Role of the Smart Grid in Facilitating the Integration of Renewables

Invited Talk

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What is a Smart Grid

"Smart grid" is a concept with many elements where monitoring and control of each element in the chain of generation, transmission, distribution and end-use allow the electricity delivery and use to be more efficient.
Motivation for a Smart Grid

Desire to make the grid smarter, safer, reliable and more cost-effective using advanced sensors, communication technologies and distributed computing.
Smart Grid Building Blocks

- Technology
- Standards
- Rates & Regulations
- Consumer Awareness & Education

Evolution of the Grid

**Before** Smart Grid:
One-way power flow, simple interactions

**After** Smart Grid:
Two-way power flow, multi-stakeholder interactions

Source: Altalink, Alberta, Canada
Intelligent Interconnected Microgrids

Intelligent Load
Demand or price-driven control of appliances

Distribution Network
Interconnected micro grids

Sensors
Detect outages, fluctuations, and disturbances

Distributed Arch.

Microgrid

Smart Inverters and Storage
Minimize voltage and power fluctuations

Control Room Functions
Balance electricity Supply/demand across the grid

Wind Power Park

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Merging Power Flow with Information Flow:
Integrated Communications
Electric Power & Communication Infrastructures

1. Power Infrastructure
- Central Generating Station
- Step-Up Transformer
- Distribution Substation
- Receiving Station
- Distribution Substation
- Distribution Substation
- Gas Turbine
- Recip Engine
- Cogeneration
- Fuel Cell
- Flywheel
- Residential
- Residential Data Concentrator
- Residential

2. Information Infrastructure
- Control Center
- Data Network Users
- Residential Data

Source: EPRI

Changing Landscape for the Electric Utility

- Renewable Energy
- Solar Panels
- Electric Vehicles

Source: EPRI
Issues with Distributed Generation

- Wind and solar are intermittent
- Hydro is space limited
- Resource is free but not always usable

Off-shore Wind turbines, Blyth, U.K.
BPA Wind Output and Load Mismatch
(January 2013)

BPA Wind Output and Load Mismatch
(April 2013)
BPA Wind Output and Load Mismatch (July 2013)

BPA Wind Output and Load Mismatch (Oct 2013)
Wind output can drop 43.7 MW in 1 minute for a single 150-MW wind farm.

Wind output can drop 113 MW in 10 minutes, and increase 106 MW in 10 minutes.

Source: NREL
Hourly wind power variation (MW) in Texas, USA (01 and 02 Jan 2008)

01 Jan 2008

02 Jan 2008

Installed Capacity 4,541 MW

Hourly wind power variation (MW) in Texas, USA (03 and 04 Jan 2008)

03 Jan 2008

04 Jan 2008

Installed Capacity 4,541 MW
Roof-top Solar Photovoltaics in Virginia

Solar Panels in Winter
7-Day Solar PV Output

7-Day Solar PV Output (intermittent)
Daily PV Output

PV AC Power Output During One Sunny Day

Daily PV Output (intermittent)

PV AC Power Output During One Cloudy Day
Solar PV Panels in Saudi Arabia

Reality Check

Solar PV Panel Cleaning (when?)
Can the Intermittency be Absorbed by the Network?

Battery storage

Compressed Air Storage

Pumped Storage

Demand Response

Demand Response is a customer action to control load to meet a certain target. Here the customer chooses what load to control and for how long.
New Paradigm for the Power System

- Historically: Demand driven supply (supply responds to demand)
- New Reality: Supply driven demand (demand needs to adjust to meet fluctuating supply with help from storage)

THE SMART GRID ECOSYSTEM

Smart grid: Bi-directional flows of energy, remote control/automation of power, integrated distributed energy…

Smart city: Complex system of interconnected infrastructures and services…

Smart Campus: A collection of buildings managed by the same facility manager…

Smart buildings: Intelligent building automation systems, smart devices, productive users, grid integration…

Supported by ICT and distributed networks of intelligent sensors, data centers/clouds
What makes a Building Smart

A single platform for monitoring and control of HVAC, lighting, water supply, sensor networks, security camera & fire emergency

Cumulative Benefits of Building Load Control

- A large number of buildings can be controlled to absorb large fluctuations of supply in the short term
- Minimal storage is required
- Investment is for monitoring and control
Addressing the Intermittency in Renewable Generation

• Smart vs. not-so-smart load control
  (adjust temperature set points in an air conditioner or water heater vs. turning the unit off)
• Size the storage to take advantage of demand dynamics
• Control the renewable generation to avoid instability (output control from PV inverters)

Thank you
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