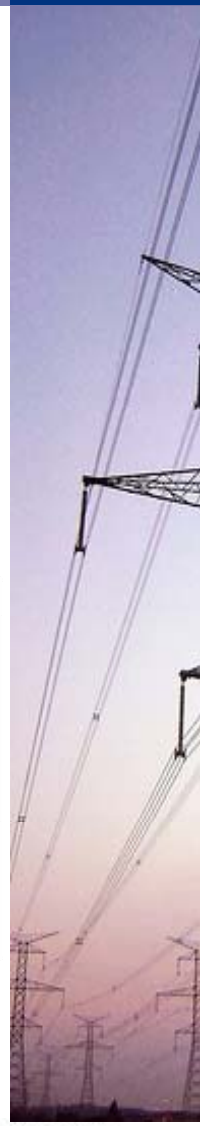
- *Monitor and collect data from sensors*
- *Analyze data to diagnose and provide solutions*
- *Real time and predictive*
- *Determine and take action autonomously or via operators*
- *Provide information and solutions to operators*
- *Integrate with enterprise-wide processes and technologies*



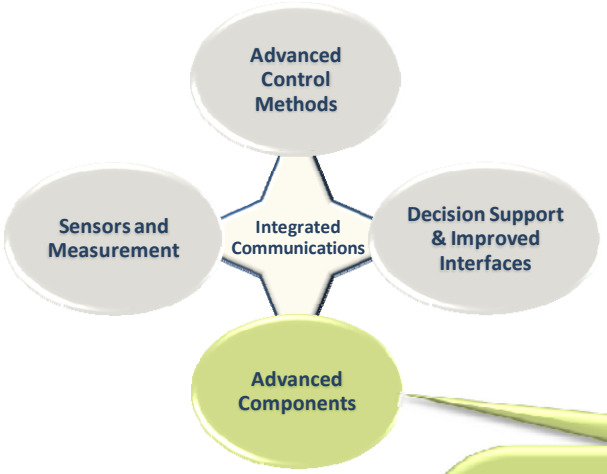
Decision Support & Improved Interfaces



Data reduction
Data to information to action
Visualization
Speed of comprehension
System operator training

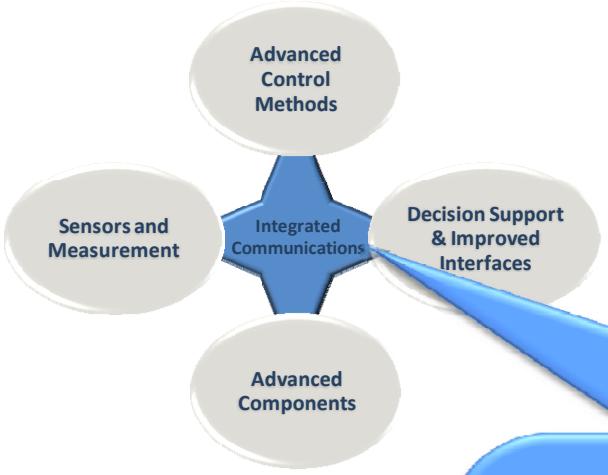


Advanced Components



Next generation FACTS/PQ devices
Advanced distributed generation and energy storage
PHEV - V2G mode
Fault current limiters
Superconducting transmission cable & rotating machines
Micro-grids
Advanced switches and conductors

Integrated Communications



Consider all needs:

- *Smart meters*
- *Smart sensors*
- *Demand Response*
- *DG dispatch*
- *Distribution automation*
- *Micro-grids*
- *Markets*
- *Work force management*
- *Mobile premises (PHEV's)*

Smart Grid Metrics

- **Metrics are needed to measure progress in achieving the vision.**
  - Build metrics are leading indicators and measure progress in the implementation of the Smart Grid.
  - Impact metrics measure how the Smart Grid influences the Key Success Factors.

If we do this right – we can all be winners
- ***Suppliers***
- ***Consumers***
- ***Society***

Value Proposition

- Utilities (What's in it for my shareholders?)
  - Rate of return, outage restoration, billing, reduce T&D losses, optimize asset utilization, maintenance, planning and improved customer satisfaction
- Consumers (What's in it for me?)
  - More reliable service, reduce business loss, energy bill savings, transportation cost savings, options, sell resources into the market
- Society (What's in it for us?)
  - Rate Downward pressure on prices, improved reliability, grid robustness, new jobs and growth in GDP, revolutionize the transportation sector and reduce import of foreign oil.
- Overall benefit to cost ratio is 4:1 to 5:1

For More Information

For additional Information:
www.netl.doe.gov/smartgrid

Federal Smart Grid Website
www.smartgrid.gov

Smart Grid Information Clearinghouse
www.sgiclearinghouse.org

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