Role of Smart Grid in Facilitating the Integration of Renewables

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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.
How Does the Electrical Grid Work?

- Power Sources
- Transformers
- Transmission lines
- Distribution centers

https://blog.arcadia.com/understanding-the-electrical-grid/
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

[Diagram showing the differences between a normal grid and a smart grid]

STAYING BIG OR GETTING SMALLER
Expected structural changes in the energy system made possible by the increased use of digital tools

-yesterday-
- today -

Few large power plants

Many small power producers

Centralized, mostly national

Decentralized, ignoring boundaries

Based on large power lines and pipelines

Including small-scale transmission and regional supply compensation

Top to bottom

Both directions

Passive, only paying

Active, participating in the system

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

Power Plant

Transmission

Distribution

Home Business

End-use Appliances
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
Merging Power Flow with Information Flow:
Electric Power & Communication Infrastructures

1. Power Infrastructure

- Central Generating Station
- Step-Up Transformer
- Distribution Substation
- Receiving Station
- Distribution Substation
- Gas Turbine
- Recip Engine
- Flywheel
- Cogeneration
- Industrial
- Commercial
- Recip Engine
- Fuel cell
- Data network Users

2. Information Infrastructure

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

Source: EPRI
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,

Microgrid

Bulk Power Plant

Control Room Functions
Balance electricity Supply/demand across the grid

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Smart Inverters and Storage
Minimize voltage and power fluctuations

Wind Power Park

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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

- Capacity: 5.5 MW
- Rotor Diameter: 174 m
- Hub Height: 130 m

Offshore Wind Turbines

- Capacity: 6.0 MW
- Rotor Diameter: 250 m
- Hub Height: 103 m

- Capacity: 17 MW
- Rotor Diameter: 150 m
- Hub Height: 151 m

Specific Power:
- 2019: 221 W/m²
- 2035: 231 W/m²
- 2019: 340 W/m²
- 2035: 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
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 Panels in Saudi Arabia

Reality Check
Solar PV Array (100kWp) Riyadh Area
7-Day Solar PV Output (Virginia)
7-Day Solar PV Output (Virginia cloudy)
Daily PV Output (Virginia)
Daily PV Output (Virginia, intermittent)
Can the Intermittency be Absorbed by the Network?
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
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SCAN ME

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