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

**Sensors**
Detect outages, fluctuations, and disturbances

**Distributed Arch.**

**Local Monitoring and Control**

**Bulk Power Plant**

**Wind Power Park**

**Smart Inverters and Storage**
Minimize voltage and power fluctuations

**Control Room Functions**
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
   - Distribution Substation

2. Information Infrastructure
   - Control Center
   - Distribution Substation
   - Gas Turbine
   - Receiving Station
   - Distribution Substation
   - Recip Engine
   - Commercial

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.

Wind Energy
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)

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

Time (Minute)

AC Power (W)
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)
I would like to see a broader IEEE

We need to ensure that we are “READY FOR RECOVERY”, when we get back to the “NEW NORMAL” after COVID-19. Let us enhance cooperation, collaboration and community spirit.

For this we need to make IEEE broader so that IEEE is more relevant to the work our members do regardless where they work.

We need more participation from volunteers globally in IEEE governance. A broader based IEEE will make the Institute more relevant to technologists and academics from all parts of the world.

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