Role of the Smart Grid in Facilitating the Integration of Renewables

Invited Speech

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"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.
Electric Power Grid

Source: www.sxc.hu
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.
Difference Between a Normal Grid And a Smart Grid

Normal Phone

Smart Phone

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Starting and End Points of a Smart Grid

From Generator to Refrigerator

Power Plant
Transmission
Distribution
Home Business
End-use Appliances
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

Distributed Arch.

Local Monitoring and Control

Sensors
Detect outages, fluctuations, and disturbances

Bulk Power Plant
Wind Power Park

Smart Inverters and Storage
Minimize voltage and power fluctuations

Balance electricity supply/demand across the grid

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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
- Commercial
- Industrial
- Residential

2. Information Infrastructure

- Control Center
- Micro-turbine
- Residential Data Concentrator
- Photo voltaics
- Batteries

Source: EPRI
Changing Landscape for the Electric Utility
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)

Installed Capacity 4,541 MW
Hourly wind power variation (MW) in Texas, USA (03 and 04 Jan 2008)

Installed Capacity 4,541 MW
Roof-top Solar Photovoltaics in Virginia
Solar Panels in Winter
7-Day Solar PV Output

PV AC Power Output During One Sunny Week

Day 1  Day 2  Day 3  Day 4  Day 5  Day 6  Day 7
7-Day Solar PV Output (intermittent)
Daily PV Output

PV AC Power Output During One Sunny Day

AC Power (W)

Time (Minute)
Daily PV Output (intermittent)
Can the Intermittency be Absorbed by the Network?

Battery storage

Compressed Air Storage

Pumped Storage
“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”.

This is different from Demand Side Management (DSM) where the load is controlled by the electric utility and the customer has no control beyond the initial consent.
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
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)
Prof. Saifur Rahman

Past-President of IEEE Power & Energy Society
Past-Chair, IEEE Publication Services & Products Board

PES accomplishments:
- PES University
- PES Corporate Engagement Program
- PES Chapters’ Councils in China, India, Africa and Latin America

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