Role of the Smart Grid in Facilitating the Integration of Renewables into the Power Grid

Keynote Speech

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PPT slides are available at www.srahman.org
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 on the basis of the energy management triangle - political objectives and technical implementation.

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

https://en.wikipedia.org/wiki/Smart_grid
Starting and End Points of a Smart Grid

It starts at the Generator and ends at the Refrigerator
Smart Grid Building Blocks
Evolution of the Grid

**Smart Grid**

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

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

Source: Altalink, Alberta, Canada
Electric Power and Communication Infrastructures

1. Power Infrastructure

- Central Generating Station
- Step-Up Transformer
- Distribution Substation
- Receiving Station
- Distribution Substation
- Commercial Gas Turbine
- Recip Engine
- Fuel cell
- Flywheel

2. Information Infrastructure

- Micro-turbine
- Residential Data Concentrator
- Photovoltaics
- Batteries
- Residential Data Concentrator
- Control Center
- Data network Users

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
Wind Energy

Onshore Wind Turbines
- Capacity 2.5 MW
- Rotor Diameter 120 m
- Hub Height 89 m
- Specific Power 221 W/m²

2019

2035
- Capacity 5.5 MW
- Rotor Diameter 174 m
- Hub Height 130 m
- Specific Power 231 W/m²

Offshore Wind Turbines
- Capacity 6.0 MW
- Rotor Diameter 250 m
- Hub Height 103 m
- Specific Power 340 W/m²

2019

2035
- Capacity 17 MW
- Rotor Diameter 150 m
- Hub Height 151 m
- Specific Power 346 W/m²

BPA Wind Output and Load Mismatch
(A typical day in January)
BPA Wind Output and Load Mismatch
(A typical day in April)
BPA Wind Output and Load Mismatch (A typical day in July)
BPA Wind Output and Load Mismatch
(A typical day in October)
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
Solar Energy
Roof-top Solar Photovoltaics in Virginia
Solar Panels in Winter
Intermittency Caused by Weather Events

Solar PV Project in UAE

Sand Storm in Abu Dhabi
In-depth look at Solar PV in Saudi Arabia

2-MW Roof-top Solar PV plant at KAUST
Solar PV Array (100kWp) Riyadh Area

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

September

July
7-Day Solar PV Output (Virginia, cloudy)
Daily PV Output (Virginia)
Daily PV Output (Virginia, intermittent)
Some Intermittency can be Absorbed by the Network with no or Little Storage

Demand Response can Provide Significant Support to Manage Intermittency
Demand Response Requires Sensor/Controller Connectivity

ICT can Provide the Platform for this Connectivity
An Open-Architecture Platform for IoT Device Integration in a Building

- Sensors/Power Meters
- Plug Load Controllers
- Controllers
- CT30 (WiFi)
- CT50 (WiFi)
- CT80 (ZigBee SE)
- ICM (WiFi)
- RTU (Modbus)
- VAV controller (Modbus)
- Nest (WiFi)
- Philips Hue (WiFi)
- Light switch (WiFi)
- Step-dimmed ballast (ZigBee)
- Smart plug (WiFi)
- Smart plug (ZigBee)
- Plug load controller (BACnet)
- Power meter (Modbus/BACnet)
- Light sensor (BACnet)
- Occupancy sensor (BACnet)
- HVAC Load Controllers
- Lighting Load Controllers
Smart Campus

Utility/Demand Response Aggregator

Customers/Operators

Buildings

Internet

HVAC

Lighting loads

Plug loads

Power meters

Water meters

PV & storage

Security camera
Field Implementation: Intelligent Interconnected Microgrids

- **Intelligent Load**: Demand or price-driven control of appliances
- **Sensors**: Detect outages, fluctuations, and disturbances
- **Distribution Network**: Interconnected micro grids
- **Distributed Arch.**: Distribution network
- **Local Monitoring and Control**: Local monitoring and control
- **Microgrid**: Microgrid
- **Wind Power Park**: Wind power park
- **Smart Inverters and Storage**: Minimize voltage and power fluctuations
- **Bulk Power Plant**: Bulk power plant
- **Control Room Functions**: Balance electricity supply/demand across the grid

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New Paradigm for the Electric Power System

Historically: Demand driven supply (supply responds to demand)

New Reality: Supply driven demand (demand needs to adjust to meet fluctuating supply with 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
Thank you