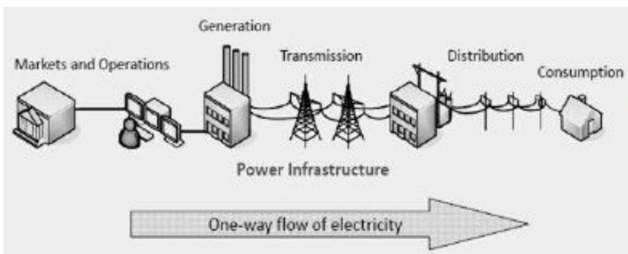
Smart Grids

Traditional Power Grid

Smart Grid



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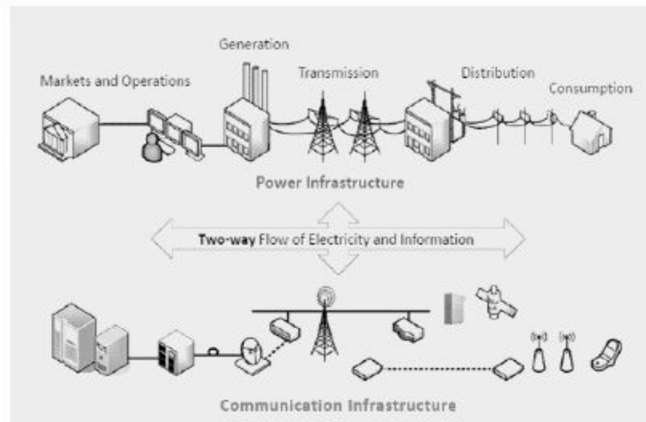
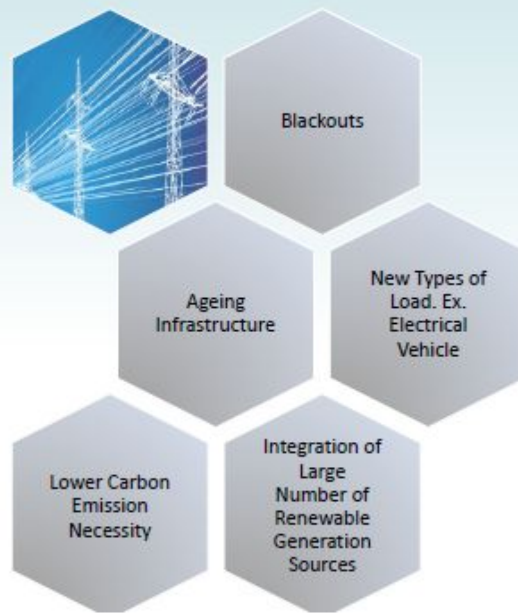


Existing Grid

- Limited Delivery System.
- High cost of power outage and power quality interruption .
- Inefficiency at managing peak load.
- Communications too slow.

Why Smart Grid



What is Smart Grid

A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

Smart grids: introduce monitoring , analysis , control and communication abilities to the Traditional grid

Allows communication and interaction between the energy consumers, appliances and the grid

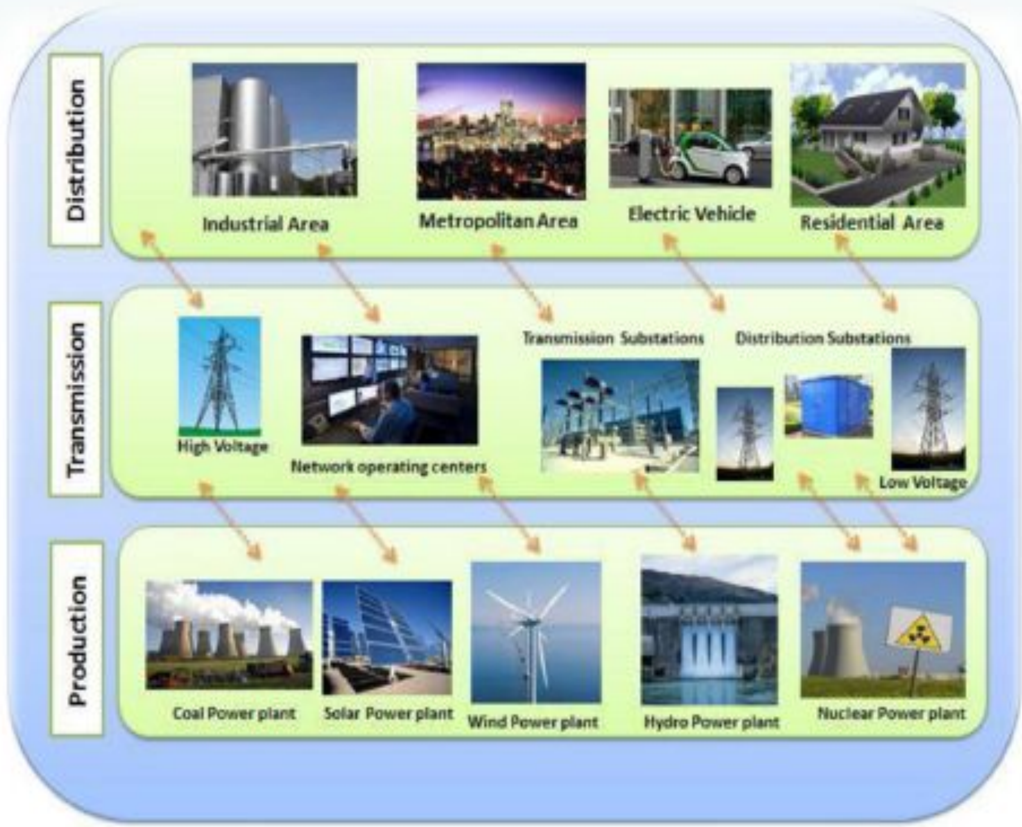
overall objective of optimizing energy usage, energy generation and energy distribution

DSM (Demand Side Energy Management): Allows better load mgmt , achieve energy efficiency and energy saving using Information collected from AMI e.g smart meters

Key Features

- Energy efficiency
- Direct load control
- Distributed generation and cogeneration
- Automated Demand Response

Smart Grid Electrical Network Architecture



- More efficient transmission of electricity

- Quicker restoration of electricity after power disturbances

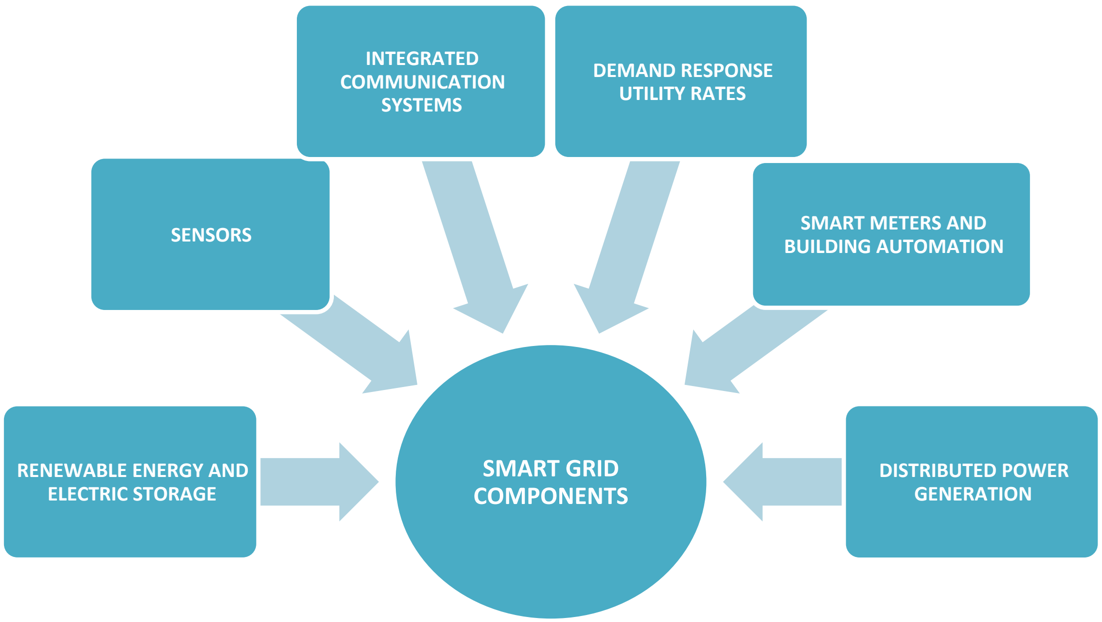
- Reduced operations and management costs for utilities, and ultimately lower power costs for consumers

- Reduced peak demand, which will also help lower electricity rates

- Increased integration of large-scale renewable energy systems

- Better integration of customer-owner power generation systems, including renewable energy systems
- Improved security

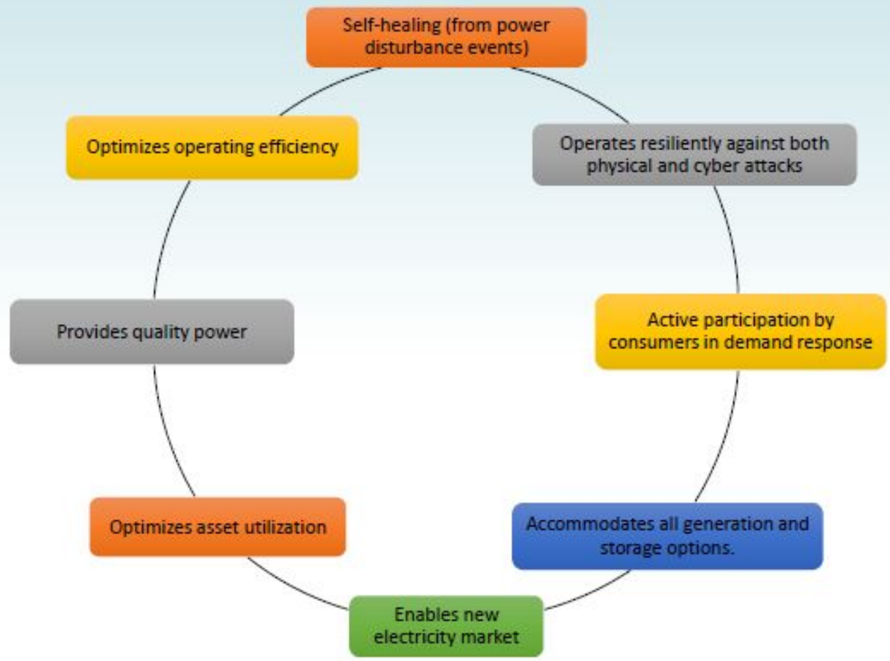
COMPONENTS OF A SMART GRID



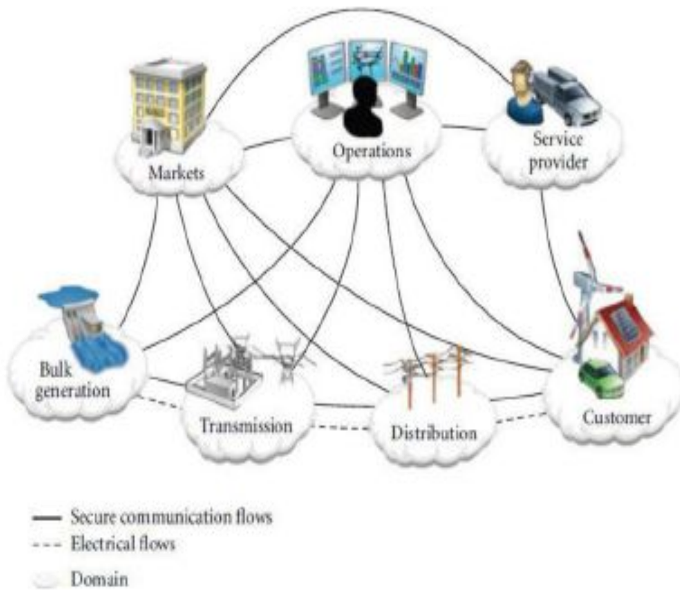
Smart Grid Components

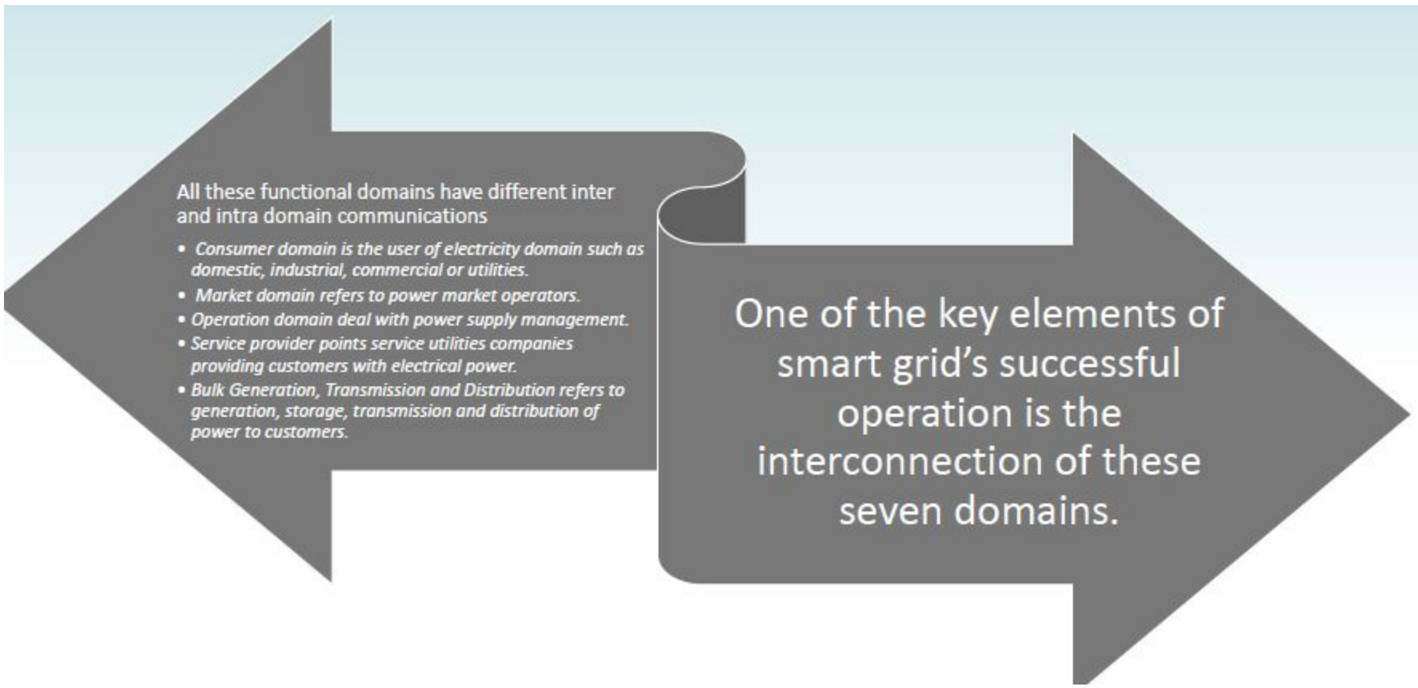
- **Smart Meter**
- **Phasor Measurement**
- **Information Transfer**
- **Distributed Generation**

Feature of Smart Grid



NIST Framework for SG




All these functional domains have different inter and intra domain communications
• Consumer domain is the user of electricity domain such as domestic, industrial, commercial or utilities.
• Market domain refers to power market operators.
• Operation domain deal with power supply management.
• Service provider points service utilities companies providing customers with electrical power.
• Bulk Generation, Transmission and Distribution refers to generation, storage, transmission and distribution of power to customers.
One of the key elements of smart grid's successful operation is the interconnection of these seven domains.

Electrical Network

Production Domain

composed of a mixture of nuclear, solar, coal, wind or hydro power plant

Transmission Domain

managed by huge number of network operating centers and substations, a large number of power lines deliver the electricity to distribution domain

Distribution Domain

sum of complex networks topologies delivers electrical power to residential areas, rural farms, metropolitan areas, and industrial areas for consumption

Communication Network

HAN

- Customer domain network
- Covers in-home smart devices and appliances
- IED send data readings over HAN to AMI applications threw home smart meter or residential gateway
- Important component of HAN is the home energy management system (HEMS) that allows consumers to see real time power consumption of household
- BAN and IAN networks refer to HAN parallel networks when implemented respectively in business/buildings or industrial areas
- Wireless technology -ZigBee, 6LowPan

NAN

- Distribution domain network
- Mesh of smart meters
- NAN connects the AMI applications access point to smart meters in customer domain and various gateways in the distribution domain
- Main purpose of this network is data collection from smart meter for monitoring and control.
- Wireless-ZigBee, 6LowPan,WiMAX, LTE, 3G and 4G. Wired -PLC and Ethernet

FAN

- Distribution domain network.
- FAN include power line monitors, breaker controllers,voltage regulators, capacitor bank controllers, recloser controllers, transformers, data collectors, etc. These are used to response automatically when detecting any abnormalities and failure.
- Enables mobile workers to access field devices using their laptops, tablets or hand-held equipment.
- Wireless - WiMAX, LTE, 3G and 4G and wired - PLC and Ethernet could be used for FAN

WAN

- Affords communications systems between smart grid & core utility system.
- It is composed by two types of networks backhaul and core network.
- Core network offers the connectivity between substations and utility systems
- Backhaul network connect the NAN network to the core network.
- Variety of technologies such as WiMAX, 4G, and PLC could be used in WAN networks. Also virtual technologies like MPLS could be used for the core network.

Different Communication Technologies

Technology	Spectrum	Data rate	Cover range	Applications	Limitations
GSM	900– 1800 MHz	Upto 14.4 Kpbs	1-10 km	AMI, Demand Response, HAN	Low date rates
GPRS	900– 1800 MHz	Upto 170 kbps	1-10 km	AMI, Demand Response, HAN	Low date rates
3G	1.92-1.98 GHz 2.11-2.17 GHz	384 Kbps-2 Mbp+s	1-10 km	AMI, Demand Response, HAN	Costly spectrum fees
WiMAX	2.5 GHz, 3.5 GHz, 5.8 GHz	Upto 75 Mbps	10-50km (LOS) 1-5 km(NLOS)	AMI, Demand Response	Not widespread
PLC	1-30 MHz	2-3 Mbps	1-3 km	AMI, Fraud Detection	Harsh, noisy channel environment
ZigBee	2.4 GHz- 868 - 915 MHz	250 Kbps	30-50 m	AMI, HAN	Low data rate, short range

Smart Grid – Major Functional Modules

- Motivation
- Sensing and Measurement
- Communications and Security
- Components and Subsystems
- Interfaces and Decision Support
- Control Methods and Topologies

Advanced Sensing and Measurement

- Enhance power system measurements and enable the transformation of data into information.
- Evaluate the health of equipment, the integrity of the grid, and support advanced protective relaying.
- Enable consumer choice and demand response, and help relieve congestion

Advanced Sensing and Measurement

- Advanced Metering Infrastructure (AMI)
  - Provide interface between the utility and its customers: bi-direction control
  - Advanced functionality
    - Real-time electricity pricing
    - Accurate load characterization
    - Outage detection/restoration

Key Components of AMI

Smart Meters

Installed at consumer premises
Measure electricity (or gas/water) usage in real-time or near-real-time
Can send and receive data

Communication Networks

Transmit data between smart meters and the utility provider
Can be wired (e.g., power line communication) or wireless (e.g., RF mesh, cellular)

Meter Data Management System (MDMS)

Collects, stores, and analyzes the data received from smart meters
Enables billing, usage analysis, and grid optimization

Role of IoT in Smart Grids

In a smart grid, IoT refers to the **network of smart devices** (like sensors, meters, switches, appliances) that **collect, share, and analyze data** in real time to optimize the generation, distribution, and consumption of electricity.

Key Roles of IoT in Smart Grids:

1. Real-Time Monitoring

- IoT sensors track power flow, voltage, frequency, temperature, and other grid parameters.
- Helps in **detecting faults or outages instantly**.

2. Demand Response and Management

- Smart appliances and meters adjust power usage based on demand signals.
- Utilities can send price-based signals to users to **shift or reduce load** during peak times.

3. Energy Efficiency

- IoT devices analyze consumption patterns to suggest or automate **energy-saving behaviors**.
- Enables **smart home automation** (e.g., turning off unused appliances).

Contd.

4. Integration of Renewable Energy
- Helps balance **variable energy sources** like solar or wind with grid demands.
- IoT-enabled inverters and storage systems respond to grid signals.

5. Predictive Maintenance
- Sensors on transformers, lines, and substations detect wear or damage before failure.
- Reduces downtime and **extends equipment life**.

6. Improved Customer Engagement
- Customers can track their real-time energy usage through apps or dashboards.
- Enables more **informed and eco-friendly decisions**.

Integration of renewable energy

Renewable energy generators are being combined into today's power grid because of environmental reasons, climate change, and its low cost.

IoT technology uses wireless sensors to collect real-time weather information to help in predicting the energy availability in the near future.

With IoT, the grid becomes

- **Self-healing**
- **More reliable**
- **Cyber-physical**
- **Data-driven**
- **Greener**

Smart Grid - Advantages

- Integrate isolated technologies : Smart Grid enables better energy management.
- Proactive management of electrical network during emergency situations.
- Better demand supply / demand response management.
- Better power quality.
- Increasing demand for energy : requires more complex and critical solution with better energy management

Disadvantages

Disadvantages

- Present Infrastructure is inadequate and requires augmentation to support the growth of Smart Grids.
- Most renewable resources are intermittent and can not be relied on (in its present form)for secure energy supply.
- Regulatory Policies to deal with consequences of Smart Grid; like off peak, peak tariffs and other related matters.
- Grid Operation : Monitoring & control