Smart Grid

A Generation View

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Power & Water Solutions

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Electrical Distribution System

Generator

- Generation
- Step up transformer – switch yard – coordination, custody transfer
- 1/2 square mile

ISO/RTO

- Transmission – 230 kv+
- Bulk power substation – custody transfer
- 100s of corridor miles

Distribution Company

- Sub-transmission – 96 – 138 kv,
  - 10s of corridor miles
- Distribution substation
- Distribution lines – 2.3 – 13 kv urban - suburban
- Distribution transformers – pad and pole
- Metering – energy, remote read, AMI
- Hundreds of square miles; millions of ‘meters’

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- Process control systems for power generation:
  - Coal, gas, and oil fired units
  - Nuclear
  - Hydro power
  - Turbine controls
  - Exciters
  - Renewables controls and monitoring
  - Cyber security

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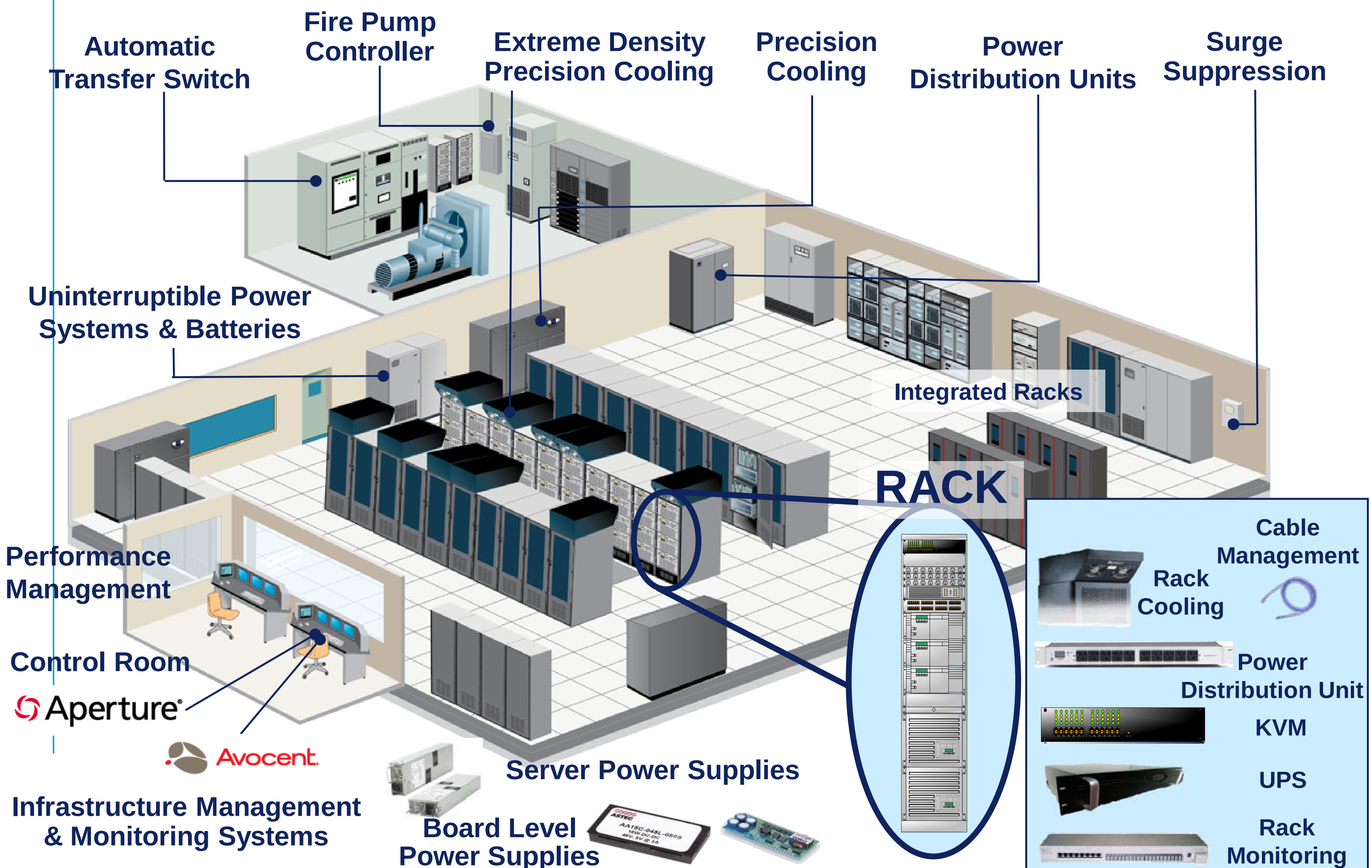
Emerson Network Power Presence within the Datacenter



Smart Grid – A Definition

- Smart Grid is an evolving infrastructure that merges information technology with T&D to:
    - Positively impact network performance and reliability
    - Accommodate load growth
    - Incorporate renewables
    - Promote demand side management
    - Offset the loss of expert resources due to an aging workforce
- Smart grid is not just technology; it involves work processes, people issues, regulatory constructs, and demand side incentives…

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Smart Grid Objectives and Challenges

- Through a ***convergence*** of energy systems, telecom, and IT restructure the grid to achieve:
  - Capacity
  - Efficiency
  - Reliability
  - Effective integration of energy from diverse sources
- Challenges:
  - Interoperability
  - Security – privacy, commercial, cyber attack
  - Systems architecture - Future proofing – information technologies, energy storage
  - Scalability

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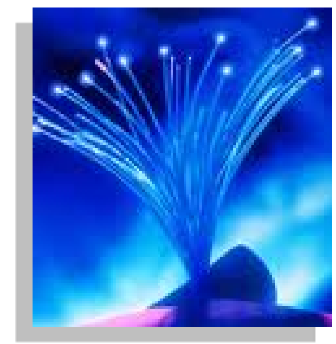
Convergence in Plant Controls

- Historically, despite changes in control architectures, DCS has remained separate from IT; now DCS is a technology in transition
  - It *has* converged with IT in terms of its use of COTS technologies
  - It *will* converge with IT in terms of applications, largely driven by security issues, cloud computing, and software-as-a-service (SaaS)
  - Will complete the transition of DCS from a hardware to a software product
  - DCS provides control but is also a data source that can drive significant operational efficiencies for clients. Clients further benefit since they are realizing incremental benefit from an existing investment

Convergence has moved applications to the forefront…

Smart Grid Technologies

- Smart Grid entails the ***convergence*** of major technologies to support enhanced operation:
  - Electrical equipment and power network architectures
  - Metering and substation automation
  - Data communications; data warehousing
  - IT applications integration
  - Demand side management



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AMI – The Face of Smart Grid

- AMI – Advanced Metering Infrastructure
  - Multi-channel meters capable of ‘daily reads’
    - Frequency is more than daily in terms of usage envisioned for meters
    - Meter communicates with concentrator; reads back-hauled with a variety of technologies
  - Supports numerous advanced capabilities
    - Multi-channel capabilities
    - Remote turn-on/turn-off
    - Time-of-use metering
    - Demand side management
    - Outage management and system status
    - Load profiling
    - Fraud detection
  - Challenges:
    - Regulatory issues
    - Write-offs of current metering technologies
    - Standards
    - Data use – lack of or limits of COTS applications

Smart Meters are largely hardware; their benefits are realized through software…

Information Technology Issues

- Communications infrastructure and security
  - Need to back-haul data via a high speed communications network
  - Meters communicate to concentrators via mesh networks; need flexibility to take it from there
  - Build, lease, or something in between?
  - Performance characteristics in light of different data classes
  - Physical layer will vary by and within a given utility
  - Security of data in transit - encryption
  - Access rights to data
  - Fraud detection and prevention i.e. mitigate commercial losses

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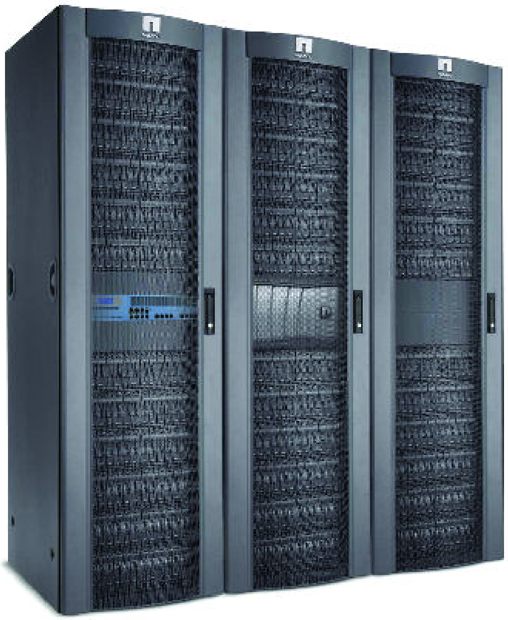
Information Technology Issues

- Data reception, storage, and management issues
  - Storage of information
  - Integrity and quality assurance
  - Data administration
  - Standards
  - Data models
  - Data access, security, and utilization
  - Enterprise integration
  - Staffing considerations
  - Need to identify applications requirements and parse data accordingly



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Challenges to Electric Utilities

Our products and services must directly impact critical utility issues…

Issue	Possible Response
Environmental Compliance CAIR, MATS	*Combustion efficiency, fuel management, emission caps, emission credits, fleet emission management*
Operational Efficiency	*Drive costs out of business, rationalize maintenance practices, outsource non-core functions, O&M costs*
Aging Asset Base	*Life extension, unit flexibility, new construction*
Aging Workforce	*Usability, training, and project and maintenance services, fleet focus*
Coal to Gas Conversion	*Controls for conversion/upgrade*
NERC-CIP Mandates	*Integrated security services and support*
Renewables mandates	*Controls, integration, fleet management, Smart Grid integration*
Manage Information Technology Change	*Advisory services, business case development, complimentary control architecture, Smart Grid integration*

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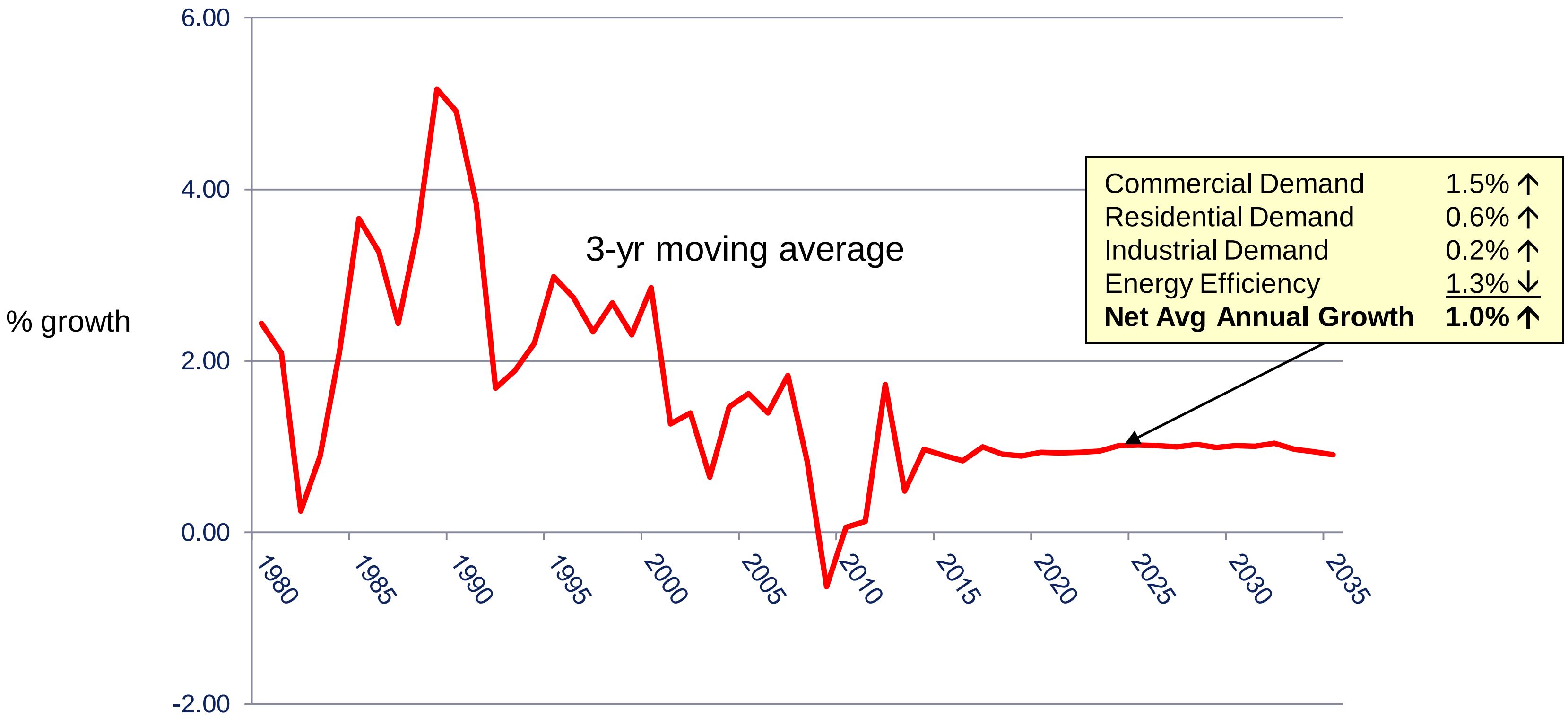
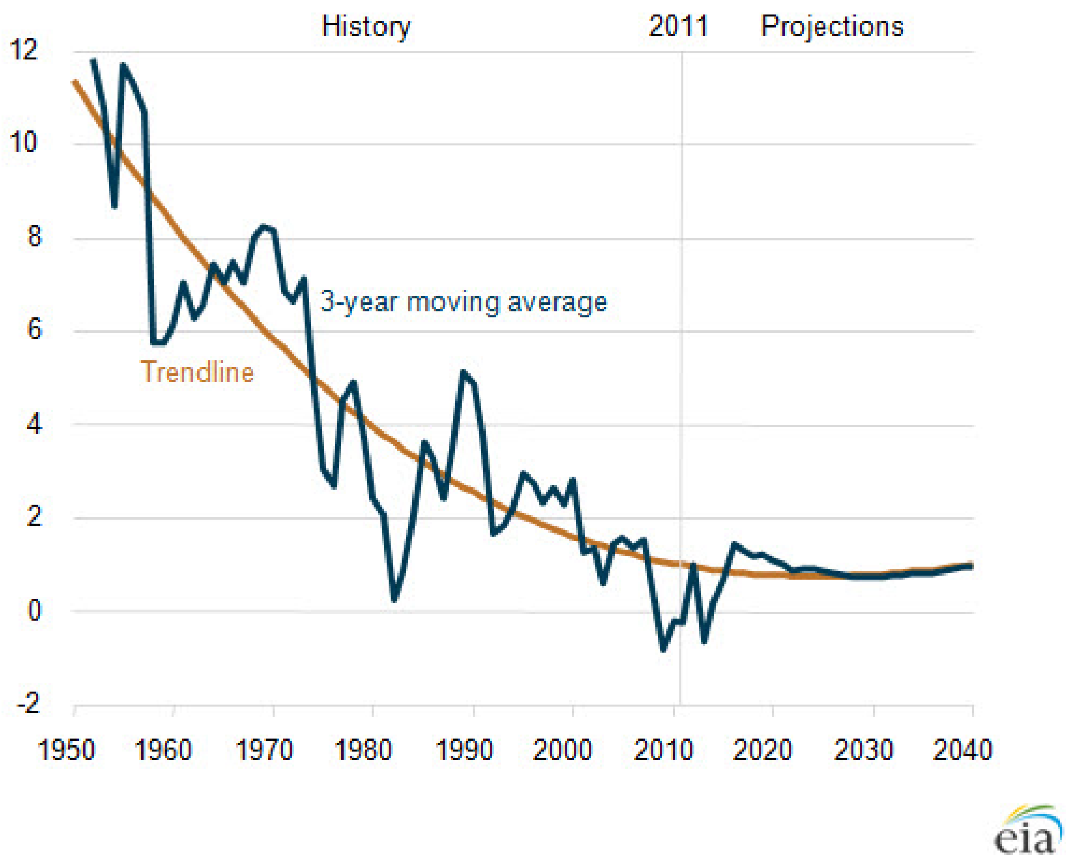
Low US Electricity Demand Growth Over the Next 20 Years



Source: EIA Annual Energy Outlook 2011

From AEO 2013

Figure 75. U.S. electricity demand growth, 1950-2040
(percent, 3-year moving average)



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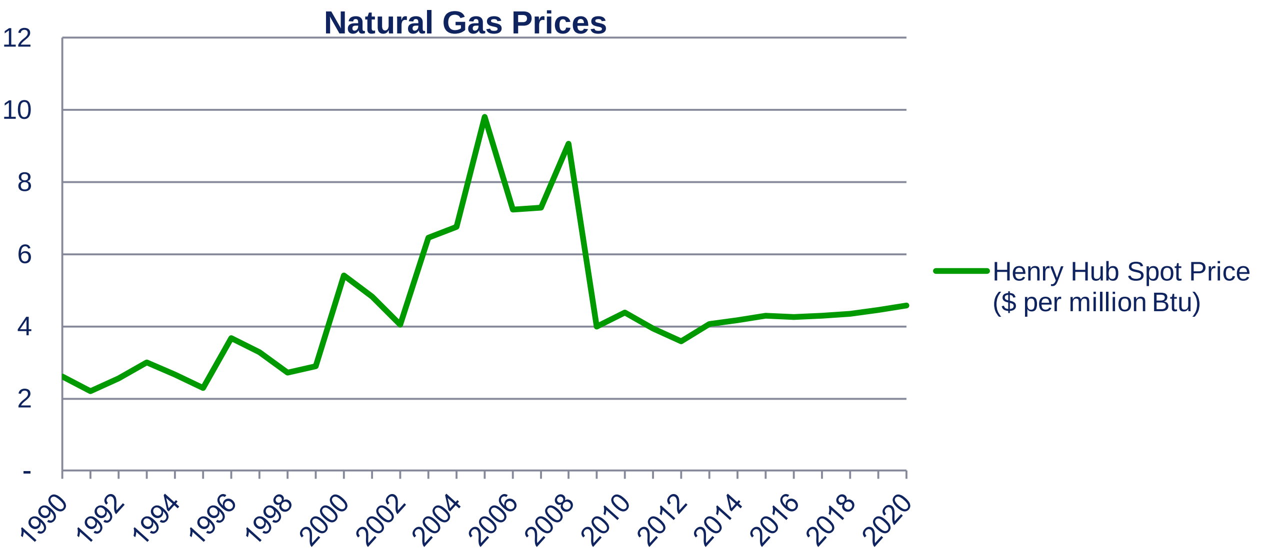
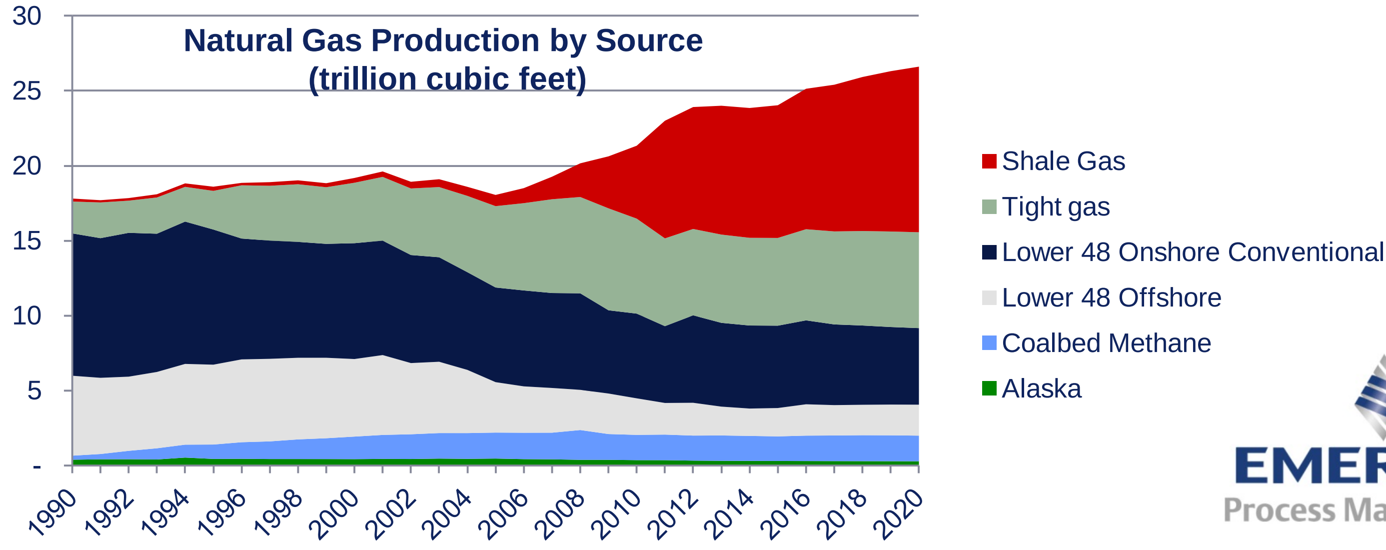
The Rise of Shale Gas Has Decreased Natural Gas Prices





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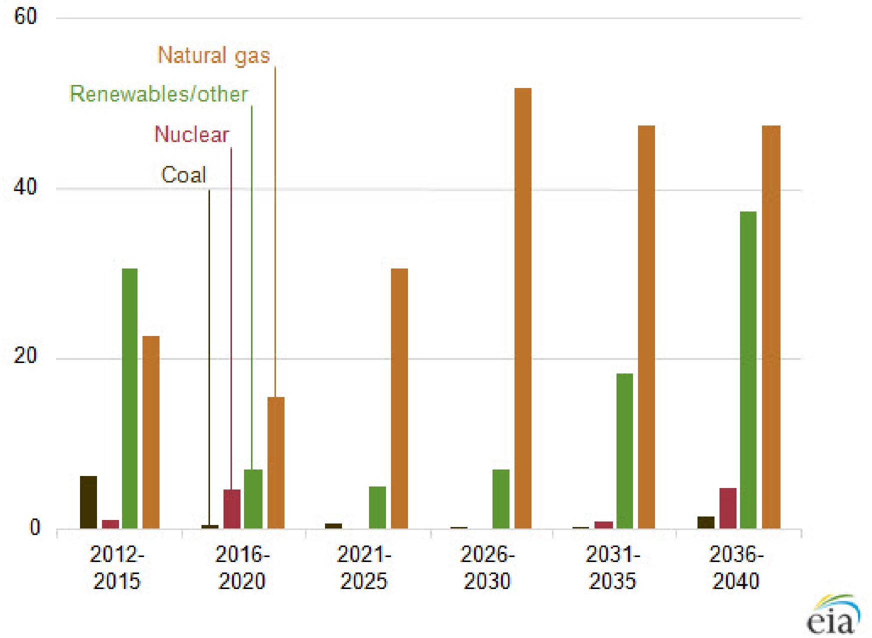
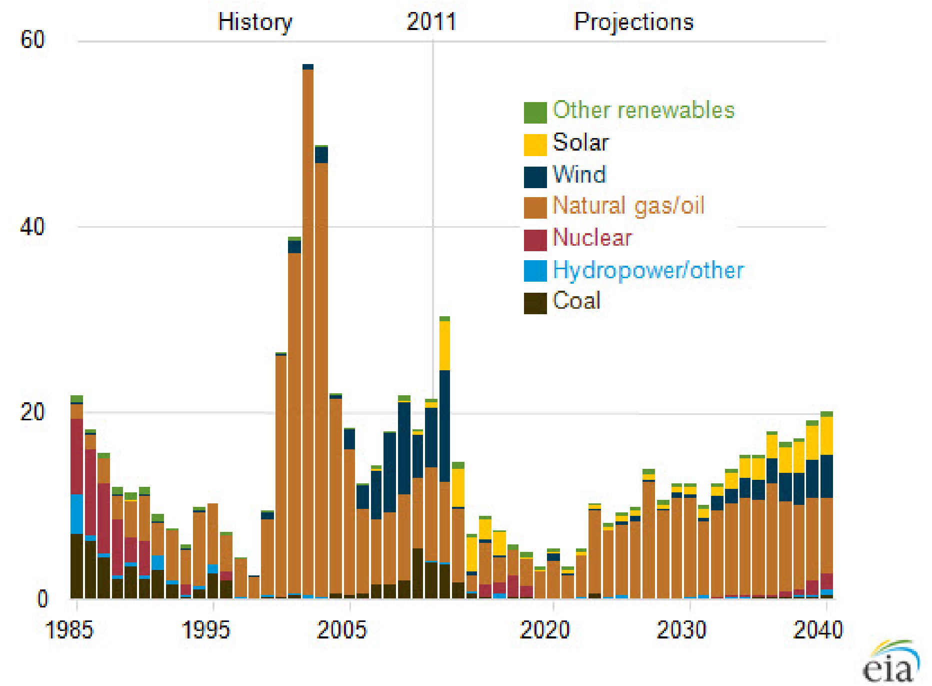
Natural Gas Expected to Be Fuel of Choice for New Plants

Figure 77. Electricity generation capacity additions by fuel type, including combined heat and power, 2012-2040 (gigawatts)



But Low Demand Means A Limited Number of New Plants in Next 10 Years

Figure 78. Additions to electricity generating capacity, 1985-2040 (gigawatts)



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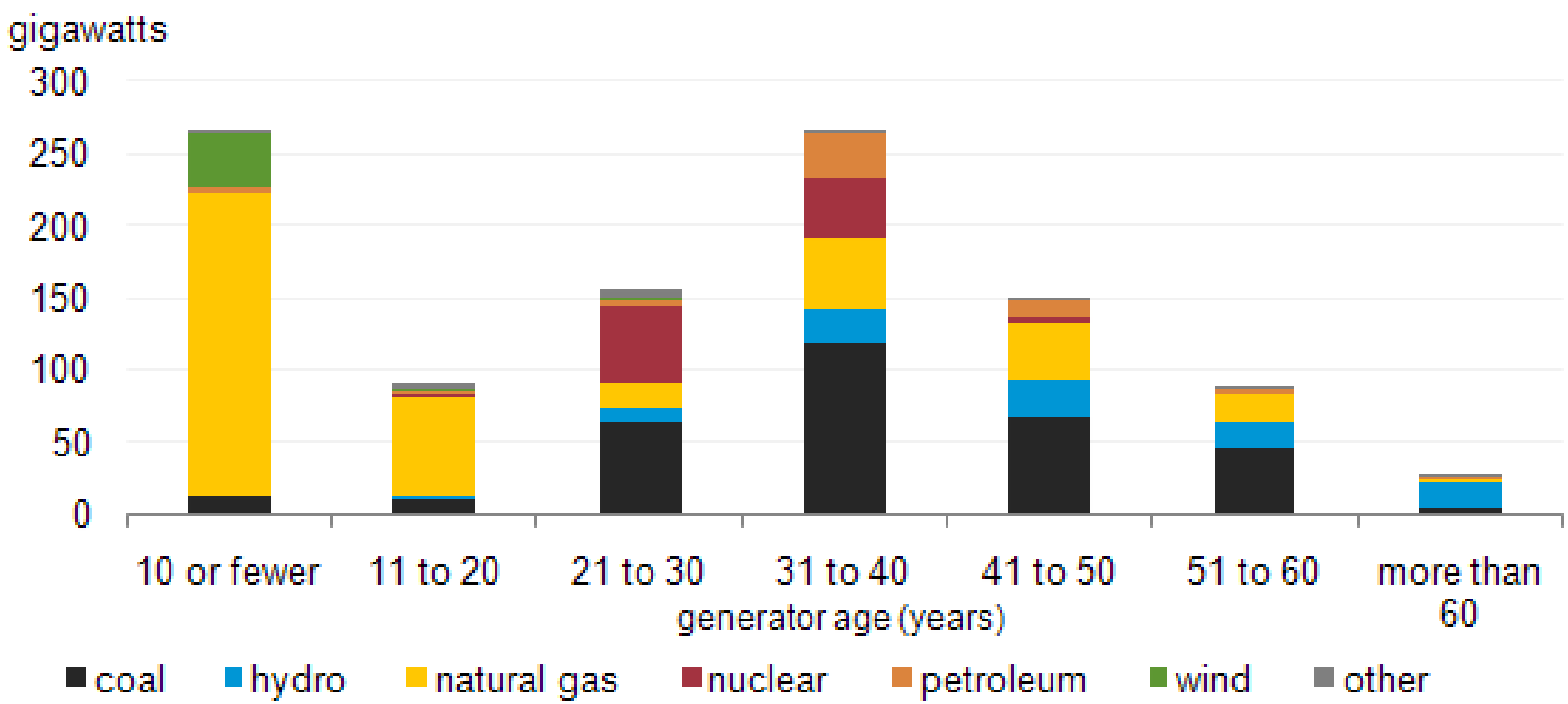
Age and Capacity of Existing Electric Generators by Fuel Type



Source: US Energy Information Administration, data as of end of 2010

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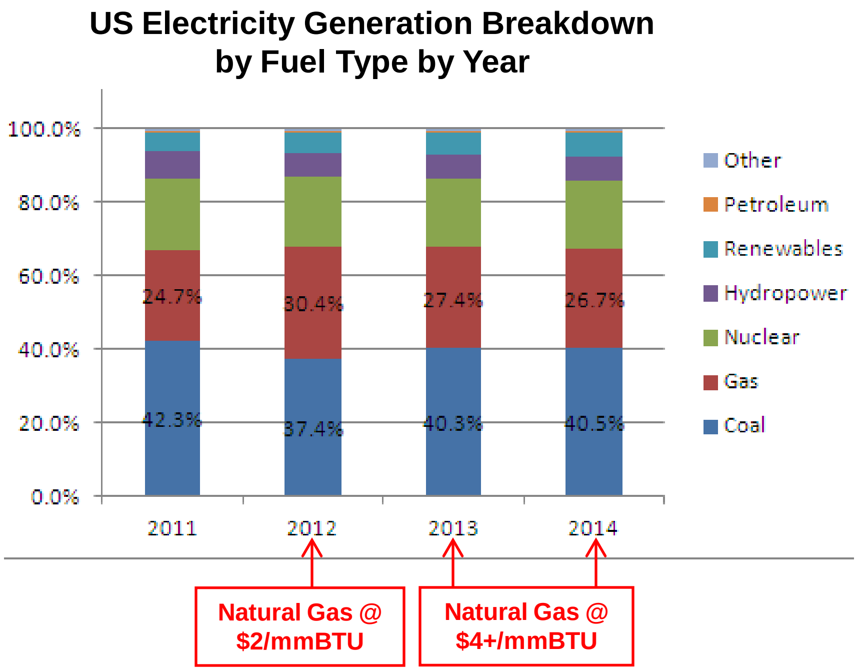
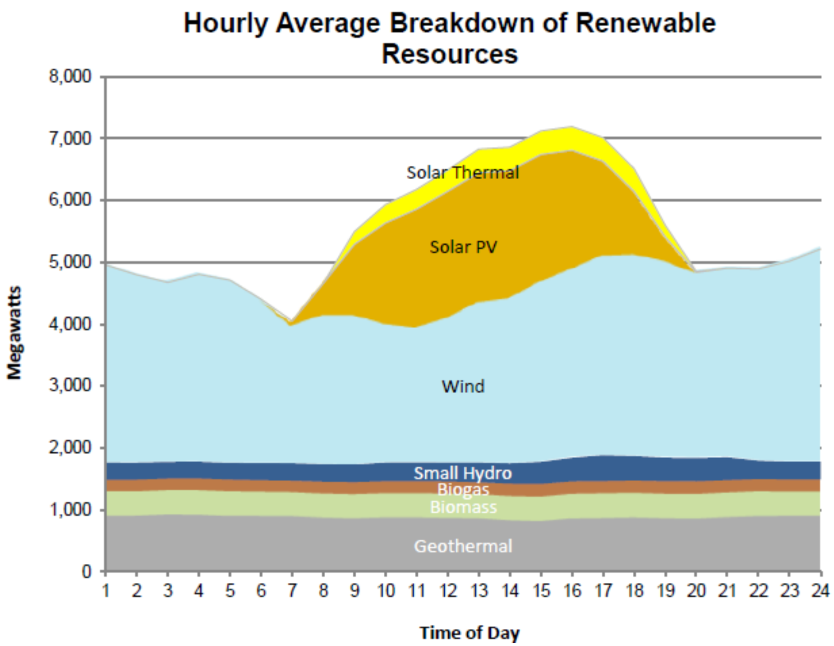
Operating Profiles Fluctuating – Predictability of Operation Diminishing





- As natural gas prices fluctuate around $4/mmBTU, many combined cycle plants become more expensive than competing coal plants
- Plant could be base loaded one month and cycling the next due to gas price fluctuations

- Due to intermittent load characteristics of new renewable generation on the grid, operating profiles are no longer predictable – gas and coal plants need to respond more quickly to balance grid

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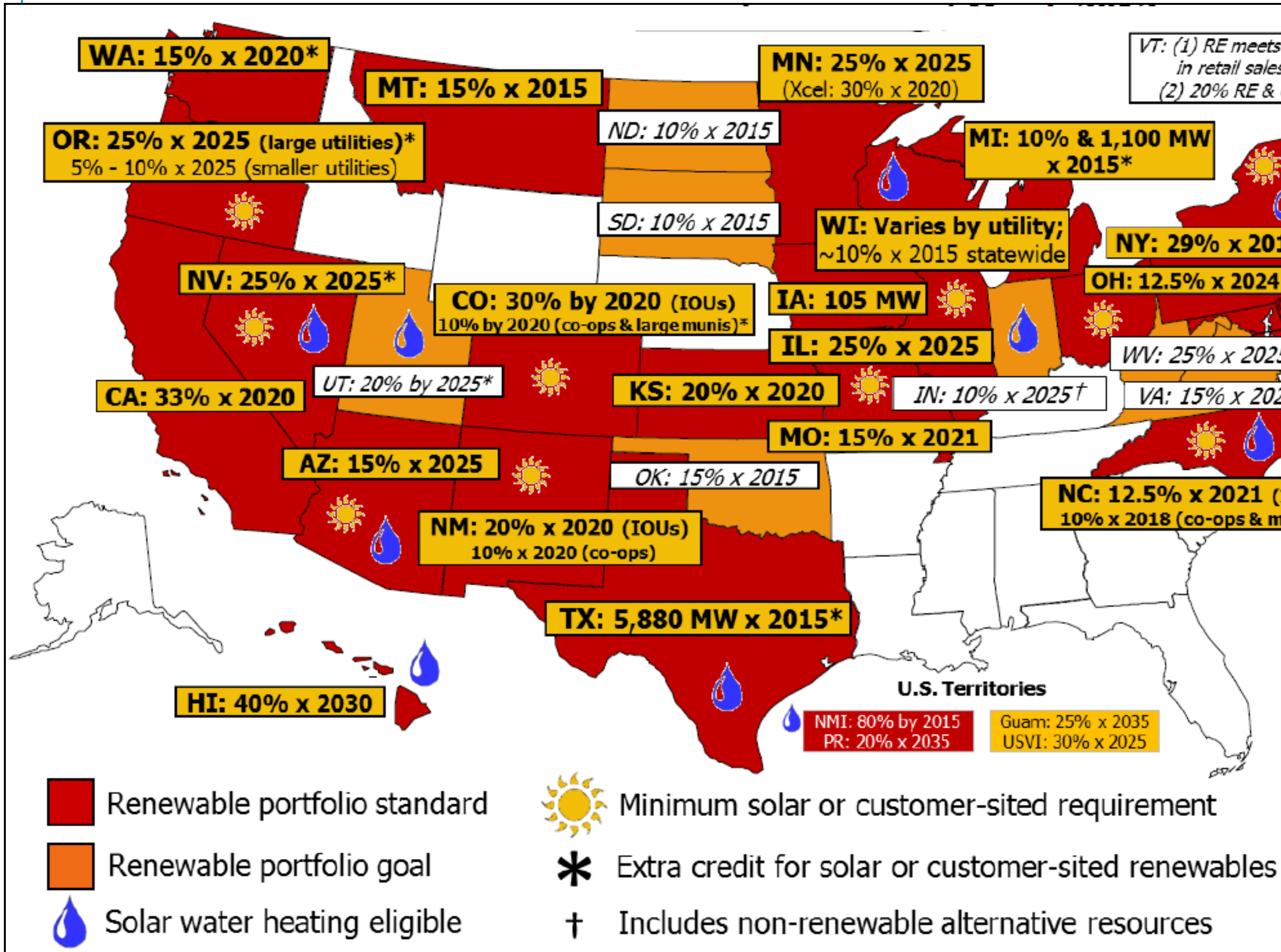
Renewable Portfolio Standards (RPS) and Incentives are Driving New Renewable Generation



29 states + Washington DC and 2 territories have Renewable Portfolio Standards

(8 states and 2 territories have renewable portfolio goals)

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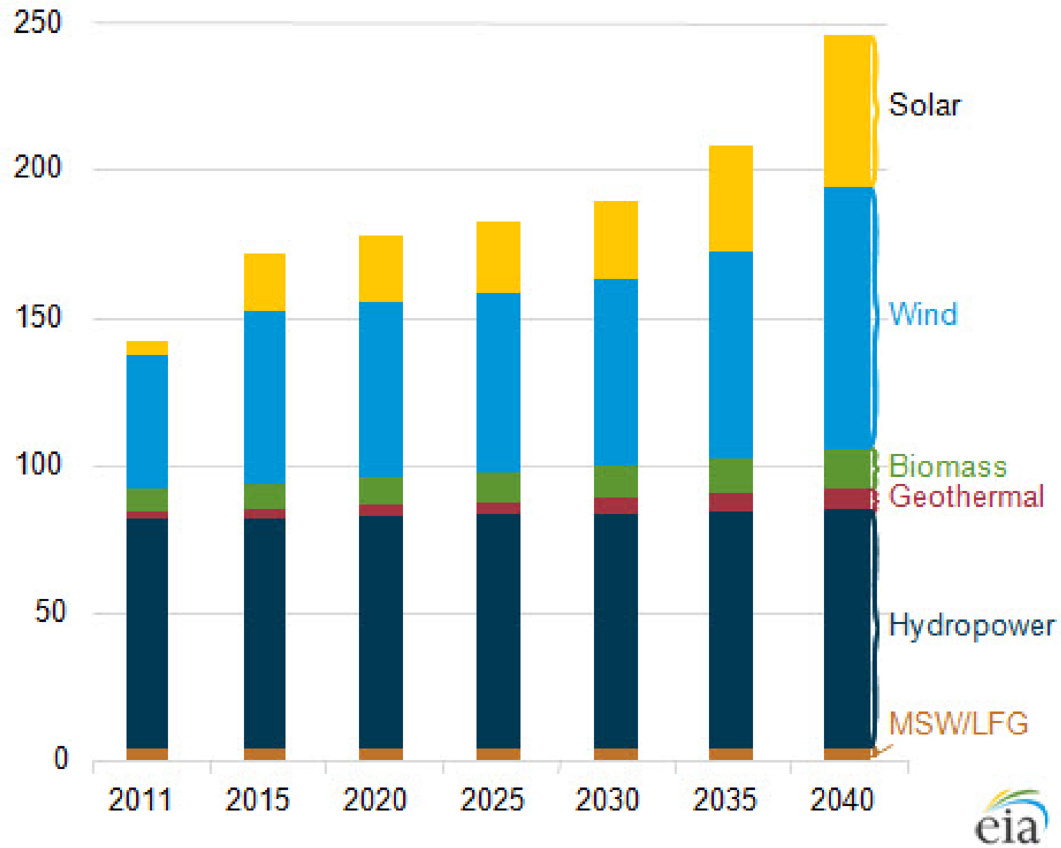
From AEO 2013

Figure 82. Renewable electricity generation capacity by energy source, including end-use capacity, 2011-2040 (gigawatts)



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NERC CIP Standards Are Driving New Cybersecurity Product / Service Needs

- Improves physical and cybersecurity for the bulk power system of North America as it relates to reliability (CIP = Critical Infrastructure Protection)
- Components for Power Generation Plants
  - 002 - Critical Cyber Asset Identification
  - 003 - Security Management Controls
  - 004 - Personnel and Training
  - 005 - Electronic Security Perimeter(s)
  - 006 - Physical Security
  - 007 - System Security Management
  - 008 - Incident Reporting and Response Planning
  - 009 - Recovery Plans for Critical Cyber Assets
- Standards are continually evolving and expanding
  - Currently affects ~120 power plants (>1500MW sites)
  - Over next few years will expand to cover majority of US power plants

IMPACT

At affected sites, utilities are implementing security software on their existing plant technologies, establishing security-related maintenance and lifecycle management practices for those technologies, and ensuring that regulatory-compliant business processes and procedures are followed.

Core Generation Capabilities

Manage Fuels

- Specify fuel requirements
- Negotiate contracts
- Procure fuel
- Receive, store, manage inventories
- Analyze, blend, predict operational ramifications
- Efficiently burn, assess fuel performance, and report
- Enforce fuel contracts

Manage Plant

- Develop generation strategy and forecasts
- Execute generation strategy
- Perform outage planning
- Monitor plant technical and commercial performance
- Report plant status and performance
- Manage resources and personnel
- Perform capital planning
- Monitor and report operational, technical, and environmental KPIs

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Core Generation Capabilities

Meet Environmental Targets

- Monitor water and air quality
- Report emissions performance as required
- Blend fuels to balance operational and emission considerations
- Control emissions management systems and equipment
- Develop, implement, and utilize control and optimization strategies to mitigate environmental impacts
- Understand and monitor environmental impacts to commercial capability; communicate with trading organization

Conduct Maintenance

- Develop maintenance strategy
- Monitor equipment condition
- Analyze and interpret condition data
- Monitor real-time plant performance
- Analyze plant performance
- Establish unit capabilities and de-rates
- Plan work
- Perform work
- Analyze work results

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Core Generation Capabilities

$$G(s) = \frac{K.(s-z_1)(s-z_2)(s-z_3)\ldots\ldots(s-z_m)}{(s-p_1)(s-p_2)(s-p_3)\ldots\ldots(s-p_n)}$$

Control Plant

- Develop and evolve control strategies
- Establish corporate control standards
- Develop alarm management practices
- Establish plant-wide controls architecture
- Leverage new technologies
- Capture best control practices
- Automate controls based on best practices
- Proceduralize use of control strategies

Optimize Plant Performance

- Establish plant performance KPIs
- Measure and record KPIs
- Analyze and report performance versus KPIs
- Implement optimization technologies based on renewables impacts
- Monitor optimization technologies and plant performance
- Develop alarm management strategy; aggressively identify and manage alarms
- Initiate corrective actions to improve plant performance
- Proceduralize use of use of optimization suites

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Core Generation Capabilities

Provide Engineering Services

- Develop technology strategies and management practices
- Select appropriate platforms
- Conduct FEED studies
- Manage interfacing with enterprise applications
- Outage planning
- Mitigate technical risks
- Establish lifecycle management practices

Manage Grid/ISO Interaction

- Identify unit capabilities and de-rates
- Support grid stability
- Declare unit
- Accept instructions
- Comply with instructions
- Provide NRT compliance information
- Provide NRT executive information
- Support settlement and billing

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Core Generation Capabilities

Provide Computing Infrastructure

- Provide connectivity and data communications
- Provide and manage enterprise computing applications
- Business continuance and disaster recovery
- Security infrastructure and services
- Internet access and presence
- Remote access and access security
- Develop technology strategies and management practices
- Select appropriate platforms
- Interface to corporate systems and applications
- Provide corporate dashboards and executive information
- Support NERC-CIP compliance

Develop Personnel

- Ensure workplace safety
- Define position responsibilities
- Manage and utilize outsourced capabilities
- Establish and deliver a training & development curriculum
- Establish operator certification levels and testing
- Establish maintenance certification levels and testing
- Provide instructional environment commensurate with training regimen (simulators)
- Determine appropriate staff levels
- Prescribe and manage appropriate incentive compensation

Core Generation Capabilities

Manage Renewable Assets

- Provide connectivity and data communications
- Extract asset performance information
- Security infrastructure and services
- Coordinate response of conventional assets to renewables
- Promote grid stability
- Develop technology strategies and management practices
- Interface to corporate systems and applications
- Provide corporate dashboards and executive information
- Settle and bill

Comply with NERC-CIP

- Develop and administer comprehensive NERC-CIP compliance approach
- Maintain appropriate records
- Secure plant premises
- Control physical access to equipment and systems
- Manage control system user roles, capabilities, rights, and privileges
- Secure electronic access to critical plant networks
- Install and manage malware patches and updates
- Provide secure access to corporate systems and applications
- Prepare for and pass NERC-CIP audits

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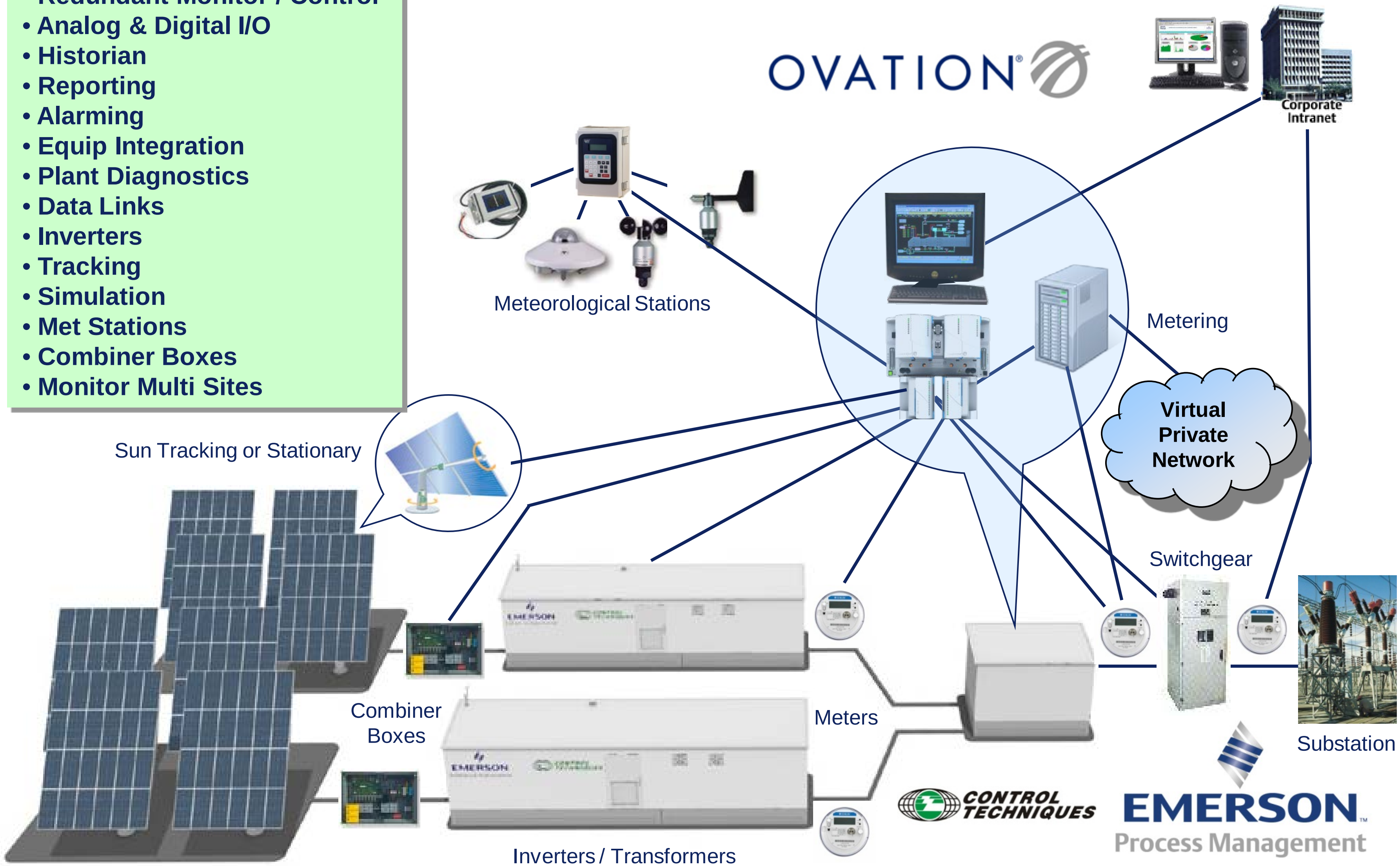
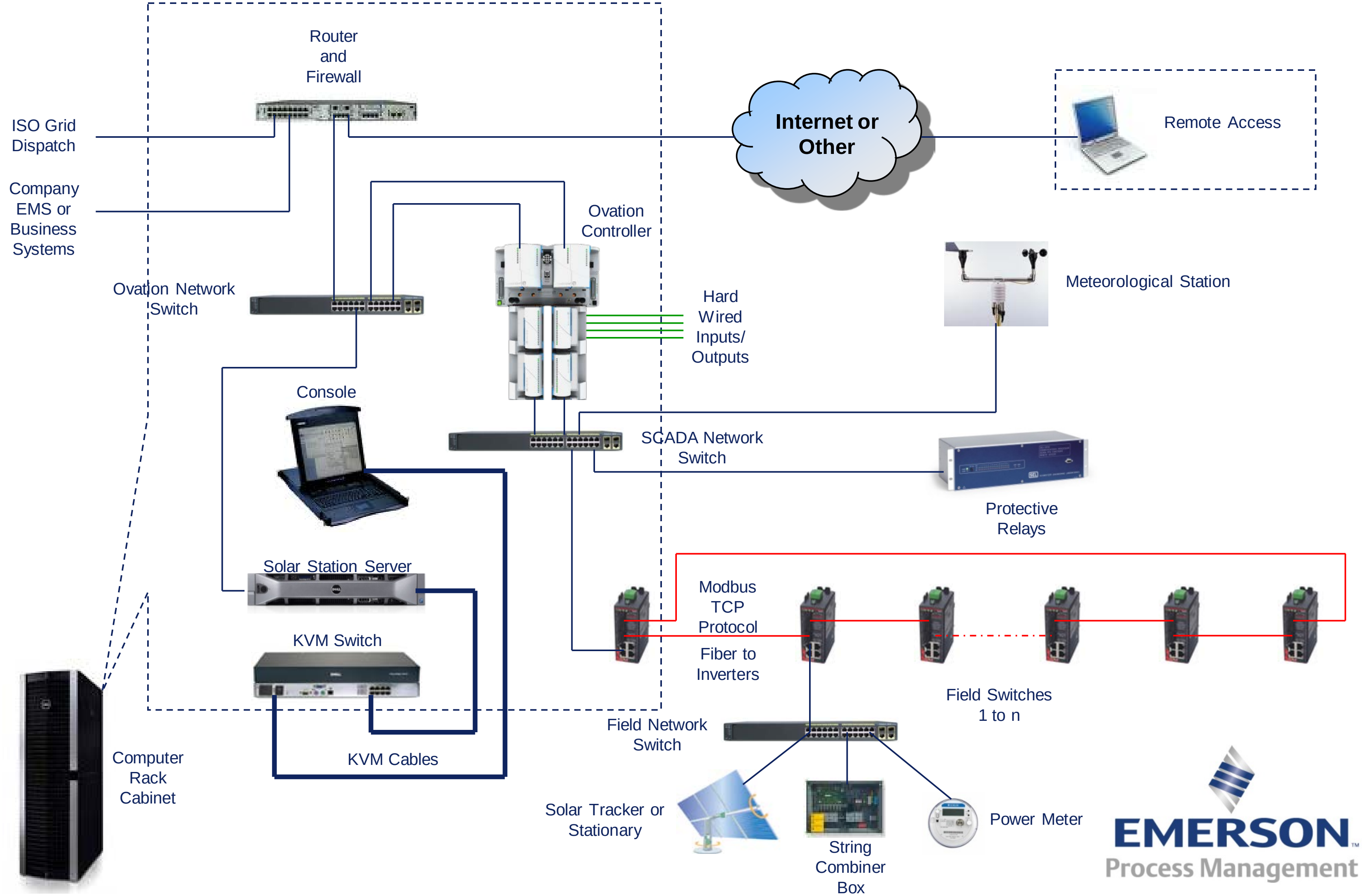
Emerson Solar PV Plant Master Controls

- Redundant Monitor / Control
- Analog & Digital I/O
- Historian
- Reporting
- Alarming
- Equip Integration
- Plant Diagnostics
- Data Links
- Inverters
- Tracking
- Simulation
- Met Stations
- Combiner Boxes
- Monitor Multi Sites



Solar PV Plant SCADA Architecture



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Ovation Generation Fleet Architecture

Applications
Wind
Hydro
Solar
Fossil
Others..

Performance Center

KEY FEATURES
- 6M points long term storage
- Analysis/reports (Performance…)
- Web interface for remote access

GENERAL FEATURES
- Flexible and expandable solutions
- High availability Architecture
- Data modeling
- AMS (Asset Management System)
- Global System Synchronization
- Alarming
- Uniformity
- Centralized/Local engineering
- Centralized/Local HMI
- Cyber Security (NERC CIP)

Dispatch Center #1

Dispatch Center #16

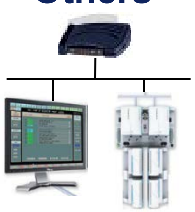
KEY FEATURES
- Data from any power plant
- Supports 5M remote points & 200K local points
- Hierarchical Alarm Management
- Smart historical queries
- Interact with grid system operator

OPTIMIZED COMMUNICATION
- Primary/Backup network
- Main/Backup dispatch centers
- Min bandwidth 64Kbps, 1.5 Mbps recommended

Hydro

Wind

Others



Power Plants in Fleet

KEY FEATURES
- Real time monitoring and control (Hard & Soft I/O)
- Predictive machinery health management
- Native Interface to substation systems (870, 850, DNP, OPC DA,..)
- Interact with Dispatch center & grid system operator
- Local historian w/30 days storage
- Time stamping (1ms or 1/8ms)power plant

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Wind Turbine Supervisory Controls

- Supervisory control
- Protective supervisory shutdown
- Programmed supervisory modes
- Programmed supervisory stop
- Turbine operating status details
- Wind Turbine power curve
- Production potential
- Other Wind Farm interfaces

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Control and EMS for Co-generation

- Generation load control
- Tie line control
- Load shedding
- Synchronizing
- Voltage and reactive power control
- Remote breaker control

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Unit Coordinated Control
Drum Boilers

- Provides a coordinated front-end control strategy that unites boiler and turbine controls
- Offers air/fuel cross limiting to regulate the fuel and air input in response to load changes
- Offers typical air flow control stations
- Furnace pressure control stations (ID fans)
- Feedwater control stations

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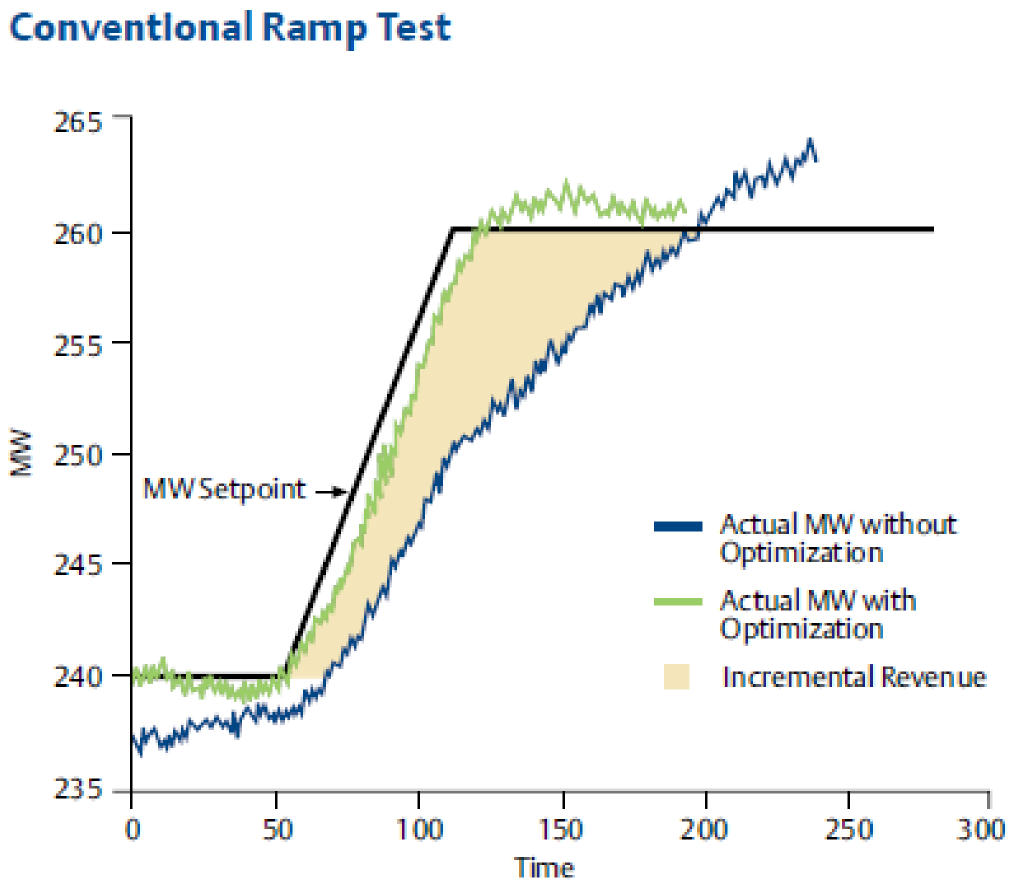
Generation Fleet Optimization

Typical Unit Operation	Key Performance Objectives	Key Process Targets
Fleet	Fleet profitability	Performance monitoring Fleet economics Fleet emissions compliance
Base-loaded	Heat rate Availability Maximum load Environmental compliance	Fuel/Combustion Steam temperature Sootblower
Load-following/Dispatched	Minimum load Forced outage rate Ramp rate Environmental compliance	Fuel/Combustion Sootblower Steam temperature Unit response
Cycling	Startup time and cost Reliability Life-cycle cost Ramp rate Environmental compliance	Fuel/Combustion Sootblower Steam temperature Unit response
Peaking	Dispatch to maximize fleet margin Reduce maintenance	Utilization

Generation Fleet Optimization - Ramping



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Information Technology Issues

- Renewables/distributed generation accommodation
  - Accommodate renewables and manage conventional assets – major initiative
  - Data models
  - Grid operator interface
  - Declare, accept, execute
  - Performance validation
  - Settlement and billing
- Integral to broader fleet management needs

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Information Technology – How to USE the Data

- Smart Grid focus is on devices i.e. meters, controllers, etc
  - Functionality
  - Standards compliant
  - Interoperable
  - Inexpensive (*very* price sensitive!)
  - Devices are net *generators* of data

- The unsaid of Smart Grid is ***applications software***
  - Net *users* of data; make operational sense of data deluge; without applications software devices will have minimal impact
  - Applications are seen as a high risk enterprise but can morph into another ERP; applications management will necessitate standardization and services

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Impacts On Software Project Outcomes

User Issues

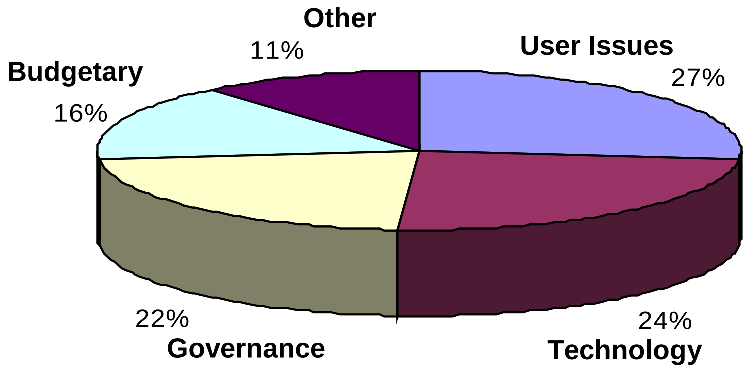
- Inadequate user involvement and support throughout software lifecycle
- Compromised by budgetary considerations and lack of governance
- Significant negative impacts on business case realization

Technology-centricity

- Technology pervades project lifecycle
- Lack of overarching architecture results in departmentally-focused projects
- Minimal process re-engineering

Governance Issues

- No overarching architectures or methodologies
- IT tends to enforce only infrastructure standards
- Differences between enterprise and operations
  - Project staffing and funding



Budgetary Considerations

- Fixation with initial capital outlay
- Focus on business case but manage projects
- Inordinate impacts on technology and scope
  - Business case articulation

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Security Threats

- Hackers – cyber vandals
- Organized crime – theft, fraud, extortion
- Hack-tavists – Politically motivated
- Cyber war – Attain one's policy objectives; current likely scenarios are in concert with a shooting war or as a precursor to a military engagement
- Compromised hardware

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Typical DCS – (and Smart Grid!) Security Concerns

- There are a great number of potential **vulnerabilities** found in control systems. These can result in performance failure, process failure, and damage to the capital equipment or loss of revenue from disruption.
- Vulnerabilities managed by:
  - System management
  - Electronic access controls
  - User management
  - Software patch management
  - Malware prevention
  - Intrusion detection
  - Aggressive user management/system administration
- Build to avert but plan to survive

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THANK YOU!