Role of the Smart Grid in Facilitating the Integration of Renewables

Keynote Speech

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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.
Difference Between a Normal Grid And a Smart Grid

Normal Phone  Smart Phone

Starting and End Points of a Smart Grid

From Generator to Refrigerator

Power Plant  Transmission  Distribution  Home Business  End-use Appliances
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 Load
Demand or price-driven control of appliances

Sensors
Detect outages, fluctuations, and disturbances

Distributed Arch.
Distribution Network
Interconnected micro grids

Smart Inverters and Storage
Minimize voltage and power fluctuations

Local Monitoring and Control

Wind Power Park

Bulk Power Plant

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
- Distribution Substation
- Commercial
- Industrial
- Residential
- Photovoltaics
- Batteries
- Residential Data Concentrator
- Control Center

2. Information Infrastructure

- Data network Users
- Recip Engine
- Fuel cell
- Micro-turbine
- Flywheel

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)
1-minute Variation of a 150MW Wind Farm Output in Texas

Wind output can drop 43.7 MW in 1 minute for a single 150-MW wind farm.

10-min Variation of a 150MW Wind Farm Output in Texas

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

Source: NREL
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

23

7-Day Solar PV Output (intermittent)

PV AC Power Output During One Cloudy Week

Day 1  Day 2  Day 3  Day 4  Day 5  Day 6  Day 7

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Daily PV Output

PV AC Power Output During One Sunny Day

Daily PV Output (intermittent)

PV AC Power Output During One Cloudy Day
In-depth look at Solar PV in KSA

2-MW Roof-top Solar PV plant at KAUST

Solar PV Panels in Saudi Arabia

Reality Check
Solar PV Array (100kWp) Riyadh Area

Solar PV Panel Cleaning Cost and Frequency
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


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)
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THANK YOU!