Role of the 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.
Electric Power Grid

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

Desire to make the grid smarter, safer, reliable and more cost-effective using advanced sensors, communication technologies and distributed computing.

Motivation for a Smart Grid on the basis of the energy management triangle - political objectives and technical implementation.

https://www.researchgate.net/figure/Motivation-for-a-Smart-Grid-on-the-basis-of-the-energy-management-triangle-political_fig1_263264024
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

- 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
Smart Grids: Electricity Networks And The Grid In Evolution

Merging Power Flow with Information Flow:

Integrated Communications
Power Flow And Data Flow

https://www.fujielectric.com/products/energy_ctrl_mng/b02.html
Electric Power & Communication Infrastructures

1. Power Infrastructure

- Central Generating Station
- Step-Up Transformer
- Distribution Substation
- Receiving Station
- Distribution Substation

2. Information Infrastructure

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

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,

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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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
- 2019: Capacity 2.5 MW, Specific Power 221 W/m², Rotor Diameter 120 m, Hub Height 89 m
- 2035: Capacity 5.5 MW, Specific Power 231 W/m², Rotor Diameter 174 m, Hub Height 130 m

Offshore Wind Turbines
- 2019: Capacity 6.0 MW, Specific Power 340 W/m², Rotor Diameter 150 m, Hub Height 103 m
- 2035: Capacity 17 MW, Specific Power 346 W/m², Rotor Diameter 250 m, Hub Height 151 m

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 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

PV AC Power Output During One Sunny Day

- AC Power (W)
- Time (Minute)
Daily PV Output (intermittent)

PV AC Power Output During One Cloudy Day

AC Power (W)

Time (Minute)
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)

New Paradigm for the Electric Power System

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.
SMART GRID TECHNOLOGIES FOR THE FUTURE

- Energy Management Systems
- Advanced Metering Infrastructure
- IoT Projects
- Demand Response
- Electric Vehicles
- Big Data

https://www.valuer.ai/blog/innovative-smart-grid-technologies-for-the-future
USING AN ELECTRIC VEHICLE TO STORE ENERGY

1. The electric vehicle is connected to the smart grid via a charging station.

2. The grid programme “knows” that the vehicle is not being used in the evening. It records the vehicle as a potential source of stored electricity.

THE AGILITY EFFECT

Big Data Challenges in Future Smart Grid

https://www.semanticscholar.org/paper/Big-data-analytics-in-smart-grids-%3A-state-of-the-art-Bhattarai-Paudyal/81da7e7aa47edbcc96374cc0a9099d50c005ee8
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