University of Bologna

Smart Grid: An Enabler

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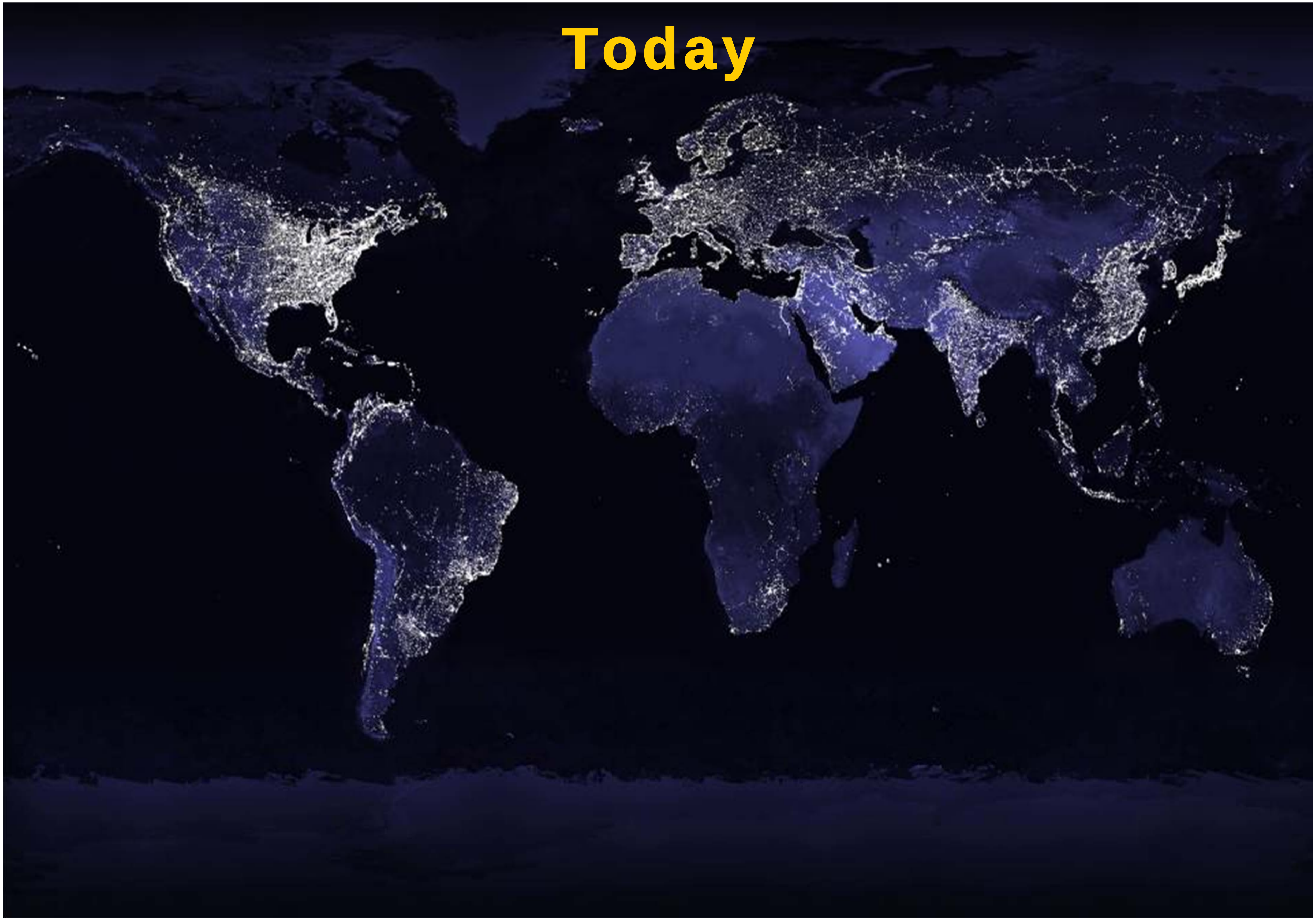
Overview

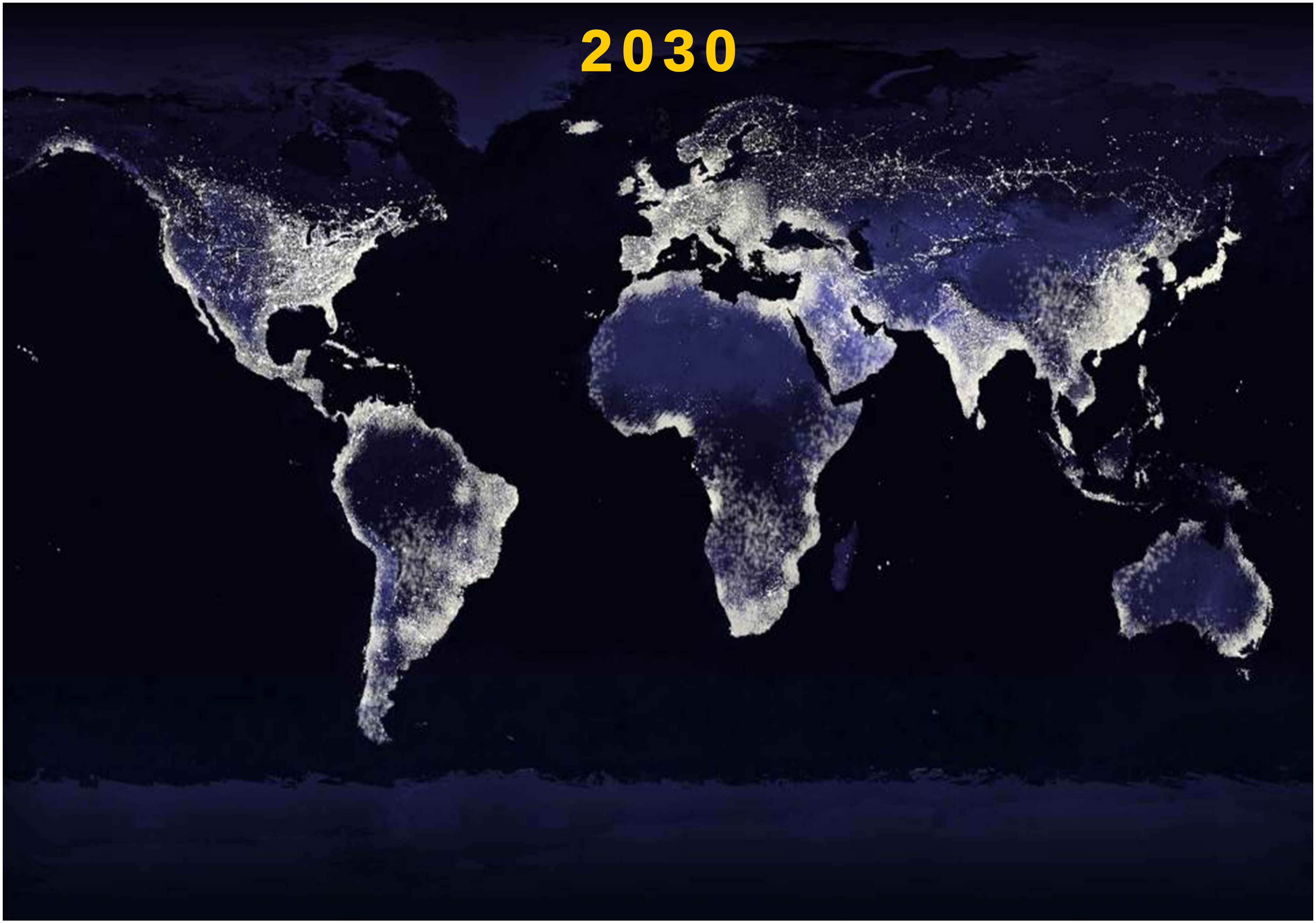
- S&C Electric Company
- Changing Power & Energy World
- Challenges and Opportunities
- Smart Grid Technologies
- Operational Framework
- Positioning for Success

S&C Electric Company

- Headquartered in Chicago, USA
- Operations in:
  - United States
  - Canada
  - Mexico
  - Brazil
  - China
  - United Kingdom
  - Australia
- 2500 employees
- Founded 1911
- Employee-owned as of 2007

S&C Electric Company
John R. Conrad Industrial Campus
Chicago, Illinois


Today


2030

Recognizing the need for Power

- Consumer electronics represent the largest single use for domestic electricity
- Computers and gadgets will account for 45% of electricity used in the home by 2020
- Increases demand for near-perfect power quality and uninterrupted power availability

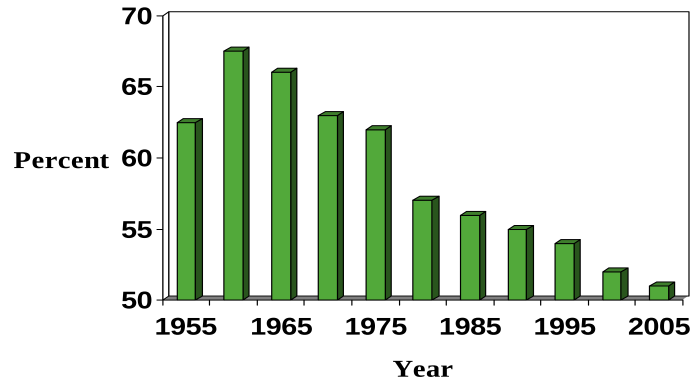
Sources: “The Ampere Strikes Back: How Consumer Electronics Are Taking Over The World,” Energy Saving Trust, June 2007; “The Rise of The Machines: A Review of Energy Using Products In The Home From The 1970s to Today” Energy Saving Trust, June 2006; “Electric Power – The Next Generation: The Intelligent Grid,” CenterPoint Energy, April 2007

And, the Response

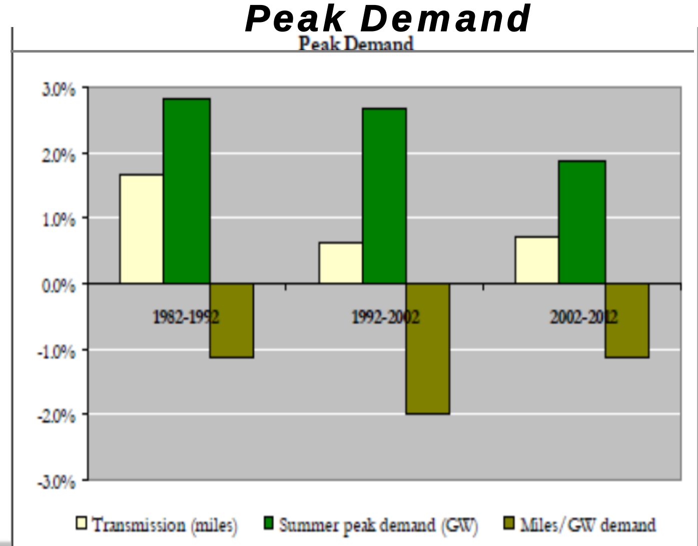
- Business as usual . . .
  - Losses are 7% to 15% in the grid and much more with generation
  - Generation ~50-70% of capacity
  - Spinning reserve drops efficiency
  - Declining US load factor on the grid
- Investments lag peak growth
  - Makes peak difficult to manage
  - Creates vulnerability
  - Living with operational risk
    - *Conservatism built in*
    - *Grid grossly underutilized*
    - *Peaks occur ≤ 1% of the time*

United States
Declining Load Factor
Load Factor = Avg. Load / Peak Load

EPRI and IEA data



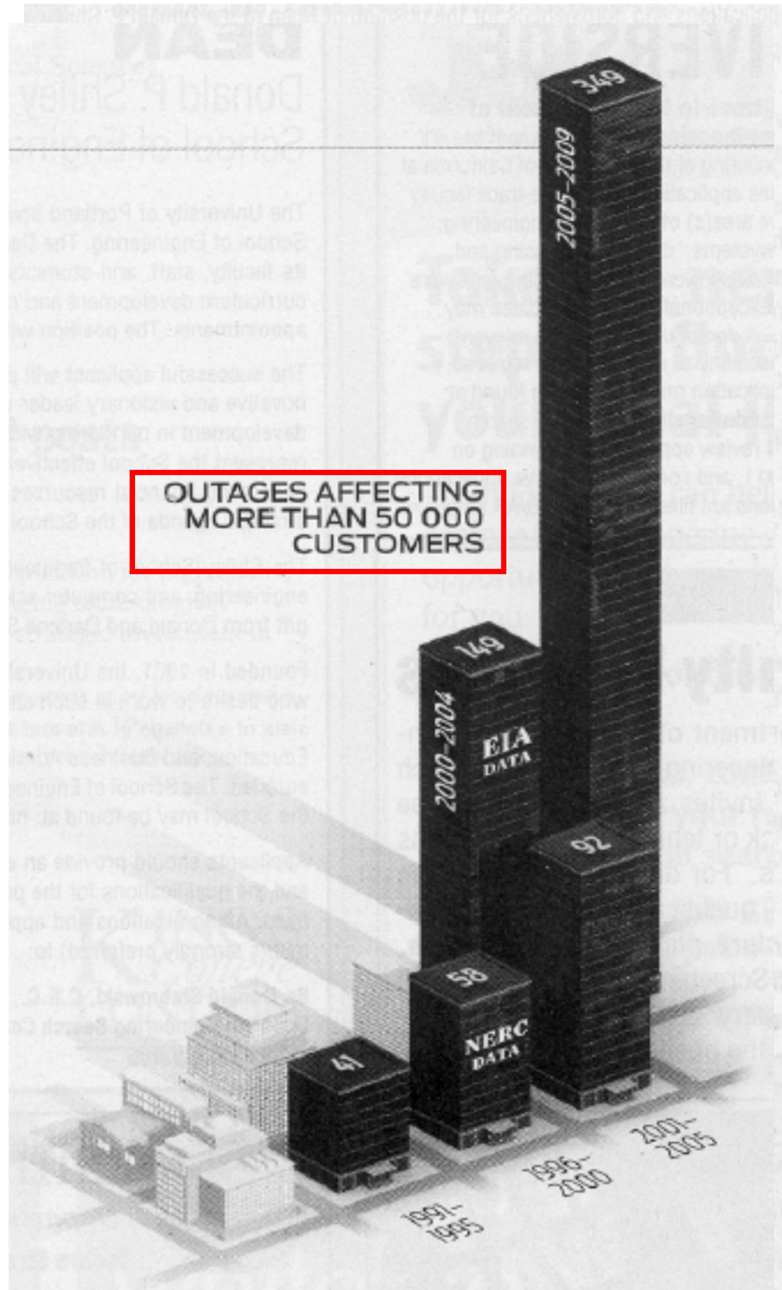
United States
Annual Average Growth in Transmission vs Summer Peak Demand



The Ramification

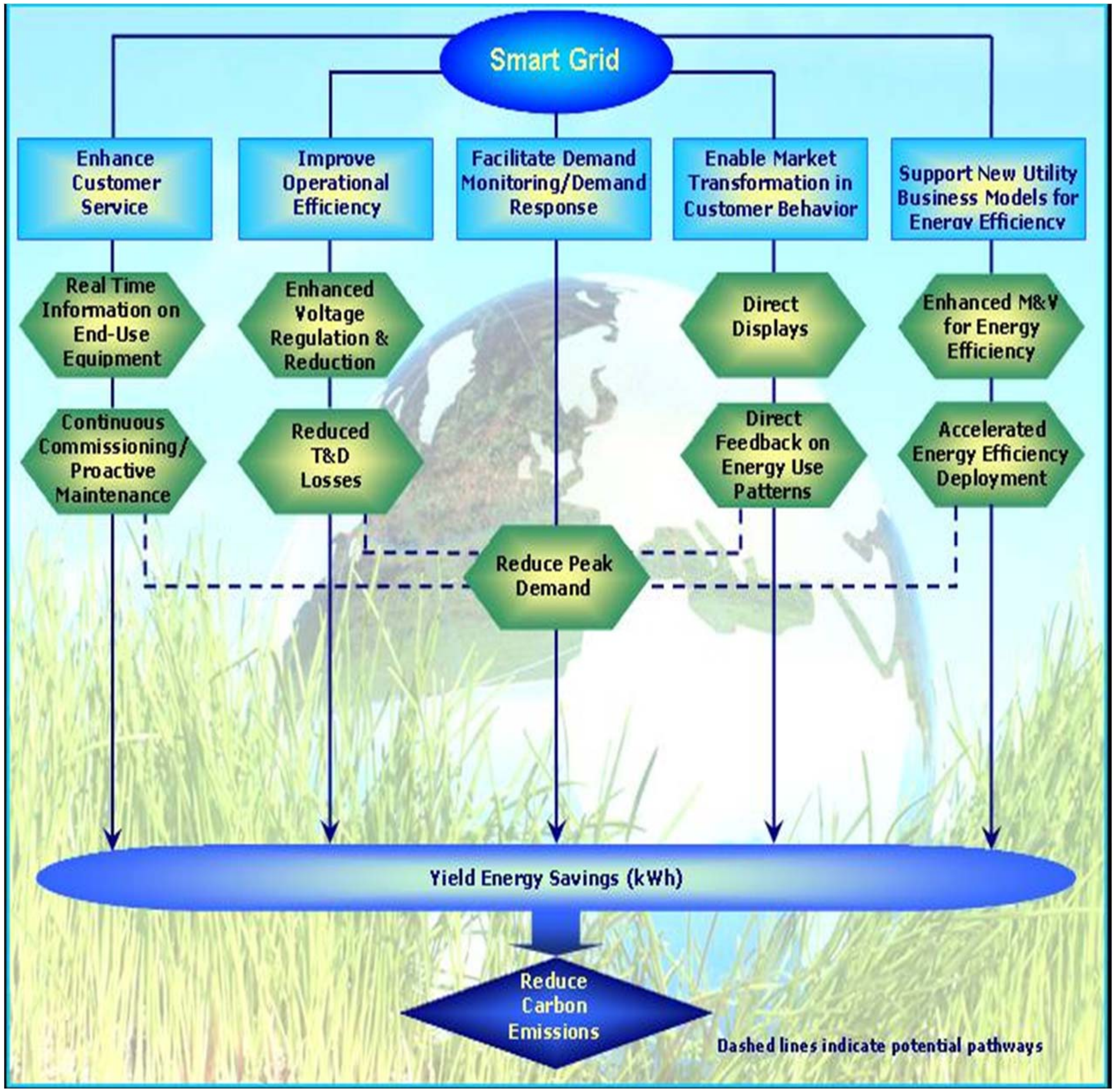
- Depreciation outpaces construction
- Assets are aging
- R&D spending is limited
- US outages up over last 15 years

- Grid modernization is inevitable
- Need to invest "intelligently"



Smart Grid: a Green Grid

- Smarter Grid utilization will defer new capacity *and* reduce carbon output…
- Initial estimated annual energy savings:
  - 37 – 194 billion kWh
  - Like 24 – 126 million metric tons of CO_2
  - Like removing 4 to 20 million cars off the road



The US and Others Around the Globe

- **United States**
  - Investing ~$7 Billion in Smart Grid
  - Standards framework in development
- **China**
  - Investing $7.3 billion; will spend $96 billion in by 2020
  - Energy needs to double to 2020
  - Will account for 18.2% of the global smart grid appliance spending by 2015
- **South Korea**
  - Investing nearly $1 Billion
  - $65M pilot for 6000 homes on Jeju island
  - Nationwide deployment by 2030
- **Brazil**
  - Forecasting 60% growth in electricity consumption between 2007 and 2017
  - 16-34% increase in renewables
  - Transforming to two-way power flow

Source: Massoud Amin, University of Minnesota

What *Does* Smart Grid Mean???

Seven characteristics (as defined by US DOE)

1. Enable Active Participation by Consumers
2. Accommodate All Generation and Storage Options
3. Enable New Products, Services and Markets (internet model)
4. Provide Power Quality for the Digital Economy
5. Optimize Asset Utilization and Operate Efficiently
6. Anticipate & Respond to System Disturbances *(Self-Heal)*
7. Operate Resiliently Against Attack and/or Natural Disaster

Source: DOE Modern Grid Initiative

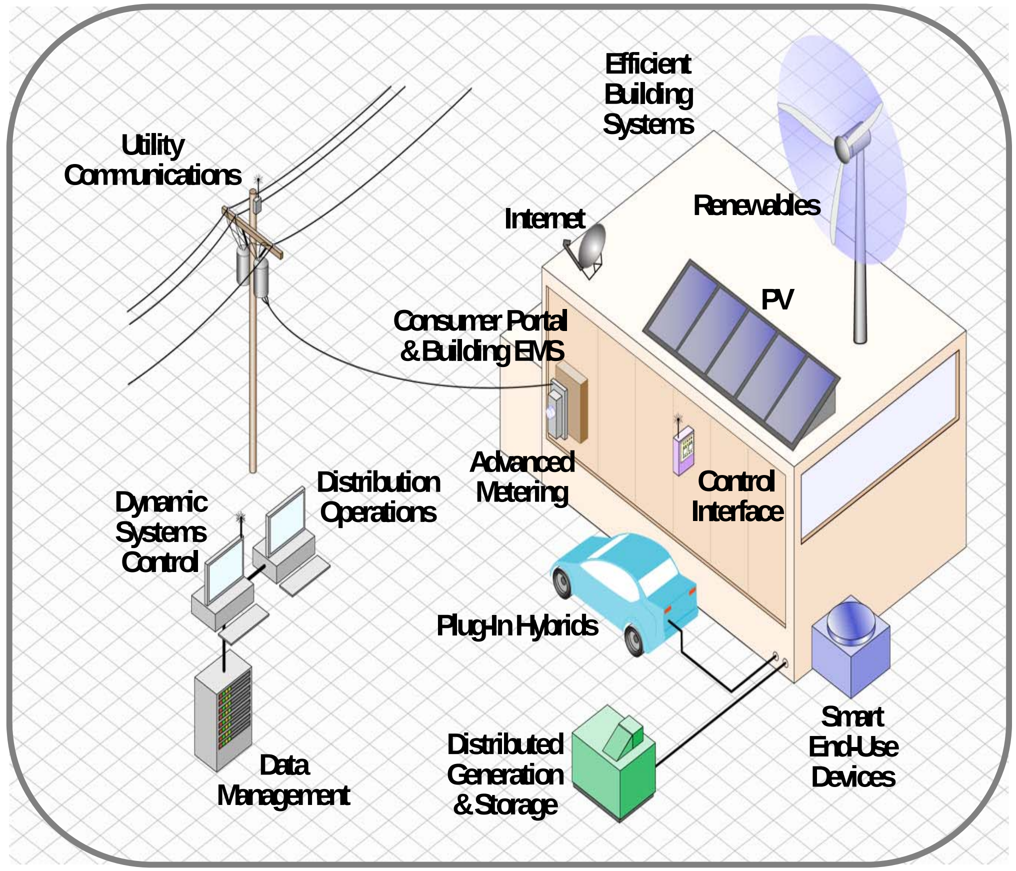
Business is Changing

Then:	Future:
Regulated business models	Emerging “customer choice”
Large generation stations	Distributed & green resources
Centralized dispatch	Distributed intelligence
Minimal constraints	Pressures for “green power”
Outages “tolerated“	Less tolerance of outages
Grid “over designed”	Infrastructure exhausted
Radial distribution	Looped or meshed distribution
Homogeneous technology	Mixing old with new
Slow distribution operations	Near real-time micro-grids
Uni-directional powerflow	Multi-directional powerflow

Distributed Energy Resources (DER)

- Sporadic nature
  - Variable output
  - Not-utility controlled
  - Capable of islanding

- New distribution sources
  - Meshed networks where parallels become the norm
  - Multi-directional flow adds complexity
    - Protection schemes
    - Safety issues
    - Fault analysis
    - N and N-1 Planning



New Smart Grid Technologies

- More intelligent components/equipment
  - Locally automated switching schemes
  - Locally automated Volt-Var schemes

- Increased observations available
  - Real-time - AMI, Intelligent Devices
  - Historical – Advanced Data Analytics

- Communications will be ubiquitous
  - Public vs. Private Infrastructure
  - RF-Mesh, WiMax, WiFi, GPRS,

Intelligent Grid


Energy Feedback Devices

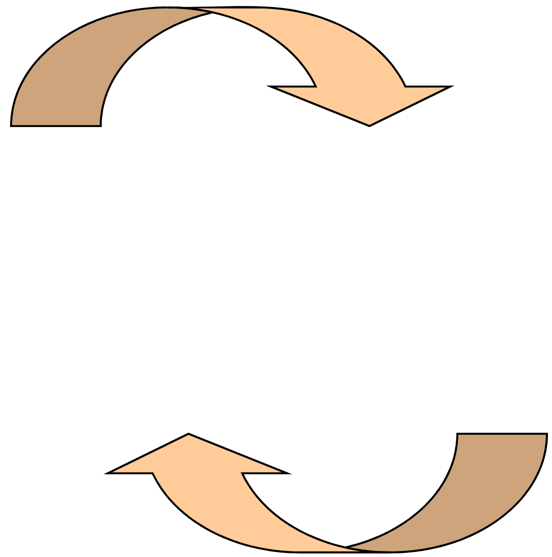


Efficient Lighting



Operations Needs Distributed Intelligence

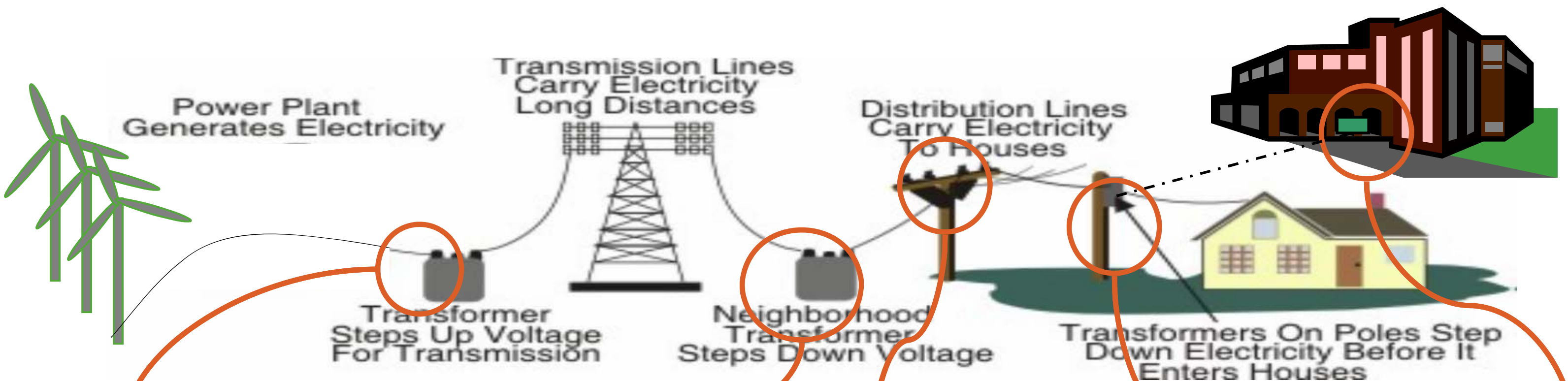
- Less Certainty:
  - Electric vehicles
  - Consumer generation
  - Consumer response
  - Variable renewables
  - Transmission constraints



- More Choices:
  - Negawatts
  - Distributed generators
  - Imports
  - Storage

- Less Time to React:
  - Automatic sensing
  - Dynamic activity
  - Distributed intelligence and control

Smart Grid Realities



Reactive Compensation

Substation Batteries 10's of MW

Distributed Intelligence and Control

Storage at Grid Edge 10's of kW

Micro-grids

Reactive Grid Codes

- Capability of synchronous generators forms basis for wind interconnection requirements
- FERC Order 661A is a USA grid code:
  - Low voltage ride-through (LVRT)
    - Generator stays on line during a 3 phase fault with normal fault clearing and subsequent post fault voltage recovery
  - Voltage support and dynamic reactive power
    - Power factor of +/- .95 with dynamic voltage support
  - SCADA compliance as agreed

- Grid codes may vary: they drive the need for dynamic, reactive power compensation

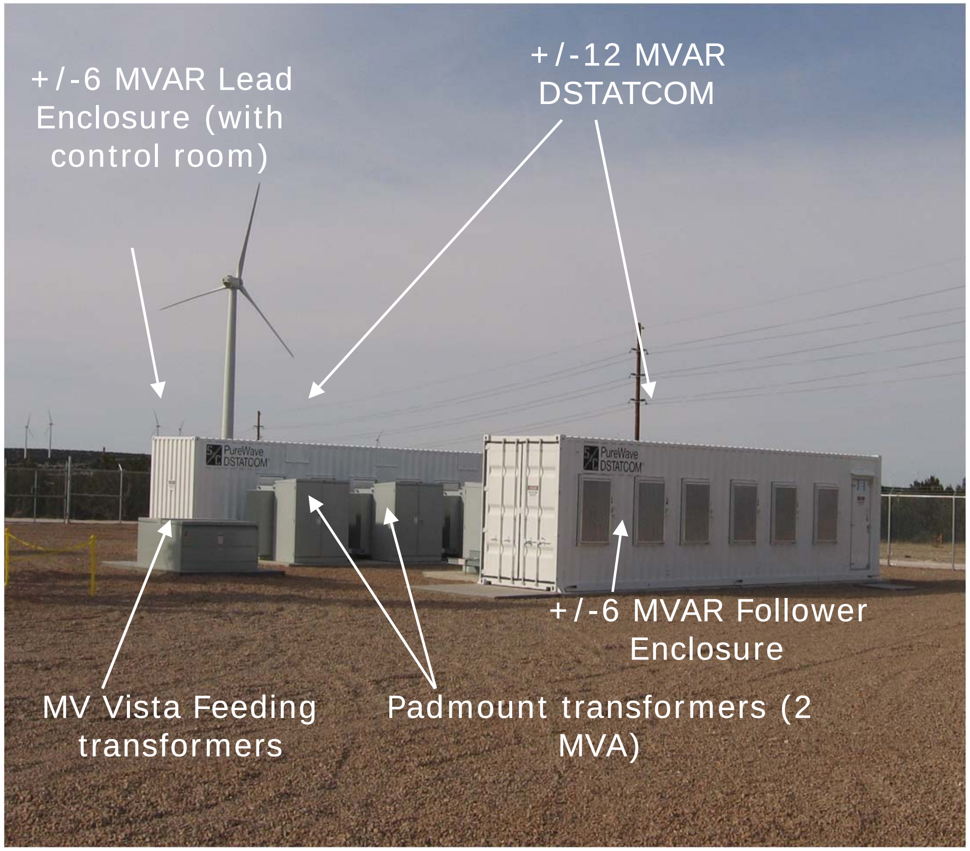
Reactive Power Compensation

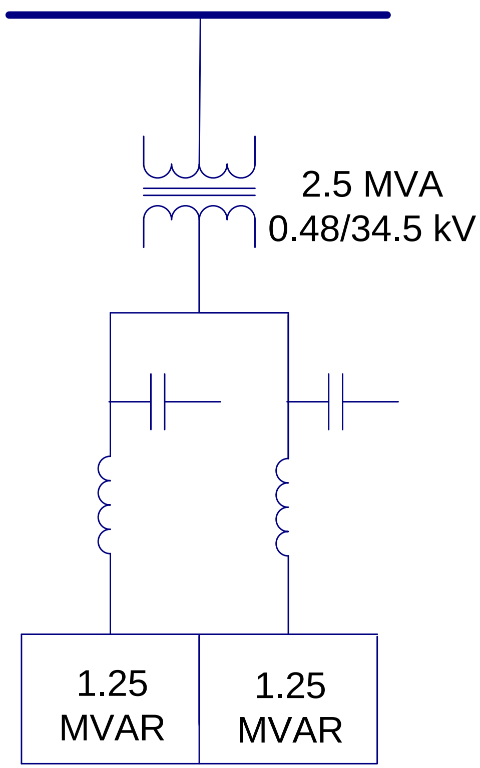
- Substation-based compensation systems
  - Mechanically-switched capacitors and reactor banks
  - Static Var Compensators
  - Hybrid compensators

- Inverter-based dynamic component
  - Modules provide reactive support for 2 - 4 seconds for LVRT and dynamic range
  - Use with mechanically switched devices

+/- 12 MVAR for 90 MW Wind Park in New Mexico, USA. Also includes 91 MVAR of switched capacitors.

Reactive Compensation Installation





1.25 MVAR modules provide 264% of continuous rating for 2 to 4 seconds

Substation Batteries: Energy Storage

- Energy Storage Benefits
  - Cost deferral of new substations
  - Improved service reliability
  - Less stress on aging infrastructure
  - Integration of renewable energy
  - Energy market value
  - Frequency regulation

- Approval challenge
  - Wide array of benefits
  - Asset classification / jurisdiction

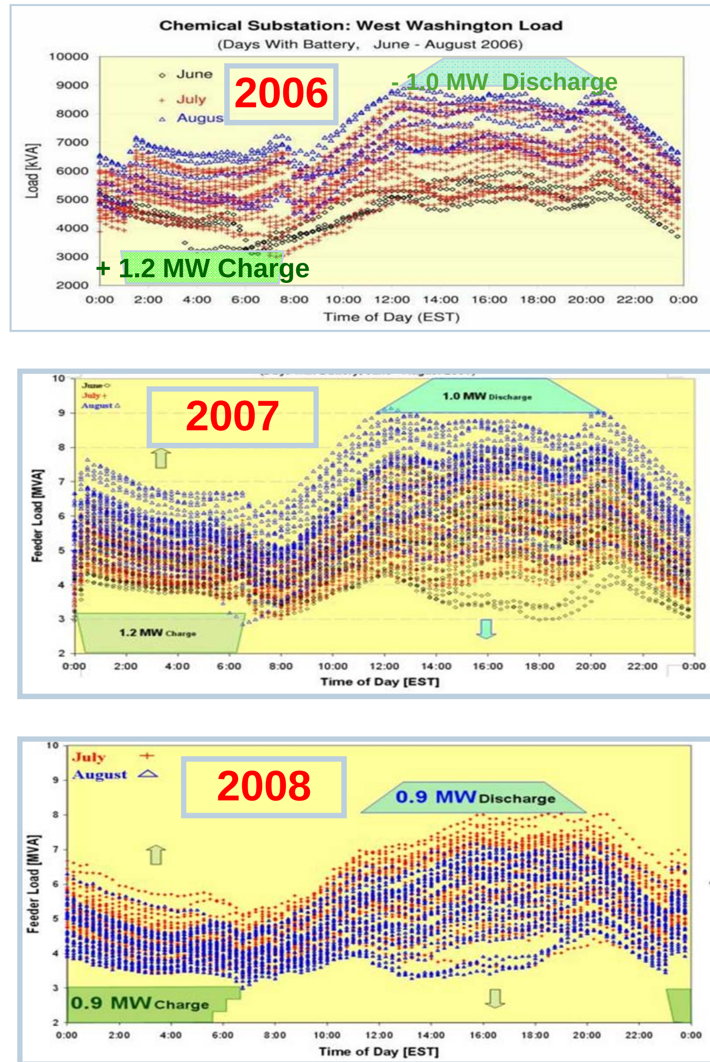
Luverne, MN
NaS Battery Installation
1.0 MW for 6 hours
Used for wind farm smoothing to facilitate dispatched wind and peak shaving

AEP NaS Battery – Charleston, WV

- 1.0 MW, 7.2 MWh at Chemical Substation
- Stores energy off-peak to battery
- Reduces substation peaks
- Technology demonstration project
- Deferred 20 MVA transformer replacement
- In service in 2006: demonstrated results year-over-year
- More details in DOE/Sandia report (SAND2007-3580)

Performance Results

Load-leveling impact of 1-MW substation electricity storage on a 10 MW feeder load

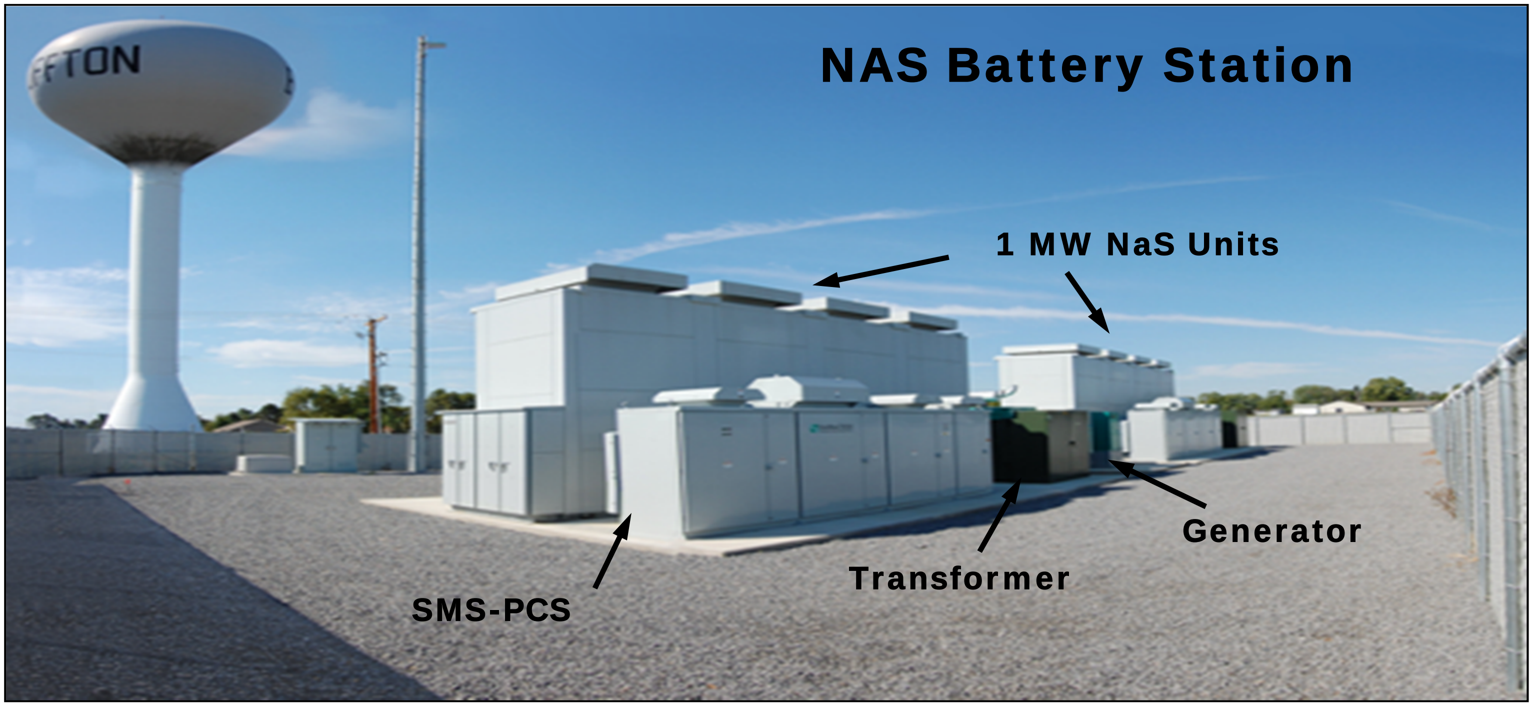


- Reduction in peak load and increase of the off-peak load in 2006. Similar results thereafter.
- Scheduled trapezoidal charge & discharge profiles
- Improved the feeder load factor by 5% (from 75% to 80%)
- Reduced the oil temperature of the 20 MVA supply transformer by about 4 degrees C

AEP Bluffton, OH

Distributed Energy Storage System – Sodium Sulfur Battery Installation

- 2.0 MW, 14.4 MWH outdoor installation in Bluffton, Ohio
- Includes dynamic islanding and triggered peak shaving
- Generator for heater backup power
- Two other identical sites in West Virginia and Indiana



Energy Storage with Dynamic Islanding

- Load information is captured by IntelliTeam II devices
- Dynamic islanding when power is lost
- The maximum number of customers are restored by the battery based upon:
  - Last load information
  - Energy in the battery
- Island is minimized as the battery depletes
- Customer load is served until battery is exhausted or power is restored

IntelliRupter

Self Powered, Self Contained, Fault-Interrupting Switch

Community Energy Storage

CES is a small distributed energy storage unit connected to the secondary of transformers serving a few houses or small commercial loads:

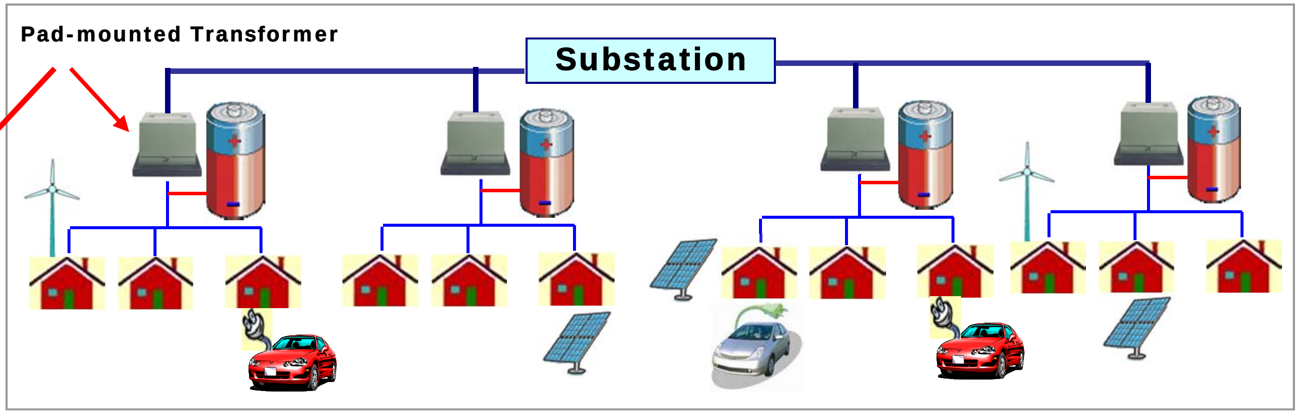
- Local voltage regulation
- Peak shaving
- Buffer plug-in vehicles
- Aggregate control

Key Parameters	**Value**
Power (active and reactive)	25 kVA
Energy	25 - 75 kWh
Voltage - Secondary	240 / 120V
Battery - PHEV	Li-Ion

Smooth effects of distributed sources, improves reliability, reduce losses, improves grid utilization

Community Energy Storage

- Improved reliability and efficiency
- Voltage sag mitigation and emergency transformer load relief
- When aggregated, it provides multi-MW over multi-hour
- Possible savings with volume from Plug-in Hybrid Vehicles



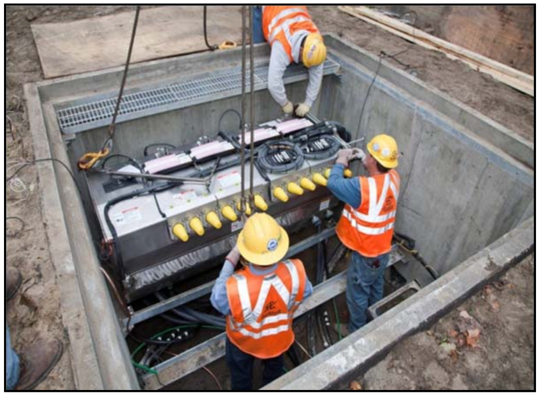
Community Energy Storage Units are installed on the low side of the pad mounted transformer

Community Energy Storage

- Example of distributed intelligence
- For peak shaving, islanding, load following, grid support
- Who will own it, manage it, pay for it?

Micro-Grid Solution

- High Speed Fault Clearing System is a non-interruptible micro-grid technology for underground distribution systems
- Main loop faults are cleared using:
  - High-speed communications
  - Fault interrupter switchgear tripping
- Maximum 6 cycle fault clearing time
- A fault on a backbone segment is automatically isolated; power flow to loads continues uninterrupted
- SCADA is not required for protection



High Speed Fault Clearing System designed for a non-interrupting underground applications

Specially configured Remote Supervisory Vista Underground Distribution Switchgear

Distributed Distribution Intelligence

- Quickly re-configures to isolate outages
- Uses Low-Energy pulse sensing to identify and react which reduces energy pushed thru circuit components by 98%
- Can be integrated with other devices
- Simple installation
- Builds intelligence for the future
  - Dynamic islanding, sensing

IntelliRupter: Self Powered, Self Contained, Fault-Interrupting Switch

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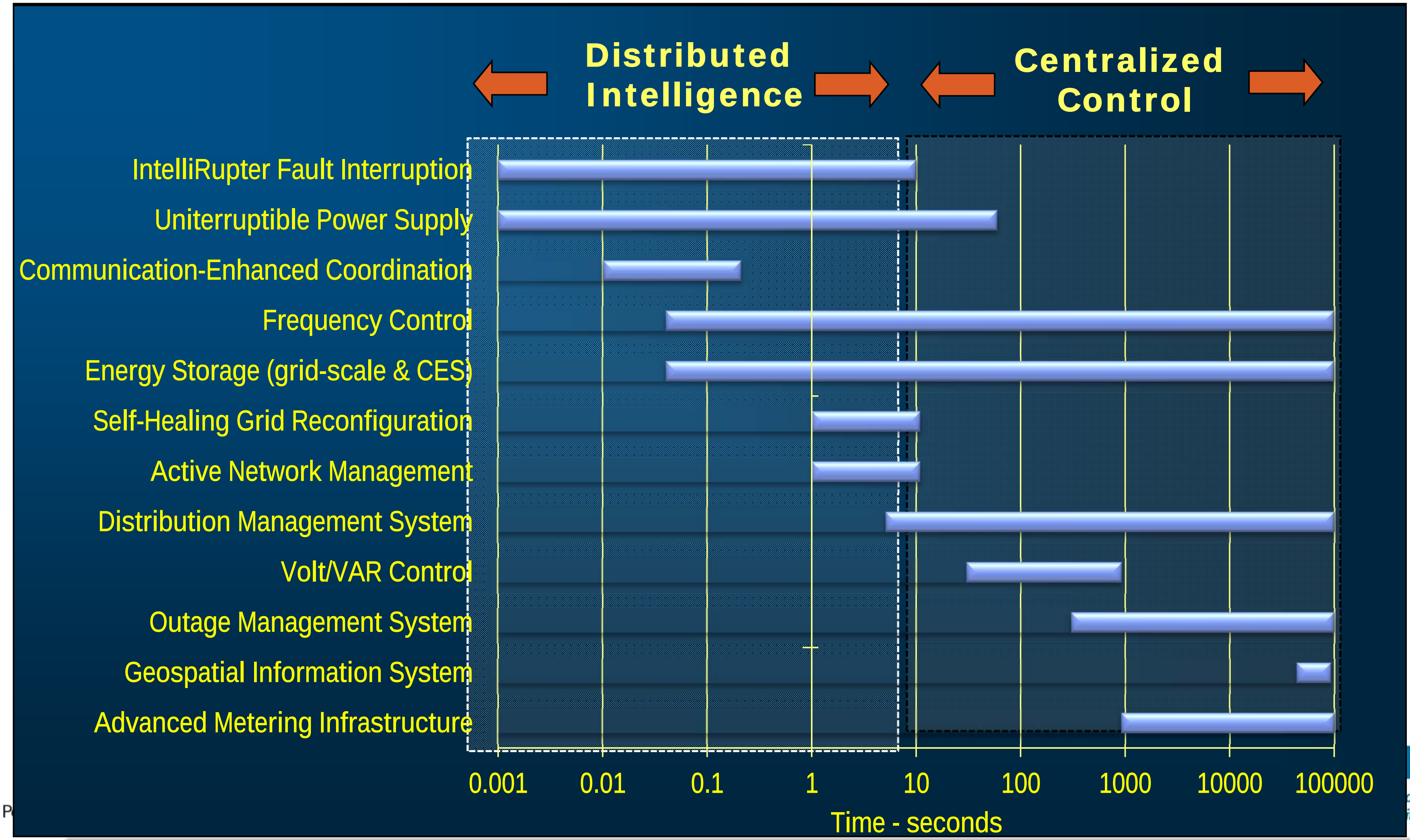
Operational Time frames
The Need for Speed…

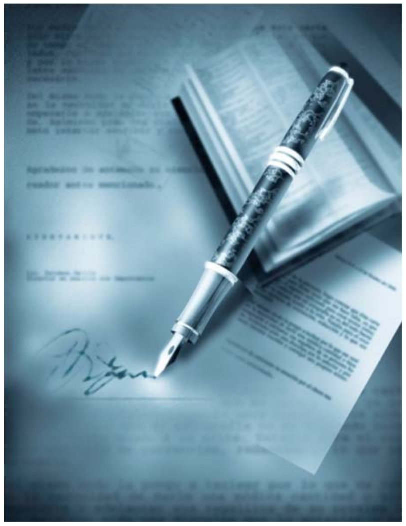


Distributed Intelligence

- Harnesses capability of microprocessors
- "Simpler" reconfiguration logic that is dynamic and can process multiple contingencies
- Robust, redundant, resilient, secure
- Vital communications are local for faster response
- Infinitely scalable – build incrementally
- Minimizes latency concerns / issues
  - Only grid sensitive data routed to mission control
  - Data stored remotely for retrieval after the event
  - Retrieval over-the-air
- Graceful performance under duress

Emerging Policy Implications

- Policy and market development
  - New technologies: storage, electric vehicles
  - New markets and incentives
- Investment requires certainty and predictability
  - Cost, risk, planning
  - Rate recovery mechanisms
  - Process and authority
- Regulatory certainty and acceptance
  - Jurisdictional clarity authority
  - Asset classification
- Consumer engagement
  - Awareness, acceptance, education
  - Consumer choice and privacy



Benefits ARE Possible: Balance is Needed

- Benefits are possible: efficiency, savings, reduced emissions, energy security, economic growth, reliability….
- Solutions require balance beyond technology: customers, policies, and markets need to be considered simultaneously

Consumers

Awareness, perception
Behavioral shifts
Education
Privacy

Markets

Business models
Cost allocation
Power markets
Utilities and suppliers

Policies

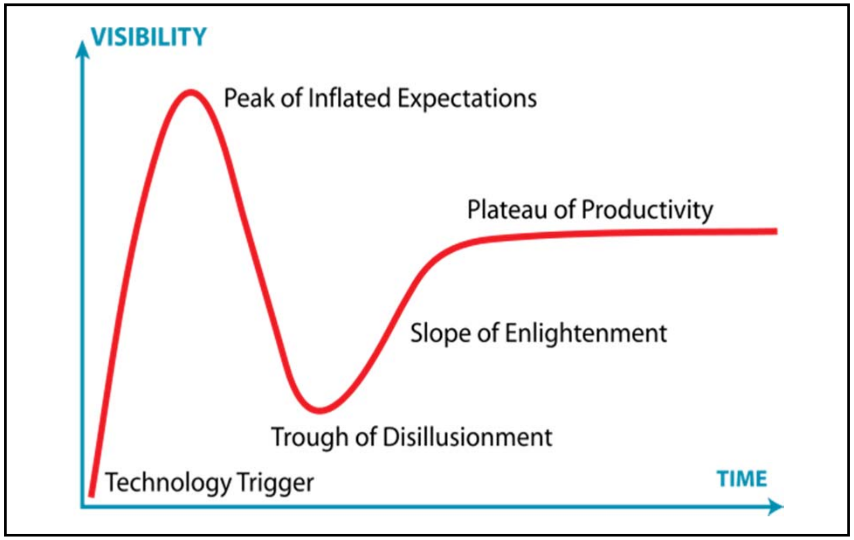
State and Federal
Environmental
Siting
Standards

Technologies

Electric vehicles
Renewables
Automation
Storage

Managing the Deployment Journey

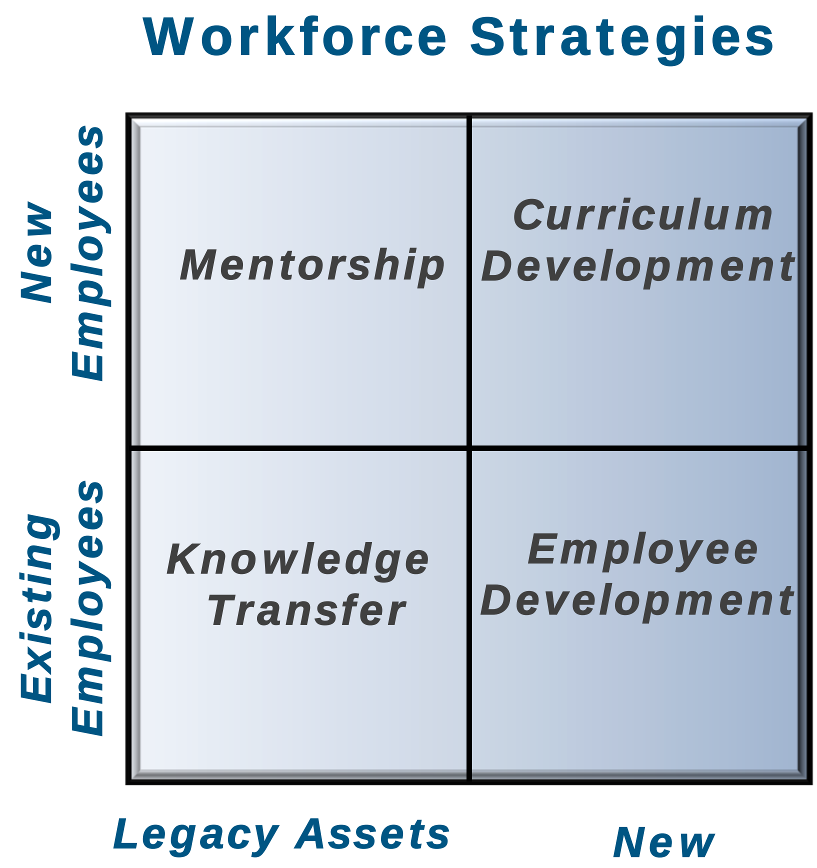
- Provide solutions that scale
  - Building on existing technology know-how and practices
  - Demonstrate successfully
  - Involve stakeholders early
  - Understand motivators
  - Consider scalability factors



- Align expectations and benefits
- Achieve faster acceptance and successful, system-wide implementations

Evolving the Workforce

- Strategies are needed:
  - Workforce is aging and soon eligible to leave
  - Technologies require new competencies, processes,
  - Tribal knowledge is associated with legacy systems
- Broad implications:
  - Recruitment, retention
  - Knowledge transfer
  - Employee development



IEEE Smart Grid

IEEE is leveraging its foundation to develop standards, share best practices, publish developments and provide educational offerings to advance technology and facilitate successful Smart Grid deployments worldwide.

- IEEE Smart Grid portal
- Monthly e-newsletter
  http://smartgrid.ieee.org/resources/smart-grid-news
- Peer-reviewed publications
- Conferences
- Standards
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Conclusions

- The energy world is changing
- A smarter grid can yield benefits
- Proven technologies are available
- Distributed intelligence is likely
- Solutions require balance
  - Consider the customer, policy, technology, and markets
- It is a journey
  - Progress logically
  - Align expectations
  - Evolve the workforce

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