SMART GRID

MODULE-I

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Evolution of "Smart Grid": -

The first official definition of Smart Grid was provided by the Energy Independence and Security Act of 2007 (EISA-2007), which was approved by the US Congress in January2007, and signed to law by President George W. Bush in December 2007. Title XIII of this bill provides a description, with ten characteristics, that can be considered a definition for Smart Grid, as follows:

"It is the policy of the United States to support the modernization of the Nation's

electricity transmission and distribution system to maintain a reliable and secure electricityinfrastructure that can meet future demand growth‖

To achieve each of the following, which together characterize a Smart Grid:

(1) Increased use of digital information and controls technology to improve reliability,security, and efficiency of the electric grid.

(2) Dynamic optimization of grid operations and resources, with full cyber-security.

(3) Deployment and integration of distributed resources and generation, includingrenewable resources.

(4) Development and incorporation of demand response, demand-side resources, andenergy-efficiency resources.

(5) Deployment of `smart' technologies (real-time, automated, interactive technologiesthat optimize the physical operation of appliances and consumer devices) for metering,communications concerning grid operations and status, and distribution automation.

(6) Integration of `smart' appliances and consumer devices.

(7) Deployment and integration of advanced electricity storage and peak-shavingtechnologies, including plug-in electric and hybrid electric vehicles, and thermal storage airconditioning.

(8) Provision to consumers of timely information and control options.

(9) Development of standards for communication and interoperability of appliances andequipment connected to the electric grid, including the infrastructure serving the grid.

(10) Identification and lowering of unreasonable or unnecessary barriers to adoption ofsmart grid technologies, practices, and services.

A common element to most definitions is the application of digital processing and communications to the power grid, making data flow and information management central to the smart grid. Various capabilities result from the deeply integrated use of digital technology with power grids. Integration of the new grid information is one of the key issues in the design of smart grids. Electric utilities now find themselves making three classes of transformations: improvement of infrastructure, called the strong grid in China; addition of the digital layer, which is the essence of the smart grid; and business process transformation, necessary to capitalize on the investments in smart technology. Much of the work that has been going on in electric grid modernization, especially substation and distribution automation, is now included in the general concept of the smart grid.

Smart Grid: -

A Smart Grid is an electricity Network based on Digital Technology that is used to supply electricity to consumers via Two-Way Digital Communication. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce the energy consumption and cost and maximise the transparency and reliability of the energy supply chain.

<u>Concept, Definitions and Need for Smart Grid</u>: -

A Smart Grid is an electricity Network based on Digital Technology that is used to supply electricity to consumers via Two-Way Digital Communication. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce the energy consumption.

The term "Smart Grid" was coined by Andres E. Carvallo on April 24, 2007 at an IDC energy conference in Chicago.

Definition: Smart grid is integration of an electric power system, communication network, advanced Sensing, metering, measurement infrastructure, complete decision support and human interfaces software and hardware to monitor, control and manage the creation, distribution, storage and consumption of energy

The areas of application of smart grids include: smart meters integration, demand management, smart integration of generated energy, administration of storage and renewable resources, using systems that continuously provide and use data from an energy network. 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.

➢ System (Generation, Transmission, Distribution) with an advanced two- way communications system

➢ Enables real-time monitoring and control

➢ Provide greater visibility and transparency

➢ Consequently, enables cost reduction and efficiency improvement

Smart Grid is based on Digital Technology that is used to supply electricity to consumers via Two-Way Digital Communication. This system allows for monitoring, analysis, control and communication within the supply chain to help improve efficiency, reduce the energy consumption and cost and maximise the transparency and reliability of the energy supply chain

The flow of electricity from utility to consumer becomes a two-way conversation, saving consumers money, energy, delivering more transparency in terms of end-user use, and reducing carbon emissions.

A smart grid distribution system, whose objective is to develop a power grid more efficient and reliable, improving safety and quality of supply in accordance with the requirements of the digital age.

✓ Higher Penetration of renewable resources or distributed generation

✓ Extensive and effective communication overlay from generation to consumers

✓ Use of advanced sensors and high speed control

✓ Higher operating efficiency.

✓ Greater resiliency against attacks and natural disasters

✓ Automated metering and rapid power restoration

✓ Provided greater customer participation

Function of smart grid components

- **Smart Devices Interface Component**

Smart devices for monitoring and control form part of the generation components ' real time information processes.

- **Storage Component**

Due to the variability of renewable energy and the disjoint between peak availability and peak consumption, it is important to find ways to store the generated energy for later use. Options for energy storage technologies include pumped hydro, advance batteries, flow batteries, compressed air, super -conducting magnetic energy storage, super capacitors, and flywheels. Associated market mechanisms for handling renewable energy resources, distributed generation, environmental impact and pollution are other components necessary at the generation level.

- **Transmission Subsystem Component**

The transmission system that interconnects all major substation and load centers is the backbone of an integrated power system. Efficiency and reliability at an affordable cost continue to be the ultimate aims of transmission planners and operators.

- **Monitoring and Control Technology Component**

Intelligent transmission systems/assets include a smart intelligent network, self - monitoring and self - healing, and the adaptability and predictability of generation and demand robust enough to handle congestion, instability, and reliability issues.

• **Intelligent Grid Distribution Subsystem Component**

The distribution system is the final stage in the transmission of power to end users. Primary feeders at this voltage level supply small industrial customers and secondary distribution feeders supply residential and commercial customers.

• **Demand Side Management Component**

DSM options provide reduced emissions in fuel production, lower costs, and contribute to reliability of generation. These options have an overall impact on the utility load curve.

Presently the Indian Electricity System faces a number of challenges such as: -

✓ Shortage of power

✓ Power Theft

✓ Poor access to electricity in Rural areas

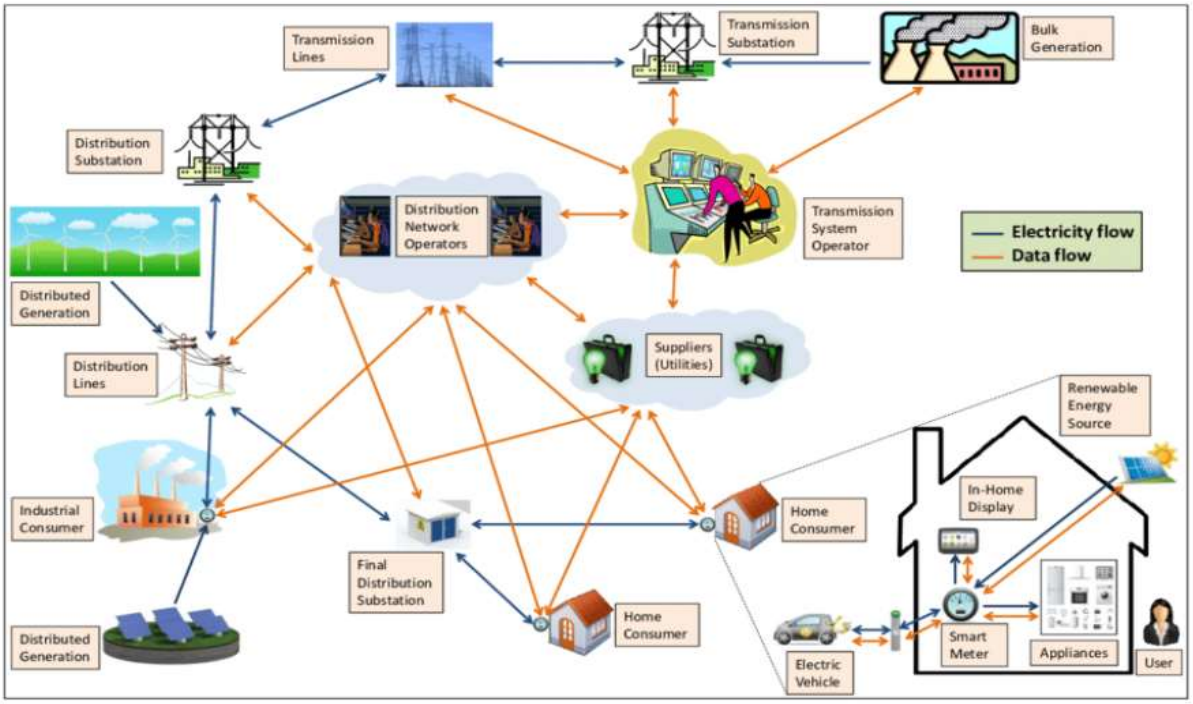
✓ Huge losses in the Grid

✓ Inefficient Power Consumption

✓ Poor reliability

To overcome these problems; smart grid is needed.

Architecture of smart Grid :-



Difference between conventional & smart grid: -

Sl.No.	Smart Grid	Conventional Grid
1.	Self-Healing	Manual Restoration
2.	Digital	Electromechanical
3.	Pervasive Control	Limited Control
4.	Two-Way Communication	One-Way Communication
5.	Distributed Generation	Centralized Generation
6.	Network	Hierarchical
7.	Adaptive and Islanding	Failures and Blackouts
8.	Sensors Throughout	Few Sensors
9.	Remote Check/Test	Manual Check/Test
10.	Self-Monitoring	Blind
11.	Many Customer Choices	Few Customer Choices
12.	Extensive real time monitoring	Lack of real time monitoring
13.	Extremely quick reaction time	Slow Reaction time
14.	Energy Storage	No energy Storage
15.	Increased customer participation	Total control by Utility

Opportunities & Challenges of Smart Grid: -

Opportunities:

1. Increased energy efficiency: Smart grid technologies can help utilities and customers to monitor and manage their energy consumption, resulting in reduced energy waste and lower energy bills.
2. Integration of renewable energy sources: Smart grid can enable the integration of renewable energy sources such as solar and wind power into the electricity grid, making it possible to generate and distribute electricity from a diverse range of sources.

3. Improved reliability and resiliency: Smart grid can provide real-time monitoring and control of the electricity grid, enabling utilities to quickly detect and respond to power outages, minimize downtime, and improve the overall reliability of the grid.
4. Enhanced grid security: Smart grid can improve the security of the electricity grid by providing advanced cybersecurity measures to protect against cyber-attacks.
5. Better customer engagement: Smart grid technologies can enable utilities to provide customers with more detailed and personalized information about their energy consumption, leading to better engagement and awareness.

Challenges:

1. High upfront costs: Implementing smart grid technologies can be expensive, requiring significant upfront investments in hardware, software, and infrastructure.
2. Interoperability and standardization: Smart grid technologies need to be interoperable and standardized to ensure that different systems can communicate and work together seamlessly.
3. Privacy concerns: Smart grid technologies can collect a lot of data about customer energy usage, raising concerns about privacy and data security.
4. Cybersecurity risks: Smart grid technologies are vulnerable to cyber-attacks, which can cause significant disruptions and damage to the electricity grid.
5. Regulatory challenges: The implementation of smart grid technologies may require changes to existing regulatory frameworks, which can be complex and time-consuming to implement.

Overall, while smart grid technologies offer significant opportunities to improve the efficiency, reliability, and security of the electricity grid, they also present significant challenges that need to be addressed to ensure their successful implementation.

Introduction to Smart Meters: -

A smart meter is an electronic measurement device installed by the utility to maintain a two-way communication between the consumer and the utility. Also manage the electrical system of the consumer.

A smart meter is capable of communicating the real time energy-consumption of an electrical system in very short intervals of time to the connected utility

In the electronic meters/electromechanical meters, the cumulative number of electricity units was recorded at the end of a month (or more). whereas a smart reader is connected to the utility which is capable of transmitting the electricity usage on a real-time basis.

Smart meters do not save energy themselves but consumers do.

The purpose of smart meters is to change the behaviour of the consumers. It is hoped that the consumers would save energy through awareness and the estimated bills.

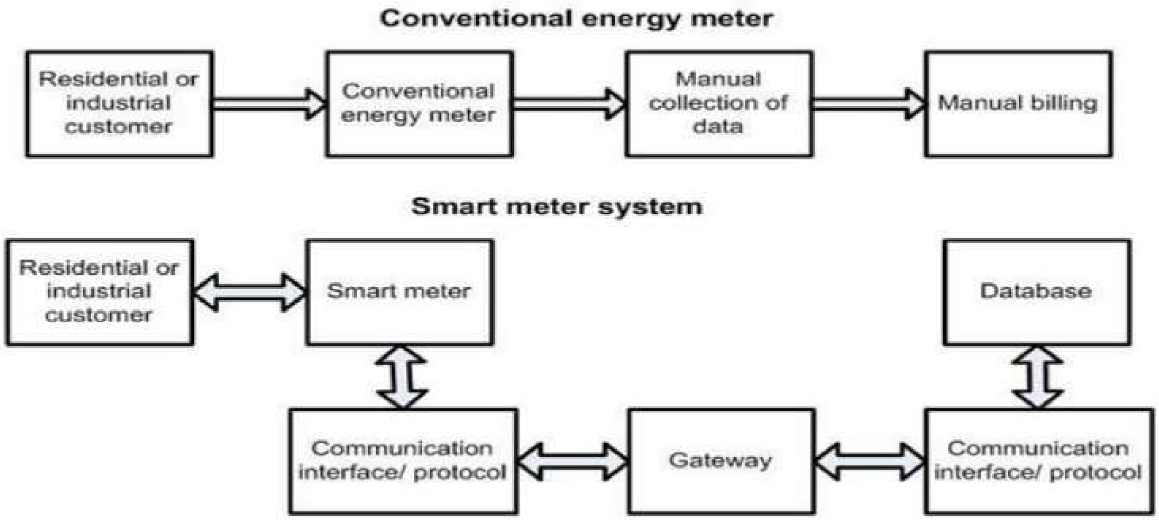


Fig 3.1 Block Diagram for Smart Meters

<u>Advantages to Smart Meters</u>: -

Accuracy in meter reading:

➢ In case of electromechanical/electronic meters, the meter readings have to be read

by a representative of the utility.

➢ Smart meters automatically transmit the readings to the connected utility.

Data Recording:

➢ Conventional meters only record the electricity consumption of a system, and nothow and when the electricity is used.

➢ Smart meters record real-time data corresponding to the electricity consumption. Itmeans that they also record the time and patterns of electricity consumption

Real time tracking:

❖ What ‘s really nice about these meters is that consumers can go online and checkout their electricity usage patterns and make changes to their consumptionaccordingly.

❖ In this way, smart meters offer a strong control to the consumers over their usage.

Automatic outage detection:

❖ A person having a conventional meter has to call the utility whenever there is apower outage whereas in case of smart meters, there is automatic outage detectionas they are constantly synchronised with the electric grid.

Better service:

➢ As smart meters are directly connected to the utility, it becomes much simpler to connect/disconnect power for a particular house/property, saving the need of a technician going to the house in person and connect/disconnect the supply.

Purpose & Benefits of Smart Meters

For utility companies: -

➢ Easy to match energy consumption and generation in both peak time and low time .

➢ Smart meter can easily connect or disconnect the service .

➢ Customers can pay through internet by reading the meter themselves so the labour cost is highly reduced .

➢ Misprint during billing should completely reduced .

➢ No more energy theft .

For customers: -

➢ They should aware about there energy uses so that they can reduce there consumption.

➢ Real time pricing encourage people to adjust their consumption habit .

➢ Payment options like prepaid etc .

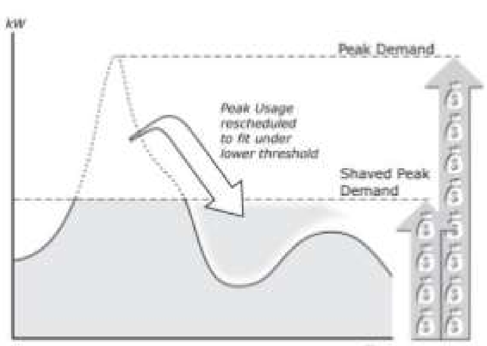
➢ A survey says this system reduce the energy consumption by 7 – 9 % .

➢ This is a win-win situation for both utility and customer.

<u>REAL TIME PRICING</u>

The benefits of real time pricing can be maximised by considering four main criteria:

- Duration for which energy consumption pricing varies
- Ability to buy energy during low energy prices
- Ability to control appliances according to energy price at a given time.
- A smart meter that measures the total usage and time of usage of energy



The occurrence of price variation can be determined by the load curve. The load curve shows the load variation on the generating station with respect to time. The load curve can be used to determine the maximum demand. Electricity prices will be greatest when there is high demand on the grid. This allows customers to limit their energy usage during the periods of maximum demand and shift their electricity consumption to the hours of less demand and thereby lower prices. This process of controlling the electric energy usage during the hours of high demand in order to reduce the billing amount is called demand side management to achieve peak shaving.

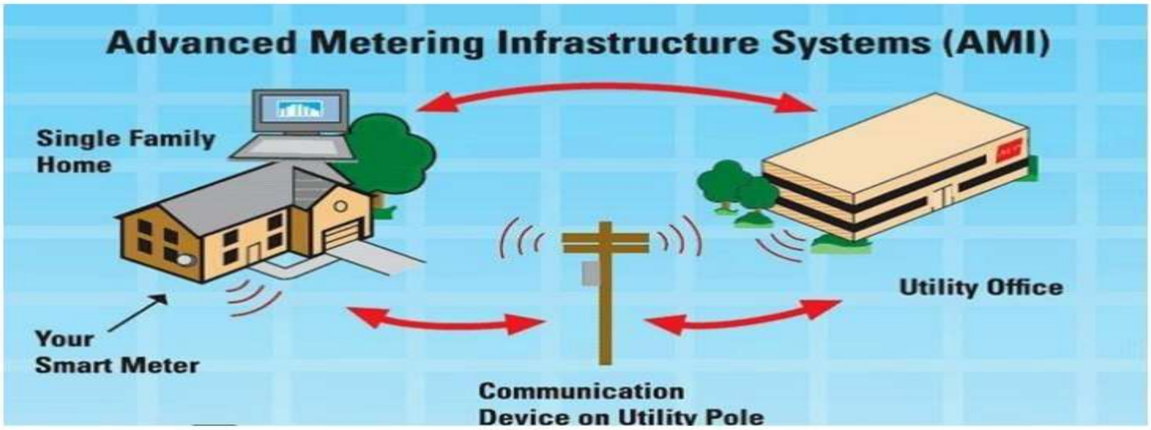
Advanced Metering infrastructure (AMI): -

The present system of energy metering as well as billing in India uses electromechanical and somewhere digital energy meter. It consumes more time and labour

One of the prime reasons is the traditional billing system which is very inaccurate, slow, costly, and lack in flexibility as well as reliability.

Today accuracy in electricity billing is highly recommended. The 'Smart energy meter' gives real power consumption as well as accurate billing. It provides real time monitoring of utility of electricity.

AMI (Advanced Metering Infrastructure) is the collective term to describe the whole infrastructure from smart meter to two-way communication network to control centre equipment and all the applications that enable the gathering and transfer of energy usage information in near real-time. AMI makes a two-way communication with customers possible and is the backbone of smart grid.



<u>Outage Management System (OMS)</u>: -

An Outage Management System (OMS) is a computer-based software system that is designed to help electric utilities manage and respond to power outages. The system is designed to provide utilities with real-time data on the status of their distribution networks, allowing them to quickly identify and respond to power outages.

The key features of an OMS include:

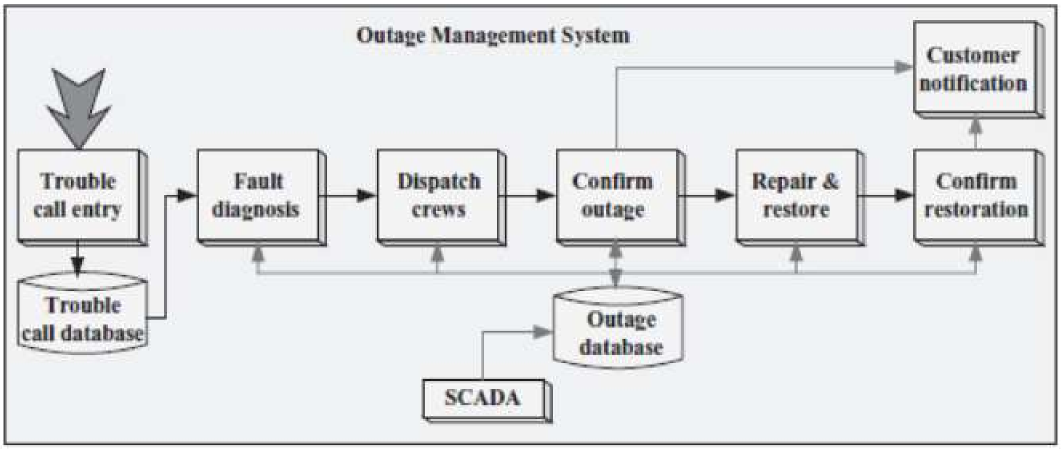
1. Fault detection: The OMS uses advanced sensors and communication systems to detect faults on the distribution network. When a fault is detected, the system automatically creates a trouble ticket and assigns it to the appropriate crew.
2. Outage notification: The OMS notifies customers of power outages via multiple channels such as text messages, phone calls, and emails.
3. Outage verification: The OMS uses customer reports and field crew observations to verify the location and scope of outages.

4. Crew management: The OMS assigns crews to repair outages, tracks their progress, and optimizes their travel routes.
5. Predictive analytics: The OMS uses historical data to predict the probability of future outages and plan preventive maintenance.
6. Reporting and analysis: The OMS provides detailed reports and analysis of outage events, enabling utilities to identify patterns and trends and improve their outage response processes.

The benefits of an OMS are numerous, including:

1. Faster restoration times: The OMS helps utilities to quickly identify the location and scope of outages, allowing them to dispatch crews more efficiently and reduce restoration times.
2. Improved customer satisfaction: The OMS provides customers with real-time information on the status of outages, reducing frustration and improving satisfaction.
3. Enhanced operational efficiency: The OMS automates many of the tasks involved in outage management, reducing the workload of utility staff and improving operational efficiency.
4. Better decision-making: The OMS provides utilities with real-time data on the status of their distribution network, enabling them to make more informed decisions about outage response and preventive maintenance.

Overall, an OMS is an essential tool for electric utilities, helping them to improve outage response times, enhance customer satisfaction, and optimize their operations.



<u>Home & Building Automation</u>: -

Home and building automation are the use of technology to automate and control various systems within a home or building, such as lighting, heating and cooling, security, and entertainment systems. The aim of home and building automation is to improve energy efficiency, comfort, convenience, and security, while reducing costs and environmental impact.

Some common examples of home and building automation systems include:

1. Smart thermostats: These devices can automatically adjust the temperature of a home or building based on the time of day, occupancy patterns, and other factors, reducing energy consumption and costs.
2. Lighting control systems: These systems can automatically adjust the lighting of a home or building based on occupancy patterns, natural light levels, and other factors, reducing energy consumption and improving comfort.
3. Security systems: These systems can include cameras, motion sensors, and other devices that can be used to monitor and control access to a home or building, improving security and safety.

4. Entertainment systems: These systems can include audio and video equipment that can be controlled remotely, allowing users to easily stream music and videos throughout the home or building.
5. Automated blinds and curtains: These devices can be programmed to open and close automatically based on the time of day, weather conditions, and other factors, reducing energy consumption and improving comfort.
6. Smart locks: These devices can be controlled remotely and allow homeowners to monitor and control access to their home or building, improving security and convenience.

Overall, home and building automation can provide numerous benefits to homeowners and building managers, including improved energy efficiency, comfort, convenience, and security. It is an increasingly popular trend in modern homes and buildings, with a wide range of smart devices and systems available on the market.

Feeder Automation: -

Feeder Automation Solution reduces capital investment in the distribution network by limiting the replacement of legacy devices. It contributes to more direct cost savings by facilitating preventative maintenance. Arctic Control is also ideally suited to retrofitting into existing disconnectors. It enables remote control of these devices and further extends the life cycle of the disconnectors themselves.

Feeder Automation Solution provides means for the utilities to reduce the frequency of power outages and faster restoration time by remote monitoring and control of medium voltage network assets such as disconnectors, load break switches and ring main units in energy distribution networks. It provides an always-on wireless connectivity together with the intelligence needed for disconnector control and monitoring.

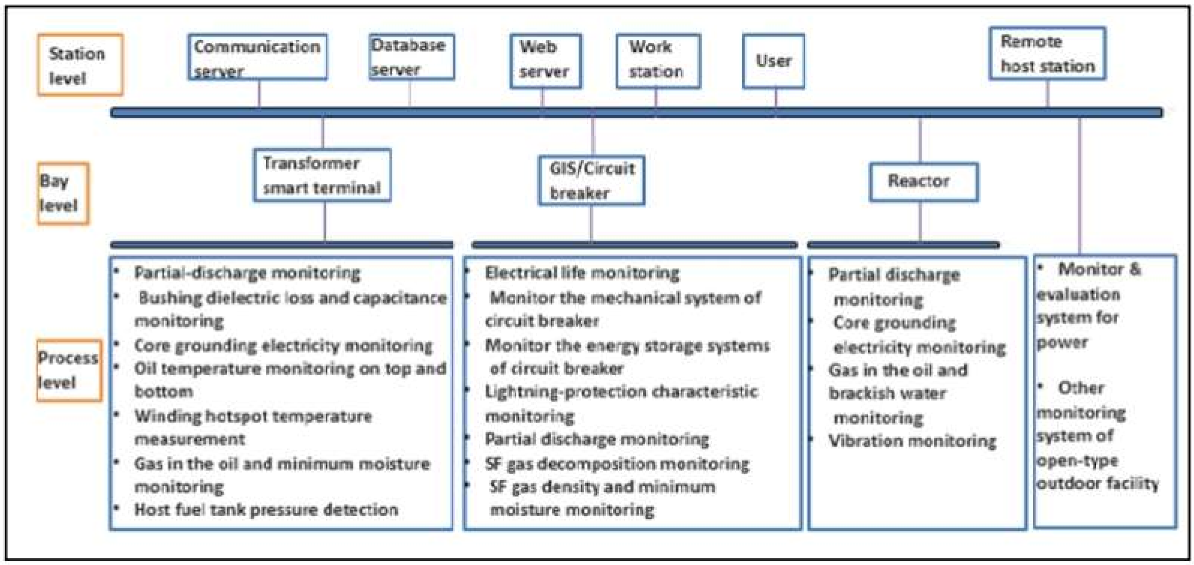
Wireless connectivity is implemented via commercial mobile networks, thus reducing investment and operational costs. Used in conjunction with always-on communication from a SCADA system, this method achieves an ideal combination of local and centralized intelligence for real time systems in a cost-efficient way

Substation Automation: -

The number of distributed energy resources and new appliances with power electronics in the distribution grid rapidly grows. This leads to power quality problems and power flow fluctuations.

An Intelligent Distribution Station is designed to maintain power quality and reliability in an economic way.

Station level includes sub-system like automation system, control system for standing area, communication system and standard time system, etc. It is used to meet the function of the primary device, to detective and control the whole or more than one station device, and to perform the function of data collection, monitoring control(SCADA), lockout operation, and synchronous phase collection, electric energy collection, information protection and relevant function



<u>Features of the Smart Station</u>: -

1. Improving power quality, reliability and load profile

2. Control of voltage pollution

3. Demand Response,

4. A system for local control and remote monitoring

5. An electricity storage system, consisting of a battery and a bi-directional inverter (ESI)

6. Stepless control of the voltage level on the LV bus bar, performed by a smart transformer

7. Bidirectional communication between home appliances and the Smart MV/LV-station, using a home automation system.

Smart Sensors: -

A smart sensor is a device that takes input from the physical environment and uses built-in compute resources to perform predefined functions upon detection of specific input and then process data before passing it on.

A sensor that includes a microprocessor that conditions the signals before transmission to the control network. It filters out unwanted noise and compensates for errors before sending the data. Some sensors can be custom programmed to produce alerts on their own when critical limits are reached.

Smart sensors enable more accurate and automated collection of environmental data with less erroneous noise amongst the accurately recorded information. These devices are used for monitoring and control mechanisms in a wide variety of environments including smart grids, battlefield reconnaissance, exploration and a great number of science applications.

Sensors will be Key enabler for the Smart Grid to reach its potential. The idea behind the ―Smart‖ Grid is that the Grid will respond to real-time demand, in order to do this, it will require sensors to provide real-time information.

Basic measurements:

Voltage Sensing, Current Sensing, Temperature Sensing, Moisture

Sensing, Continuity Sensing and Phase Measurements

Wireless Sensor Networks for Automated Meter Infrastructure (AMI)

Smart Voltage Sensors

Smart Capacitor Control: That can Monitor and control Capacitor Banks

Remotely

Smart Sensors for Outage Detection

Smart Sensors for Transformer Monitoring

High Voltage Line Temperature and Weather Condition Sensors

Distributed Generation Sensors for Load Balancing

Potential advantages of the smart-sensor concept include:

- Lower Maintenance
- Reduced Down Time
- Higher Reliability
- Fault Tolerant Systems
- Lower Cost
- Lower Weight

Geographic Information System (GIS): -

Geographic Information System (GIS) is a computer-based tool for storing, analysing, and visualizing spatial data. It is used to collect, manage, and analyse geographical information, and to create maps and other visual representations of that information. GIS is based on a database of geographic information, which is linked to a map or other visual display of that information.

GIS is used in a wide range of fields, including environmental management, urban planning, transportation planning, public health, and emergency management. It allows analysts to overlay different data layers, such as demographic information, land use, and environmental features, to identify patterns and relationships that might not be apparent otherwise

GIS software typically includes tools for data entry, data editing, data analysis, and data visualization. Some GIS software also includes tools for modeling and simulation, which allow users to test different scenarios and predict future outcomes. There are many different GIS software packages available, ranging from free and open-source options to commercial software with advanced features.

GIS has become an important tool in many industries, and its use is likely to continue to grow as technology advances and more data becomes available.

Intelligent Electronic Devices (IED): -

The name Intelligent Electronic Device (IED) describes a range of devices that perform one or more of functions of protection, measurement, fault recording and control.

An IED consists of a signal processing unit, a microprocessor with input and output devices, and a communication interface

. An intelligent electronic device (IED) is a device that is added to industrial control systems (ICS) to enable advanced power automation

IED configuration consist of

- ➢ Analog/Digital Input from Power Equipment and Sensors
- ➢ Analog to Digital Convertor (ADC)/Digital to Analog Converter (DAC)
- ➢ Digital Signal Processing Unit (DSP)
- ➢ Flex-logic unit
- ➢ Virtual Input/ Output
- ➢ Internal RAM/ROM
- ➢ Display

In the electric power industry, an intelligent electronic device (IED) is an integrated microprocessor-based controller of power system equipment, such as circuit breakers, transformers and capacitor banks IEDs receive data from sensors and power equipment and can issue control commands, such as tripping circuit breakers if they sense voltage, current, or frequency anomalies, or raise/lower tap positions in order to maintain the desired voltage level

IEDs are used as a more modern alternative to, or a complement of, setup with traditional remote terminal units (RTUs). Unlike the RTUs, IEDs are integrated with the devices they control and offer a standardized set of measuring and control points that is easier to configure and require less wiring.

Most IEDs have a communication port and built-in support for standard communication protocols (DNP3, IEC104 or IEC61850), so they can communicate directly with the SCADA system or a substation programmable logic controller. Alternatively, they can be connected to a substation RTU that acts as a gateway towards the SCADA server.

Intelligent electronic devices (IEDs) are Microprocessor-Based devices with the capability to exchange data and control signals with another device (IED, Electronic Meter, Controller, SCADA, etc.) over a communications link. IEDs perform Protection, Monitoring, Control, and Data Acquisition functions in Generating Stations, Substations, and Along Feeders and are critical to the operations of the electric network.

IEDs are widely used in substations for different purposes. In some cases, they are separately used to achieve individual functions, such as Differential Protection, Distance Protection, Over- current Protection, Metering, and Monitoring. There are also Multifunctional IEDs that can perform several Protection, Monitoring, Control, and User Interfacing functions on one hardware platform.

IEDs receive measurements and status information from substation equipment and pass it into the Process Bus of the Local SCADA. The substation systems are connected to the Control Centre where the SCADA master is located and the information is passed to the EMS Applications.

IEDs are a key component of substation integration and automation technology. Substation integration involves integrating protection, control, and data acquisition functions into a minimal number of platforms to reduce capital and operating costs, reduce panel and control room space, and eliminate redundant equipment and databases.

IED technology can help utilities improve reliability, gain operational efficiencies, and enable asset management programs including predictive maintenance, life extensions, and improved planning.

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IEDs are widely used in substations for different purposes. In some cases, they are separately used to achieve individual functions, such as differential protection, distance protection, over current protection, metering, and monitoring. There are also multifunctional IEDs that can perform several protection, monitoring, control, and user interfacing functions on one hardware platform.

The main advantages of multifunctional IEDs are that they are fully IEC 61850 compatible and compact in size and that they combine various functions in one design, allowing for a reduction in size of the overall systems and an increase in efficiency and improvement in robustness and providing extensible solutions based on mainstream communications technology.

IED technology can help utilities improve reliability, gain operational efficiencies, and enable asset management programs including predictive maintenance, life extensions, and improved planning.