Innovation & Smart Grids

Clark W. Gellings
Fellow
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Tomorrow’s Power System

Requires a full portfolio of innovative technologies.

One size does not fit all
Key Technical Issues

- Smart Grid
- Energy Efficiency
- Long-Term Operations
- Renewable Resources and Integration
- Near-Zero Emissions
- Water Resource Management
Many Definitions

IntelliGrid

GRIDPOINT

GALVIN ELECTRICITY INITIATIVE

Smart Grid

DRSG

Demand Response and Smart Grid Coalition

GRIDWISE ALLIANCE

SMART GRID CITY™

EUROPEAN TECHNOLOGY PLATFORM FOR THE ELECTRICITY NETWORKS OF THE FUTURE

Modern Grid

Illinois SMART GRID Initiative
What is The Smarter and Stronger Grid?

Many Definitions – But One VISION

- Engaging Consumers
- Enhancing Efficiency
- Ensuring Reliability
- Enabling Renewables & Electric Transportation

Interconnected by a Communication Fabric that Reaches Every Device
Smart Grid Domains

Source: EPRI Report to NIST on Smart Grid Interoperability, June 2009
Dynamic Systems Infrastructure: Basics

- Efficient Building Systems
- Internet
- Consumer Portal & Building EMS
- Advanced Metering
- Control Interface
- Smart End-Use Devices
- Dynamic Systems Control
- Utility Communications

Efficient Building Systems

Internet

Consumer Portal & Building EMS

Advanced Metering

Control Interface

Smart End-Use Devices

Dynamic Systems Control

Utility Communications
The Portal Empowers Consumers

- Connectivity to electricity markets
- Information on consumption
- Access to other services

Choice
Convenience
Value
The Portal Empowers Consumers

- Choose suppliers
- Select tariff
- Monitoring usage
- Respond to price signals
- Monitor appliances and devices
- Remotely program operations
- Consolidate bills
- Outage detection
- PQ monitoring
- Security
- Data
- Entertainment
Dynamic Systems Infrastructure: Utility Operations

- Utility Communications
- Dynamic Systems Control
- Data Management
- Distribution Operations
- Advanced Metering
- Consumer Portal & Building EMS
- Control Interface
- Efficient Building Systems
- Internet
- Smart End-Use Devices
- Internet
Dynamic Systems Infrastructure: Consumer Opportunities

- Utility Communications
- Internet
- Efficient Building Systems
- Consumer Portal & Building EMS
- Advanced Metering
- Control Interface
- Data Management
- Distribution Operations
- Dynamic Systems Control
- Plug-In Hybrids
- Smart End-Use Devices
- Consumer Portal & Building EMS
- Advanced Metering
- Control Interface
- Data Management
- Distribution Operations
- Dynamic Systems Control
- Plug-In Hybrids
- Smart End-Use Devices
Dynamic Systems Infrastructure: Consumer Opportunities

Utility Communications

Dynamic Systems Control

Distribution Operations

Data Management

Efficient Building Systems

Internet

Consumer Portal & Building EMS

Advanced Metering

Plug-In Hybrids

Distributed Generation & Storage

PV

Renewables

Control Interface

Smart End-Use Devices

Internet Renewables

PV
Dynamic Systems Infrastructure

Utility Communications

Dynamic Systems Control

Distribution Operations

Data Management

Efficient Building Systems

Interoperability and Functionality

Internet

Consumer Portal & Building EMS

Advanced Metering

Control Interface

Plug-In Hybrids

Distributed Generation & Storage

Smart End-Use Devices

CWG/9250P
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Dynamic Systems Infrastructure
The Evolution of Dynamic Systems

**Historic**
- Low TOU penetration and response
- Not verifiable
- Modest use of load control

**Tomorrow**
- Standardized design
- Interoperable devices
- Make it simple and automated

**Future**
- Learn and adapt to consumer and building behavior

Evolve to
- Automated Demand Response
- Provide for development
- Ubiquitous System
- Enable
- Dynamic Systems
Dynamic Systems Infrastructure – Example

- Thermostat receives day-ahead hourly prices
- Consumer sets upper and lower limits
- Thermostat “learns” thermal, consumer and weather impacts

Efficient Building Systems

Dynamic Systems Control

Data Management

Distribution Operations

Advanced Metering

Plug-In Hybrids

Distributed Generation & Storage

Smart End-Use Devices

PV

Renewables

Internet

Consumer Portal & Building EMS
Smart Infrastructure… “Prices to Devices”

Day-ahead Hourly Prices

- Off-Peak Prices
  - Baseload Generation
  - Load-Following Generation

- On-Peak Prices
  - Interruptible Load

Built-In Demand + Smart Demand Response = Renewable Generation - Fuel-Based DG

Smart End-Use Devices
Dynamic Systems Infrastructure – Example

- Efficient Building Systems
- Data Management
- Distributed Generation & Storage
- Plug-In Hybrids
- Smart End-Use Devices
- Renewable Sources (PV, Wind)
- Control Interface

Graph showing demand over time with segments for PreCool, Clip, and Recover.
New Infrastructures Need to be Integrated

Low-Carbon Generation

Local Energy Networks

Smart Grids

Electric Transportation
Building-Level Local Energy Network
Campus-Level Local Energy Network
Bulk Power System

Central Generation

Market Operator

Regional Transmission Operator

Transmission Substation

Compressed Air Energy Storage

Large Scale Wind

Central Station PV or Solar-Thermal

Central Generation
Community-Level Local Energy Network
Distribution System
Creating an Architecture with Multi-Level Controllers

Bulk Power System

Market Operator

System Operator

Distribution System

Distribution Management System

Community LEN

Master Controller

Campus LEN

Master Controller

Building LEN

Master Controller
Example of Losses in the Value Chain

U.S.: More than 210 billion kWh per year is lost in the delivery of electricity from power plant to end-use devices
Reduced Losses: Opportunities for Improving Efficiency

Transmission

Shield Wire Segmentation
Advanced Conductors
Bundle Optimization
Corona/Insulation Losses
Voltage Optimization

Distribution

Substation Regulators
Capacitor Banks
Sectionalizers
Distributed Regulators

Communication Network

Realtime Metering

Advanced Distribution Optimization
Increased Power Flow

- **Power Flow Technologies**: 20% - 50%
- **Reconductor**: 20% - 50%
- **Current Uprating**: 15% - 20%
- **Voltage Upgrades**: 50% - 100%
- **AC to DC Conversion**: 50% - 250%

**Lead Time** vs **Cost**
High-Temperature, Low-Sag Conductors

Aluminum-Zirconium Alloy (240°C peak)

3M Composite Core

COMPOSITE OPTICAL FIBERS ALUMINUM
Solid State Current Limiter (SSCL)

Value
• Enhanced ability to utilize existing equipment to manage increasing fault current

R&D Highlight
• First ever 15kV class SSCL design, manufacture and testing at full power

Next Steps
• Design refinement for field testing, 69kV design

SSCL: 15kV, 1200 A continuous 80 kA rms Symmetric fault current
How It Works – The Sagometer

• A small camera “looks at” a target on the line
• Artificial intelligence in the camera determines sag (clearance)
• Data is sent, along with weather and load information, to the DTCR software package
Sensor Applications
Automate Inspection & Condition Assessment

- FirstEnergy
- NYP A
- Con Ed
- Duke
- ATC
- TVA
- Tri-State
- Alliant
- SCANA
- CenterPoint
- Southern Company
- Wireless Mesh
- Antenna Array
- On-Line FRA
- 3D Acoustics
- Backscatter

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Smart Grid: Enabling PHEV Through Smart Charging

- Utility – Auto industry collaboration
- Standardize interface vehicle-to-grid
- Open systems

AMI Path

Standard Interface

Non-AMI Path

Smart Charging Back End
Energy Management, Cust ID, Billing
Power Semiconductor Devices & Applications

(a) Ratings (Source: Siemens)
(b) Various applications (Source: ABB)
Flexible AC Transmission Systems (FACTS)

• FACTS: A “World Class” set of electric transmission VAR and flow path control devices that have extremely fast time response capabilities to match changing load and flow conditions

• FACTS devices utilize solid state electronic switches, which evolved from the “Second” Silicon Revolution
  – High speed
  – High power (voltage and current)
Apply Dynamic Thermal Circuit Rating (DTCR)
FACTS Enhances Transmission Capacity

FACTS Device

Static Synchronous Compensator (STATCOM)

Air
FACTS Redirects Flow

Unified Power Flow Controller

FACTS Device
FACTS Redirects Flow

 Convertible Static Compensator (CSC)
FACTS in DC Transmission
Energy Balance
Imbalance Conditions

• Over-generation
  – Total Generation > Total Load
  – Frequency > 60 Hz
  – Generators momentarily speed up

• Under-generation
  – Total Generation < Total Load
  – Frequency < 60 Hz
  – Generators momentarily slow down
Together…Shaping the Future of Electricity