20EEE473C

Elements of Smart Grid.

Unit-I.

Introduction to Smart Grid:

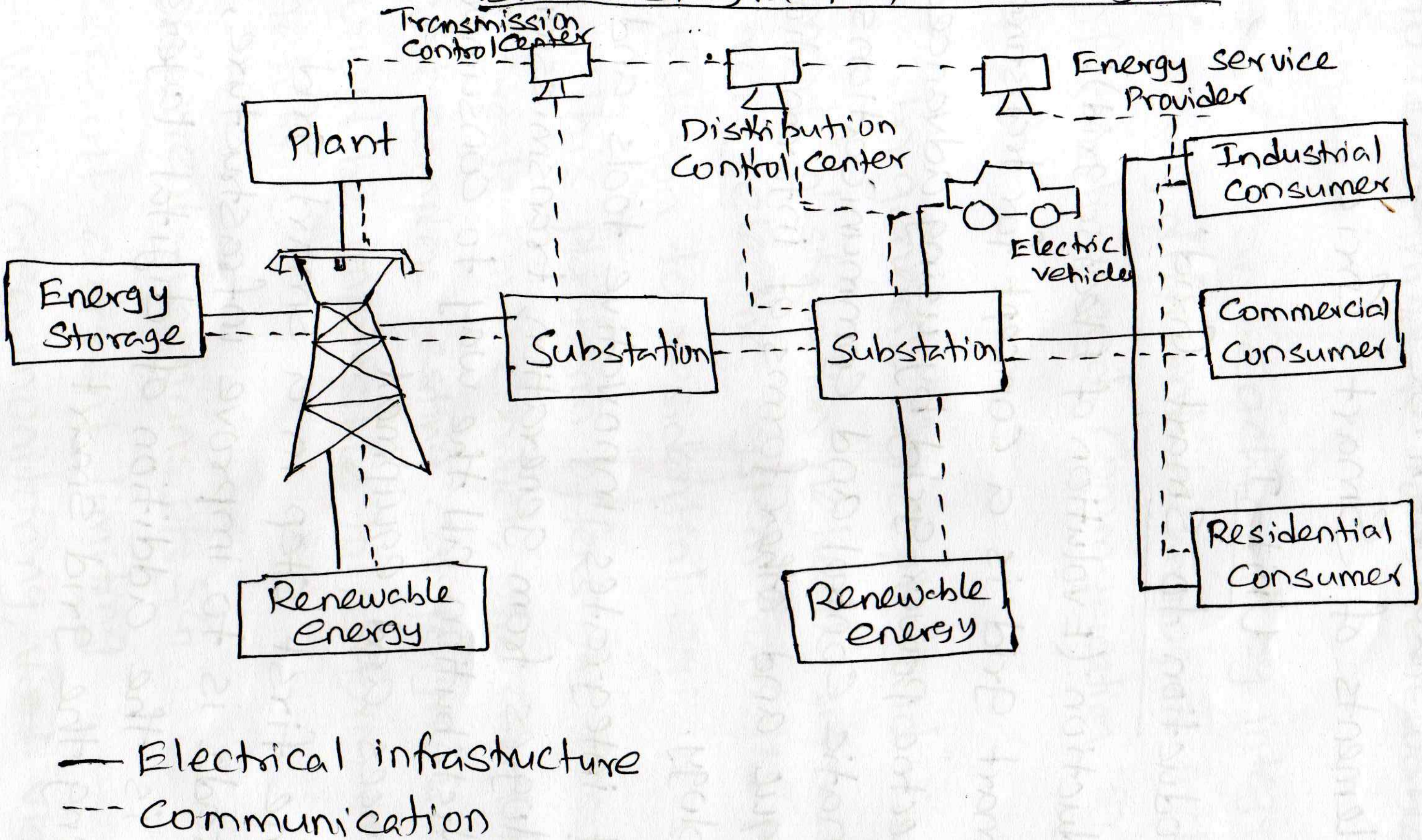
Introduction: (Evolution of Electric grid):

Smart grid is a concept for transforming the electric power grid by using advanced automatic control and communications technique and other forms of information technology.

It integrates innovative tools and technologies from generation, transmission and distibution all the way to consumer appliances and equipment.

The first step in a smart grid up grade is to improve infrastucture, next is the addition of digital layers, making the grid smart

Block diagram of Smart grid



Concept of smart grid:

~~Concept~~

→ A smart grid (SG) has been defined by the smart grids european technology platform (SGETP) as "An electricity network that can intelligently integrate the actions of all users connected to it (generators, consumers etc.) in order to deliver sustainable, economic and secure electricity supply".

→ The primary goal of a SG is to deliver the optimal amount of information and load control for customers or distributors in order to reduce system demands and costs, while increasing energy efficiency.

→ The SG concept is associated naturally with the production of energy through Renewable Energy sources (RES), Promoting social benefits like reduced emissions, lower energy costs and greater flexibility to accommodate new renewable energy sources.

→ These can be achieved by integration of many different technologies including Information and Communication Technology (ICT).

In general, "Concept grid" is a real "Smart" distribution network representing a real electric system from the primary substation to residential appliances.

This platform offers the possibility to create and conduct, the complete safety and complex testing campaigns which would be impossible to perform on a real network.

Different functions of SG:

- Fault current limiting
- Wide area monitoring, ~~Visual~~ visualization

and control
- Dynamic capability, Rating
- Power flow control
- Adaptive Protection.

Need of Smart grid:

* A Smart grid entails (involves) technology that will allow an easier integration and higher penetration of renewable energy.

* It will be essential for accelerating the development and widespread usage of plug-in hybrid electric vehicles (PHEVs).

* The benefits associated with the Smart grid includes:
  - 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.

* It decreases power theft.

Smart grid drivers:

* Increasing demand:
  Information and communication technology, Measurement and control demand response, Advanced metering infrastructure. (AMI)

* High aggregate Technical & Non-Technical Losses:
  18% - 62%

* Ageing Assets:
  Transformers, feeders etc.

* Grid to carry more power:
  Need for, Reliability and greater security

* Billing and Collections:
  Profitability of distribution Companies

* Energy mix :

Need for Renewable energy (Hydro, Solar, wind, biomass, biogas) to reduce Carbon footprint.

* Deliver Sustainable energy :

Voltage & VAR Control, Resource Planning, analysis and forecasting tools, Fault detection, identification and restoration (FDIR)

* Increased efficiency :

Direct load Control, Distributed energy resources, Distributed energy resources integration, Energy Storage, Advanced metering infrastructure (AMI).

* Empower Consumers :

Consumer education and awareness, Residential Consumer energy management, Information and Communications technology.

*Improve reliability:

System wide monitoring, Measurement and Control, Distributed energy resources, Distributed energy resources integration, Energy storage, Advanced metering infrastructure (AMI).

Opportunities:

The basic research and development and fundamental technologies that will move the Smart grid forward

1. Integrated Communications:

- To connect components to open architecture for drive real-time information and control allowing every part of the grid to both "talk" and "listen" at the same time.

2. Sensing and measurement technologies:

- To support faster and more accurate responses such as remote monitoring, time-of-use pricing, and demand side management

3. Advanced components:

- To apply the latest research in superconductivity, storage, power electronics and diagnostics.

4. Advanced Control methods:

- To monitor essential components that enable rapid diagnostics and precise solutions appropriate for any event

Renewable Energy	Integrating Renewables	Distributed Generation	Electric Vehicle Integration
Flexible Generation	Cyber security	Energy Storage	Demand Response
Dynamic Reactive Power	Wireless Communication	Distribution Automation	Smart meters
Flexible Transmission	Wide area Measurement	Substation Automation	Home energy Monitoring

Challenges and benefits:

Challenges:

- Policy and regulation

- Ageing and outdated Infrastructure
- Lack of integrated communication Platform
- High capital and operating costs
- Big data handling
- Compatibility of older equipment
- Lack of standards for interoperability
- Smart grid cybersecurity
- Lack of smart consumers.

Technology	Challenges	Obligations.
Self-Healing Action	security	Exposed to internet attacks (virus, worms etc.), question of National security
	Reliability	Failure during natural calamities, system outages and total blackout
Renewable energy Integration.	Wind/solar Generation	Long-term and un-predictable intermittent sources of energy,

		Unscheduled power flow and dispatch.
	Power flow Optimization	Transmission line congestions and huge investments.
	Power System stability	Decoupling causes system stability issues
Energy storage Systems	Cost	Expensive energy storage systems like Ultra-capacitors, SMES, CAES etc.
	Complexity	Complex costomary design module and networks.
	Non-Flexibility	Unique designs for all individual networks not ease adaptation.
Consumers Motivation	Security	Malware, data intercepting data corruption, illegal power handling and smuggling
	Privacy	Sharing of data cause privacy invasion etc.

	consumer awareness	Corruption and system threats like security and privacy issues.
Reliability	Grid Automation.	Need of strong data routing system with secure and private network for reliable protection, control and communication.
	Grid Reconfiguration	Generation demand equilibrium and power system stability with grid complexity.
Power Quality.	Disturbance identification	Grid disturbances due to local faults in grids, load centers or sources
	Harmonics Suppression	System instability during sags, dips or voltage variation such as over-voltages, under-voltages, voltage flickers etc.

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Benefits:

- Self-Healing: A smart grid automatically detects and responds to routine problems and quickly recovers if they occur, minimizing downtime and financial loss.
- Resists Attack: A smart grid has security built-in from the ground up.
- Motivates and ~~ind~~ includes the consumer: A smart grid gives all consumers (industrial, commercial and residential) visibility in to real-time pricing, and affords them the opportunity to choose the volume of consumption and price that best suits their needs.
- Reduction in AT & C losses
- Reduction in CO_2 emission
- Enabling energy Audit
- Reduction in cost billing
- Remote load control

- Shifting of peak requirement to non-peak time
- Integration of Renewable energy
- Clean Energy Development
- Provides power quality
- Optimizes assets and Operates efficiently
- Safety, Reliable and efficient
- Improved national security
- Improved Environmental conditions
- Improved Economic growth

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	Failure and blackouts
8.	Sensor 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~~ reaction time	Slow reaction time
14.	Energy storage	No energy storage
15.	Increased customer participation	Total control by Utility

National and international initiatives in Smart grid:

1. Smart grid Policies for USA:

The Energy Policy Act (EPA) of 2005 is the first federal law that specifically promotes the development of smart meters.

It directs utility regulators to consider time-based pricing and other forms of demand response for their states.

Utilities are required to provide each customer a time-based rate schedule and a time-based meter upon customer request.

The 2007 Energy Independent and Security Act (EISA) lays out a national policy for the smart grid in U.S.

- The Act assigned NIST (National Institute of Standards and Technology) the primary responsibility to coordinate development of standards for the smart grid.

- NIST is also supporting future FERC (Federal Energy Regulatory Commission) and State PUC (Public Utility Commission) rulemaking to adopt smart grid standards.

* Key Federal policy recommendations:
  - Enable cost-effective smart grid investment
  - Unlock innovation
  - Empower and inform consumers
  - Secure the grid.

EISA established a federal smart-grid investment matching grant program to reimburse 20% of qualifying smart-grid investments.

The next important legislative effort is the American Recovery and Reinvestment Act (ARRA) of 2009.

It accelerates the development of smart-grid technologies by appropriating $4.5 billion for electricity delivery and energy reliability modernization efforts.

Utilities and other investors can apply stimulus grants to pay up to 50% of the qualifying smart-grid investments.

2. Smart grid policies for U.K.:

To modernize and reduce the carbon footprint of electric grids, one major initiative of the United Kingdom is to encourage energy efficiency through smart-meter deployment.

The British government expects full penetration of smart meters by 2025, with a total financial investment of £8.6 billion ($13.5 billion) and total benefit of £14.6 billion ($22.9 billion) over the next 20 years.

3. Global smart grid:

The global smart grid federation (GSGF) is committed to creating smarter, cleaner electricity ~~ste~~ systems around the world.

By linking major public - private stakeholders and initiatives of participating countries, the federation shares practices, identifies barriers and solutions, fosters innovation and addresses key technical and policy issues.

4. National initiatives in India:

In India compelling vision to add 175 GW of renewable energy (100 GW Solar, 60 GW wind, 10 GW Biomass and 5 GW of small hydro) by 2022 to the Indian grid.

NSGM (National smart grid Mission) has been in operation since 2016. NSGM has its own resources, authority, functional and financial autonomy to plan and monitor, implementation of the policies and programs related to smart grids in the country.

Corresponding to the NSGM project management unit at national level, each of the states will also have a state level project management unit which would be chaired by the power secretary of the state.

The smart grid knowledge centre (SGKC) being developed by POWERGRID with funding from MoP will act as a resource centre for providing technical support in all matters including manpower, capacity building, outreach etc.

Unit - 2

Smart grid Technologies (Transmission)

Introduction:

Smart energy is the process of using devices for energy-efficiency. It focuses on powerful, sustainable, renewable energy sources that promote greater eco-friendly while driving down costs.

Technology Drivers:

Now, we will discuss the major driving factors of smart grid technology. These factors are referred to as "Global Drivers of Smart Grid".

There are several factors that drive the energy industry to modernize the electric power grid.

The factors that emphasize the need for a smart grid to overcome the challenges faced by power sectors are reffered to as "smart grid drivers".

Smart grid development is based on some factors such as economic competitiveness, customer empowerment, energy reliability, global warming, highly increased energy demand and energy security.

Now, let us discuss the four important smart grid drivers in detail.

1. Economic competitiveness:

To address the issue of economic competitiveness, the following jobs can be performed in the smart grid.

i) Use of alternative energy sources:

In an electric grid, a new business model can be developed by including alternative energy source to reduce the issue of a drain of technical resources in an ageing workforce.

ii) Decreasing outage duration:

By reducing the outage duration,

we can increase energy reliability.

iii) Reduction in labour cost:

The labour cost can be reduced by replacing manual meter readings and field maintenance.

iv) Reduction in transmission losses:

The energy losses in transmission and distribution systems can be decreased significantly by improved system planning and asset management.

All these four actions can prevent power theft and fraud.

This will provide better billing and protect the revenues of power sectors.

2. Empowering Customers:

Customer empowerment can improve energy utilization by consumers.

Customers can be triggered for effective energy utilization. It is very important to empower the customers to satisfy their energy demands and provide uninterruptible power.

3. Global warming:

In power generation, fossil fuels are the major sources of carbon emission.

Therefore, we must find alternative power generation fuels to protect the world from global warming.

In this series, renewable energy sources like solar energy, wind energy etc. have become a good choice for power generation.

Renewable energy sources can be integrated with existing power system and managed by the smart grid.

Therefore, the development of smart grid can create an eco-friendly power generation system.

4. Increase in Electricity demand:

The increase in population and technological advancement has increased the demand for electricity.

The world energy outlook 2014 datasheet estimates that the world's electricity demand will increase by almost 80% over the period of 2012 to 2040.

To meet this increased demand for electricity, smart grid technology has become very essential.

Hence, we may conclude that the Smart grid drivers are the forces that emphasize on requirements of the smart grid for addressing the issues faced by the power sectors.

Smart Energy resources:

Smart energy is the process of using devices for energy-efficiency. It focuses on powerful, sustainable, renewable energy sources that promote greater eco-friendliness while driving down costs.

We have heard of smart phones and Smart TVs, but what is smart energy? What makes it so "smart" anyway?

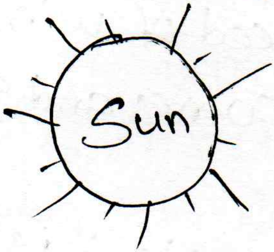
It has to be renewable. Renewable energy comes from non-depletable sources that won't run out.

Solar energy has become one of the dominant focus for those looking to harvest the power of renewable energy.

To understand better, let's look

at the popular form of renewable energy ~~(Solar energy)~~ in particular and see its impact on the smart energy market.

Solar Energy:



One of the more promising renewable energy options, solar energy has already made its impact felt.

A particularly recognizable form of renewable energy, solar is one of the most talked-about even among those who know little about the field.

Solar power generation has experienced a tremendous growth in recent years due to growing demand for renewable energy sources.

Wind energy:

Eventhough wind energy dates back

from early centuries, today's applications are more geared toward utilities and supply of power to larger regions.

Wind power is higher at higher speed of wind, but since the speed of wind constantly changes, power comes and goes in short intervals.

Inconsistency in power output is the main reason why wind farms cannot be used in utility portfolio.

Natural gas:

Natural gas proves to be another form of popular renewable energy.

Unlike traditional fossil fuels, natural gas burns cleaner emissions that have a negligible effect on the environment.

The burning of natural gas presents one of the problems smart energy now faces.

In order to get the environment-friendly effects of natural gas, it must be burnt in the proper facility.

This highlights the need for greater investment and infrastructure in order for renewable smart energy to be fully implemented and realized.

Smart substations:

Smart substations are the auxiliary control system that collects all the information from various auxiliary systems and shares the effective information among various auxiliary systems.

A smart substation play a significant role in the smart grid, which is one of the basic platforms to promote a new energy revolution and technology innovation.

With the development of advanced, reliable and environmental-friendly intelligent electronic devices, the smart substations are based on digitalization, communication platform networking and standardization.

Therefore, the IEC 61850 (International Electrotechnical Commission) based smart substations stand for the technology development trend in smart grid

Functions of smart substation:

- information collection
- measurement
- Control
- protection
- Computation and monitoring
- real-time automatic control of smart grid
- intelligent regulation.
- Online analysis and decision
- interaction with adjacent substation

~~Smart~~

Substation Automation:

Substation automation system (SAS) provides protection, control, automation, monitoring and communication capabilities.

Substation automation refers to, using data from intelligent electronic devices (IED), control and automation capabilities within the substation, and control commands from remote users to control power-system devices.

Many power system automation are monitored by SCADA (Supervisory Control And Data Acquisition).

In essence, the smart grid is a data communications network integrated with the power grid that enables power grid operators to collect and analyze data about power generation, transmission, distribution and consumption.

While modern data communication has evolved from telephony modems to IP networks, many power utilities are still deploying modem access and serial bus technology to communicate with their substations.

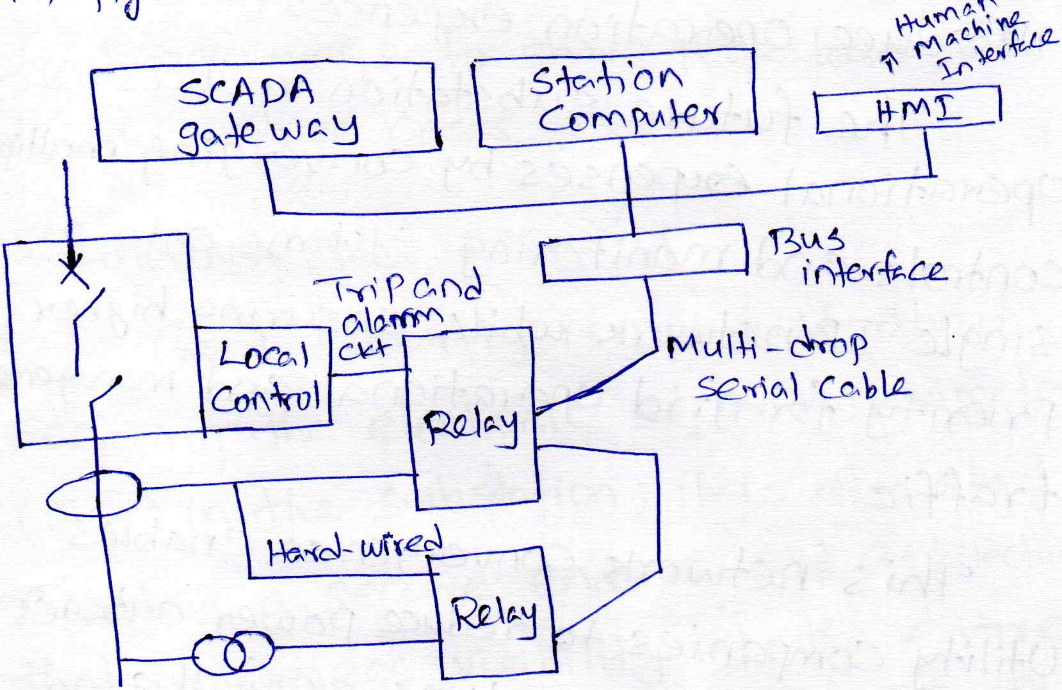
The existing SCADA remote terminal unit (RTU) systems located inside the substation cannot scale and evolve to support next generation intelligence.

Since flexible IEC-61850-compliant intelligent electronic devices (IED) and utility-grade rugged IP routers and Ethernet switches have become more widely available, many utilities are now ready to transform their communications ~~from~~ networks from serial to IP-based communications.

Substation Automation Equipment:

The components of a typical legacy

Substation automation system are shown in fig.



Traditionally, the secondary circuits of the circuit breakers, isolators, current and voltage transformers and power transformers were hard-wired to relays.

Relays are connected with multi-drop serial links to the station computer for monitoring and to allow remote interrogation.

Substation Automation Business Factors and Benefits:

1) Reduce operation expenses:

The future substation reduces operational expenses by converging multiple controls and monitoring systems onto a single IP network while ensuring higher priority for grid operational and management traffic.

This network convergence enables utility companies to reduce power outages and service interruptions as well as decrease response time by quickly identifying, isolating, diagnosing and repairing faults.

2) Reduce capital expense:

As demand for energy continues to grow, utilities must find ways to generate power to meet out the loads.

The cost of providing spinning reserves

for peak load is extremely high.

Therefore, utilities are challenged to find new ways to share peak load and thereby reduce costs

3) Improve grid security:

Grid security is not just about securing the electronic security perimeter (ESP) in the substation; it is also about creating a secure end-to-end architecture that maximizes visibility into the entire network environment, devices and events.

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.

Feeder automation solution provides means for the utilities to reduce the frequency of power outage and faster restoration time by remote monitoring and control of medium voltage network assets such as disconnectors, ring-main units in energy distribution networks.

It provides a 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 SCADA system, this method achieves an ideal combination of local and centralized intelligence for real-time systems in a cost-efficient way.

Transmission Systems:

Transmission systems in many countries are facing even more demanding operating conditions with increasing demand for renewable energy generation.

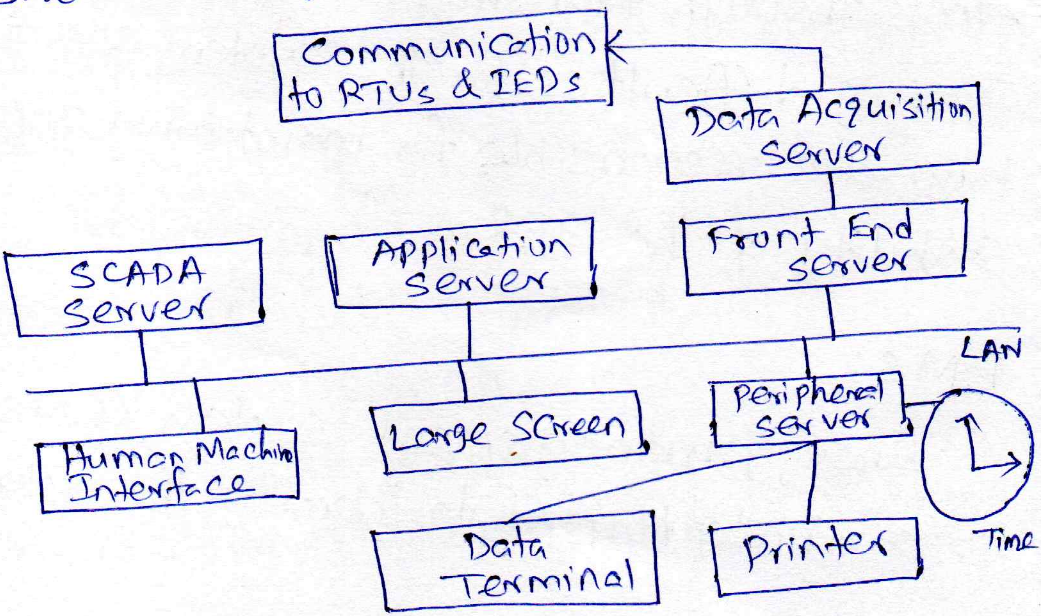
The variability of the power output of renewable energy sources and unplanned flows through transmission grids are causing difficulties for the system operators, who are responsible for maintaining the stability of the system.

EMS:

Energy management system (EMS) is a concept used to identify the systems performing the functions of forecasting, monitoring, measuring and control of both energy generation and energy consumption for a reliable and stable operation of modern smart electrical grids.

The first EMS application placed in control centers across the country was known as supervisory control and data acquisition (SCADA) system.

A typical EMS system configuration is shown in fig.



Energy management system (EMS) were designed originally at a time when the electrical power industry was vertically integrated and had centralised communications and computing systems.

With deregulation of the power industry and the development of smart grid, decision-making is becoming decentralised and the coordination between different factors in various markets becomes important.

System status and measurement information are collected by Remote Terminal Units (RTUs) and sent to the control center through the communication infrastructure.

The front-end server in EMS is responsible for communicating with the RTUs and IEDs.

Different EMS applications reside in different servers and are linked together by the Local Area Network (LAN).

EMS applications include Unit Commitment, Automatic Generation Control (AGC) and security assessment and Control

The purpose of Unit Commitment within a traditional power system is to decide how many and which generators should be used and to allocate the sequence of starting and shutting down generators.

Similarly, in a power system AGC carries out load frequency control and economic dispatch.

AGC also performs functions such as reserve management (maintaining enough reserve in the system) and monitoring/recording of system performance.

The security assessment and control application includes; security monitoring, security analysis, preventive control, emergency control and fault diagnosis.

When the system is insecure, security analysis informs the operator, which contingency is causing insecurity and the nature and severity of the anticipated emergency.

FACTS devices:

FACTS devices are static power electronic devices installed in AC transmission networks to increase power transfer capability; stability and controllability of the networks through series and/or shunt compensation.

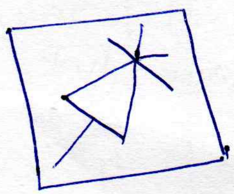
In general, FACTs devices can be Classified into four categories.

- Series Controllers:
  * Thyristor Controlled series Compensator (TCSC)
  * Static synchronous Series Compensator (SSSC)
  * Fault Current Limiter.
- Shunt Controllers:
  * Static VAR Compensator (SVC)
  * Static Synchronous Compensator (STATCOM)
- Combined series-series Controllers:
  * Integral power flow Controller (IPFC)
- Combined series-shunt controllers:
  * Unified power flow controller (UPFC)

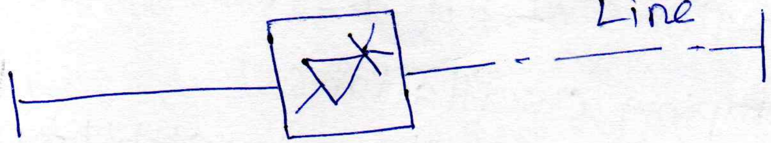
Benefits of FACTS:

- Increases the power transfer capability of transmission network
- Provides direct control of power flow over designated transmission routes.
- Increases the loading capability of lines to their thermal capability.

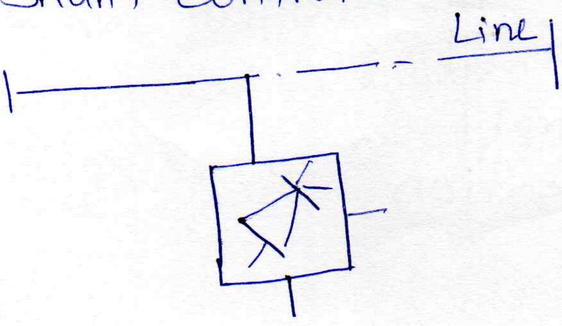
General Symbol of FACTS Controllers:



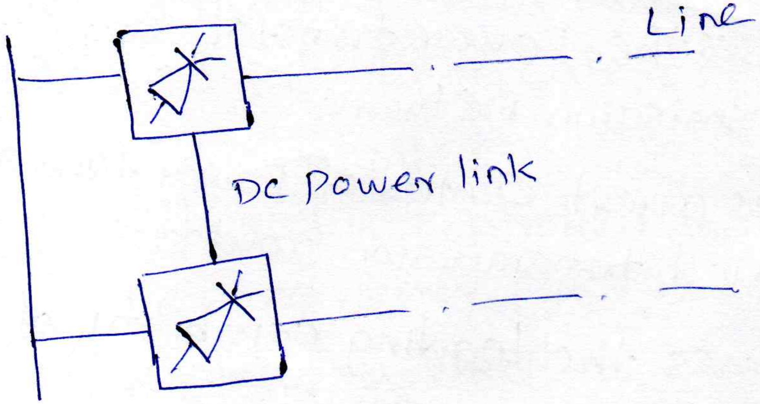
Series Controller:



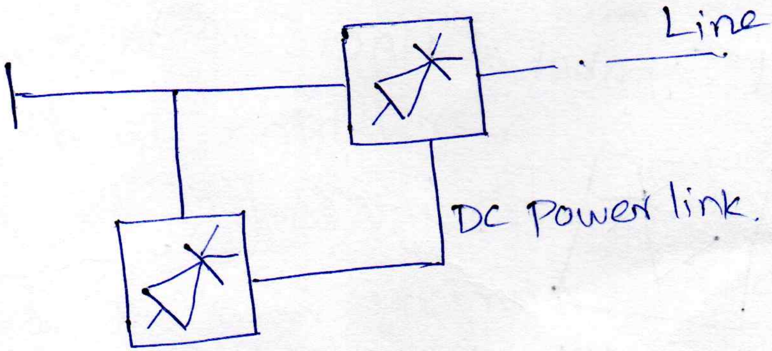
Shunt Controller:



Unified Series Controller:



Unified series-shunt controller:



Applications of FACTS devices:

- Damping oscillations
- transient and dynamic stability
- voltage stability
- Voltage control
- Var Compensation

- power flow Control
- Active and reactive power control

HVDC:

DC Transmission now became practical when long distances were to be covered.

With the fast development of converters (rectifiers and inverters) at higher voltages and larger currents, DC transmission has become a major factor in planning of power transmission.

Today, the highest functional DC voltage for transmission is +/- 600 kV.

DC transmission is now an integral part of the delivery of electricity in many countries throughout the world.

Comparison between AC & DC Transmission:

The two modes of transmission (AC and DC) can be compared based on the following factors.

1) Economics of transmission.

2) Technical performance

3) Reliability

1) Economics of power transmission:

In DC transmission, inductance and capacitance of the line has no effect on the power transfer capability of the line and the line drop.

Also, there is no leakage or charging current of the line under steady state.

A DC line requires only 2 conductors whereas AC line requires 3 conductors in 3-phase AC systems.

The cost of terminal equipment is more in DC lines than in AC line.

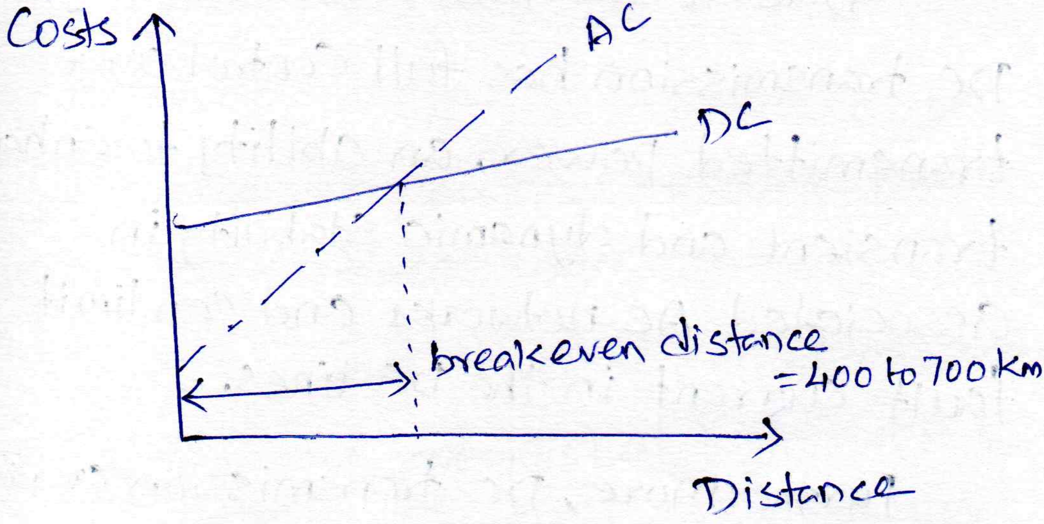


Fig. shows the relative costs of AC and DC transmission lines Vs distance.

Breakeven distance is one at which the cost of the two systems is the same.

It is understood from the figure that a DC line is economical for long-distance transmission which is greater than the break-even distance.

2) Technical performance:

Due to its fast controllability, a DC transmission has full control over transmitted power, an ability to enhance transient and dynamic stability in associated AC networks and can limit fault current in the DC lines.

Furthermore, DC transmission overcomes some of following problems associated with AC transmission.

- Stability limits
- Voltage control
- Line compensation
- Problems of AC interconnection

3) Reliability:

The reliability of DC transmission systems is good and comparable to that of AC systems.

The reliability of DC links has also been very good.

Disadvantages of DC transmission:

1. High cost of conversion equipment
2. Inability to use trans-formers to alter voltage levels
3. Generation of harmonics
4. Requirement of reactive power
5. Complexity of controls.

Over the years, there have been significant advances in DC technology, which have tried to overcome the disadvantages listed above except for (2). These are,

1) Increase in the ratings of a thyristor cell that makes up a valve

2) Modular construction of thyristor valves.

3) Twelve-pulse (and higher) operation of converters.

4) Use of forced commutation.

5) Application of digital electronics and fiber optics in the control of converters.

Applications of DC transmission:

Due to their costs and special nature most applications of DC transmission generally fall into one of the following three categories.

1) Underground or Underwater cables.

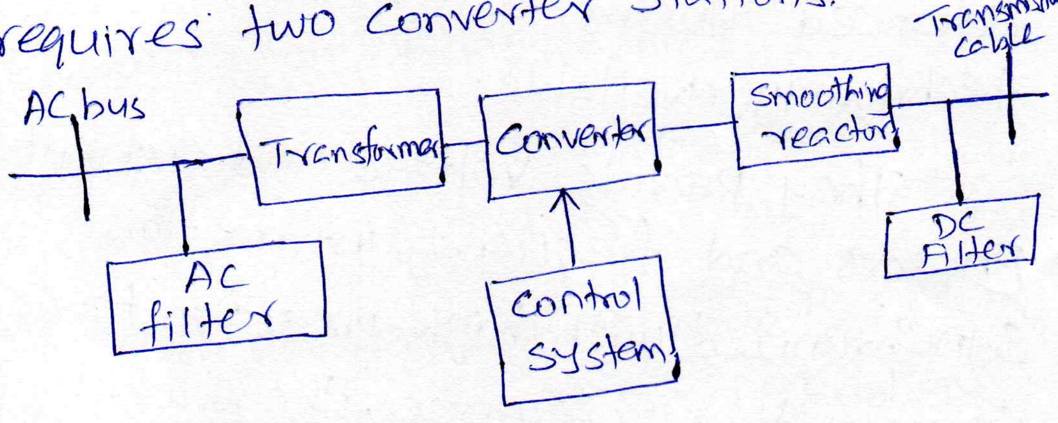
2) Long distance bulk power transmission

3) Stabilization of power flows in integrated power system.

HVDC Converter Station:

The major components of HVDC transmission system are converter station where conversions from AC to DC (Rectifier Station) and from DC to AC (Inverter Station) are performed.

A point-to-point transmission requires two converter stations.



Wide area monitoring, Protection and Control:

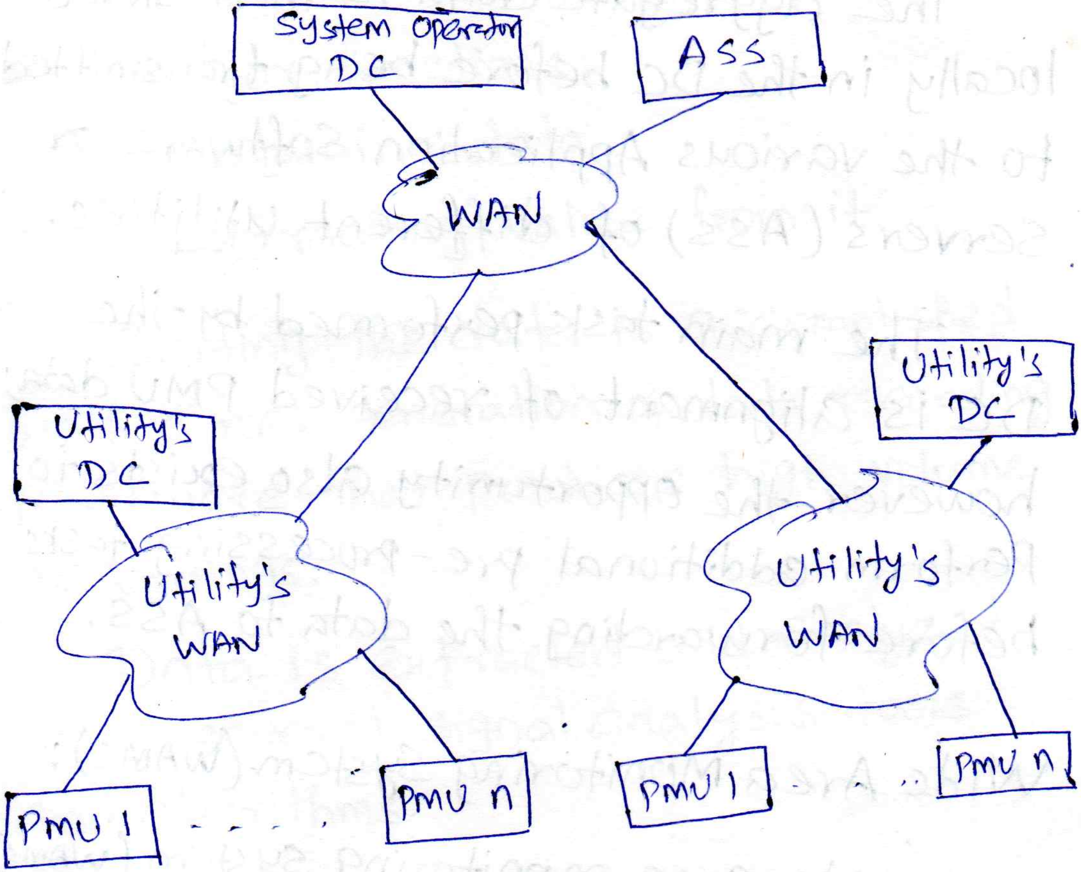
Wide Area Monitoring, Protection and Control (WAMPAC) involves the use of wide area synchronized measurements, reliable and high bandwidth communication networks and advanced centralized protection and control schemes.

Smart Modular Technology (SMT) and related applications are the essential element and enabler of WAMPAC.

Presently, Phasor measurement units (PMU) are the most accurate and advanced synchronized measurement technology available.

They provide voltage and current phasors and frequency information synchronized with high precision to a common time reference, the Global Positioning System (GPS).

A generalized WAMPAC System is as shown in fig. below.



In this system, the necessary synchronized voltage and current phasors are produced by PMUs.

The measurement data from these PMUs are transmitted through a Wide-Area Network (WAN) and aggregated at one or more Data Concentrators (DCs).

The aggregate data is then stored locally in the DC before being transmitted to the various Application Software or Servers (ASS) of different utilities.

The main task performed by the DC is alignment of received PMU data; however, the opportunity also exists to perform additional pre-processing tasks before forwarding the data to ASS.

Wide Area Monitoring System (WAMS):

Wide area monitoring system (WAMS) is an advanced measurement technology to collect information based on the new data acquisition by PMU and allow monitoring transmission system conditions over large areas in order to detect and further counteract grid instabilities.

The WAMS technologies perform the two major functions:

- Obtaining data
- Extracting value from it

Getting the data is accomplished with a new generation of data recording hardware that produces high volume recordings.

Data is extracted and analyzed using several signal analysis tools and algorithms.

Need of WAMS:

* In order to avoid regional blackouts such as those occurred in India in 2003.

* When constant monitoring applications are available immediate action can be taken if some failures are detected.

* This early warning system contributes

to increase system reliability by avoiding the spreading of large area disturbances, and optimizing the use of assets.

Applications of WAMS:

- Phase angle monitoring
- Voltage stability monitoring
- Line thermal monitoring
- Event driven data archiving
- Power Oscillation monitoring
- Power damping monitoring
- SCADA/EMS integration
- Communication gateway.

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Unit-4 SMART METERS

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 and 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 thus facilitate real-time pricing, automated recording of the electricity consumption and a complete eradication of errors due to manual readings and reduce labor cost and enable instant fault detection.

Advantages of Smart Meters:

1. **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.
2. **Data Recording:** Conventional meters only record the electricity consumption of a system, and not how and when the electricity is used. Smart meters record real-time data corresponding to the electricity consumption. It means that they also record the time and patterns of electricity consumption.
3. **Real time tracking:** What‘s really nice about these meters is that consumers can go online and check out their electricity usage patterns and make changes totheir consumption accordingly. In this way, smart meters offer a strong control to the consumers over their usage.
4. **Automatic outage detection:** A person having a conventional meter has to call the utility whenever there is a power outage whereas in case of smart meters, there is automatic outage detection as they are constantly synchronized with the electric grid.
5. **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 andconnect/disconnect the supply.

The smart meters shall have the following minimum features:

1. Measure and Compute electrical parameters.
2. Store and communicate requested data as per programmed interval.
3. Detect, resolve abnormal & tamper events and store the same
4. Inbuilt memory to store all relevant meter data, events for a required period.
5. Meter communication protocol shall be as per open standard.
6. Options for both Prepaid and postpaid metering.
7. Shall be configurable remotely.
8. Interface to a Home Display Unit
9. Support remote firmware upgrade
10. Support remote load management
11. Load Reconnect / Disconnect switch

Advanced Metering Infrastructure (AMI):

AMI is the convergence of the grid, the communication infrastructure, and the supporting information infrastructure. The network - centric AMI coupled with the lack of a composite set of cross industry AMI security requirements and implementation guidance, is the primary motivation for its development. The problem domains to be addressed within AMI implementations are relatively new to the utility industry; however, precedence exists for implementing large - scale, network - centric solutions with high information assurance requirements.The defense, cable, and telecom industries offer many examples of requirements, standards, and best practices that are directly applicable to AMI implementations.

The functions of AMI can be subdivided into three major categories:

Market applications: serve to reduce/eliminate labor, transportation, and infrastructure costs associated with meter reading and maintenance, increase accuracy GIS AND GOOGLE MAPPING TOOLS 23 of billing, and allow for time - based rates while reducing bad debts; facilitates informed customerparticipation for energy management

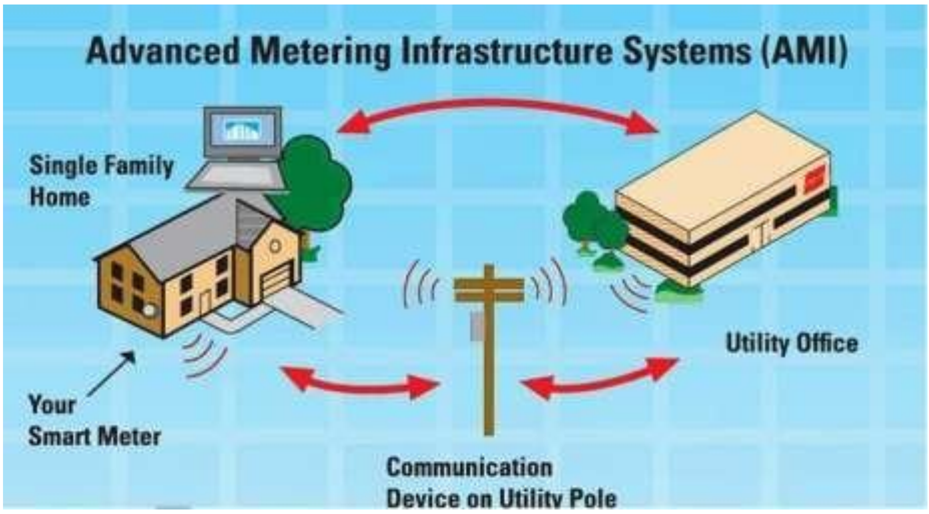
Customer applications: serves to increase customer awareness about load reduction, reduces bad debt, and improves cash flow, and enhances customer Convenience and satisfaction; provides demand response and load management to improve system reliability and performance

Distribution operations: curtails customer load for grid management, optimizes network based on data collected, allows for the location of outagesand restoration of service, improves customer satisfaction, reduces energy losses, improves performance in event of outage with reduced outage duration and optimization of the distribution system and distributed generation management, provides emergency demand response monitoring, control, and data acquisition will extend further down the network to the distribution pole-top transformer and perhaps even to individual customers by means of an advanced metering infrastructure (AMI) and/or demand response and home energy management systems on the Home Area Network (HAN).

More granular field data will help increase operational efficiency and provide more data for other smart grid applications, such as outage management. AMI networks enable utilities to accomplish meter data collection, customer participation in demand response, and energy efficiency and support the evolution of tools and technology that will drive the smart grid future, including integration of electric vehicles and distributed generation. Without the collection of AMI (interval) metering data, it is difficult to determine when customer consumption occurs in time

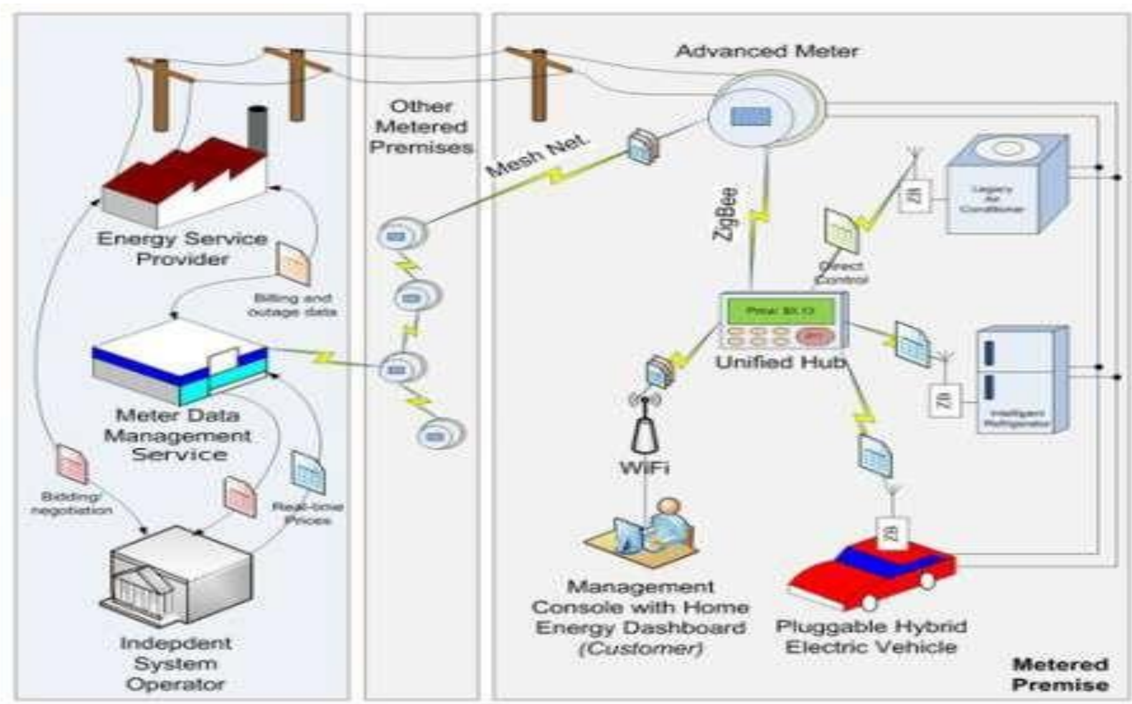
Smart meters and related sub meters that form the end points in the AMI architecture provide two critical roles. One is access to more granular interval usage data; Second a durable communications link that is bidirectional (two- way) to deliver messages/instructions to the meter.

The purpose of an AMI communications system is to provide electric utilities with a communications network permitting connectivity between grid devices such as electric meters and a head-end system. AMI communications network options are numerous: they can be power line carrier (PLC), satellite, cellular (2G, 3G, or 4G), WiMAX, RF mesh, etc.



- **Smart meters at the consumer's location**
- **Fixed communication networks between consumers and service providers**
- **Data reception and management systems that make the info available to the service provider (meter data management system or "MDMS")**

- **MDMS: software applications that receive and store meter data and perform other functions**



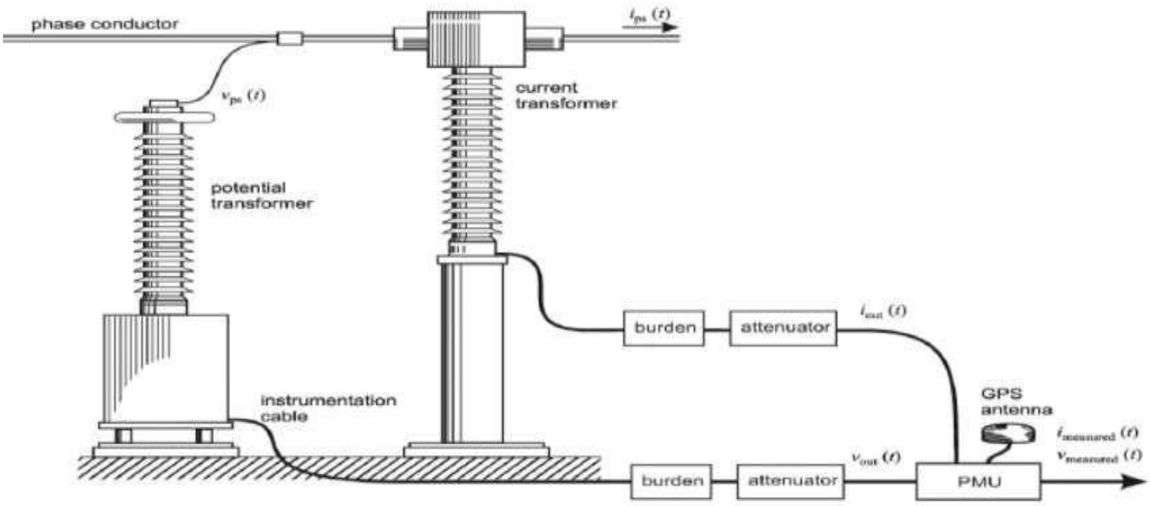
Why implement AMI?

- **Regulators of regulated utilities and unregulated utilities required to "consider and determine" whether smart metering is appropriate**
- **If so, these entities must set smart metering standards for the Utilities**

Phasor Measurement Unit:

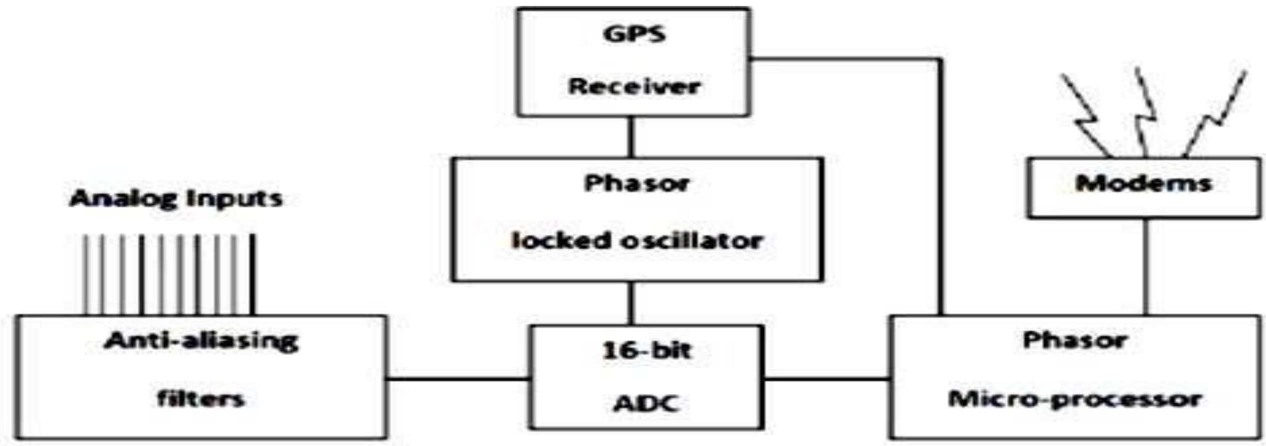
- A Synchrophasor is a phasor that is time stamped to an extremely preciseand accurate time reference.
- Basically, a solid-state relay or digital fault recorder with GPS clock.
- Synchronized phasors (synchrophasors) provide a real-time measurement of electrical quantities across the power system.
- The resultant time tagged phasors can be transmitted to a local or remotereceiver at rates up to 60 samples per second.
- Continuously measures voltages and current phasors and other keyparameters and transmits time stamped messages.

Phasor Measurement Unit – Connections:



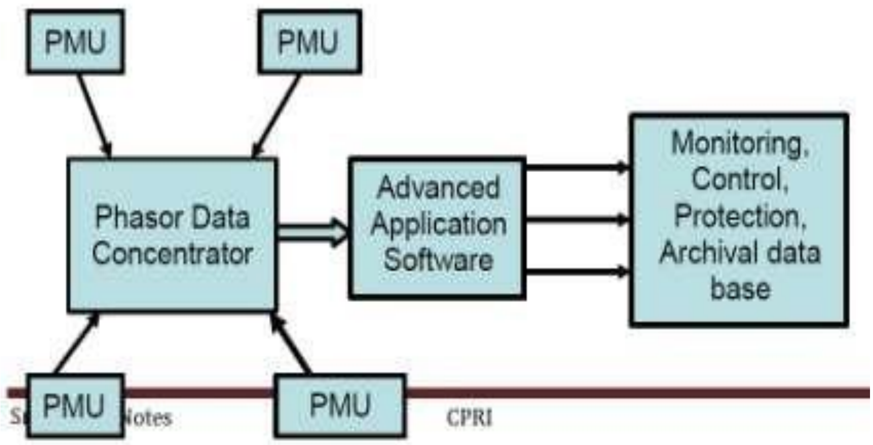
Current and potential transformer connections with PMU

The analog signals are sampled and processed by a recursive Phasor algorithm to generate Voltage and Current Phasor. Different components of a PMU are shown by a block diagram in below figure,



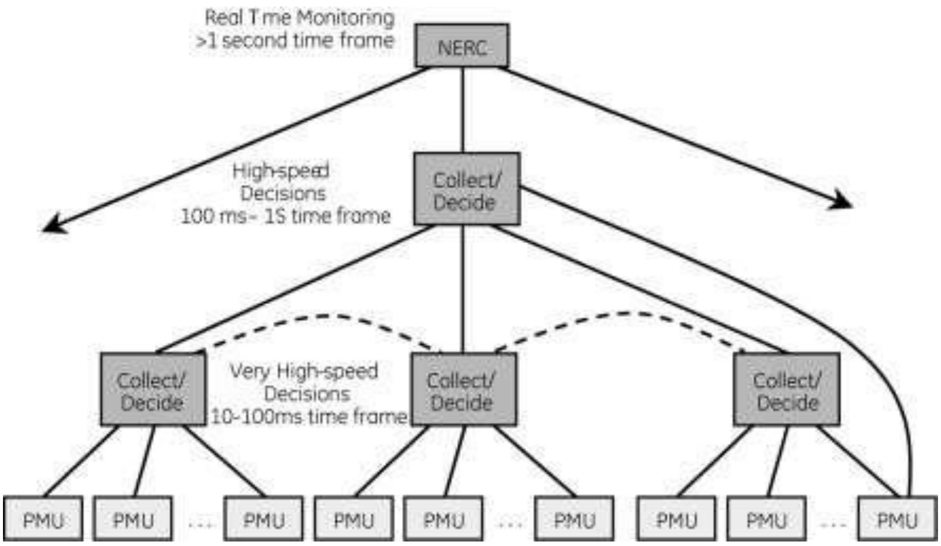
Components of a Phasor Measurement Unit

A phasor is a complex number that represents both the magnitude and phase angle of the sine waves found in electricity. Phasor measurements that occur at the same time are called "Synchrophasors", as are the PMU devices that allow their measurement. In typical applications phasor measurement units are sampled from widely dispersed locations in the power system network and synchronized from the common time source of a global positioning system (GPS) radio clock. Synchrophasor technology provides a tool for system operators and planners to measure the state of the electrical system and manage power quality. Synchrophasors measure voltages and currents at diverse locations on a power grid and can output accurately time- stamped voltage and current phasors. Because these phasors are truly synchronized, synchronized comparison of two quantities is possible, in real time. These comparisons can beused to assess system conditions. The technology is relevant in the smart grid regime which also looks at reliability improvement under optimum power delivery. The PMU technology would allow increased power flow over existing lines. Synchrophasor datacould be used to allow power flow up to a line's dynamic limit instead of to its worst-case limit.

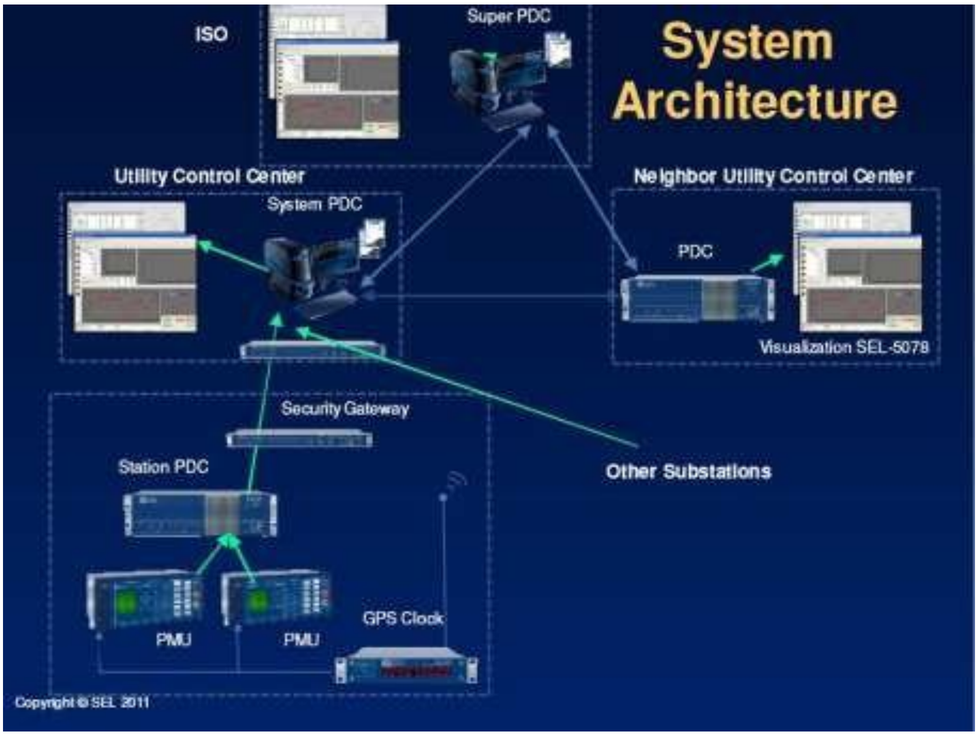


PMU used to Wide Area Monitoring, Protection and ControlPhasor

Measurement Unit-Data Collection Topology:



Phasor Measurement Unit – System Architecture:



Phasor Measurement Unit Phasor Data Concentrator:

- Aligns information by time the incoming PMU messages from multiple measuring devices and sends out the aggregated synchronized data set asa single data stream.
- Archive data and process the information.
- Exchange records with PDCs at other locations.

Communication:

- Links multiple PMUs to a PDC (or PDCs to other PDCs) for real timedata transfer.

- Secure VPN connection from a communications centre.

Phasor Measurement Unit – Message Information:

- The captured phasors are to be time-tagged based on the time of the UTC time reference.
- The Time Stamp is an 8-byte message consisting a 4 byte "Second Of Century – SOC", a 3-byte Fraction of Second and a 1-byte Time Quality indicator.
- The SOC time-tag counts the number of seconds that have occurred since inception of PMU, With 3-bytes for the Fraction of Second, one second can be broken down into 16,777,216 counts or about 59.6 nsec/count and the Time Quality byte contains information about the status and relative accuracy of the source clock.

Phasor Measurement Unit – Measurements:

PMUs measure (synchronously):

- Positive sequence voltages and currents
- Phase voltages and currents
- Local frequency
- Local rate of change of frequency
- Circuit breaker and switch status

Phasor Measurement Unit -Applications:

- Global behavior may be understood from local measurement
- Phasor measurement data can be used to supplement/enhance existingcontrol center functions and provide new functionalities.
- Phasor measurement data with GPS signal can provide synchronized voltage and current phasor measurements across a wide region
- By measuring the phase directly, the power transfer between buses can becomputed directly
- High sampling rate (30 samples per second) Extended visibility: beyondone's own operating region
- Disturbance monitoring –transient and steady-stat responses

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.

IED configuration consist of,

1. Analog/Digital Input from Power Equipment and Sensors

2. Analog to Digital Convertor (ADC)/Digital to Analog Converter (DAC)

3. Digital Signal Processing Unit (DSP)

4. Flex-logic unit

5. Virtual Input/ Output

6. Internal RAM/ROM

7. Display

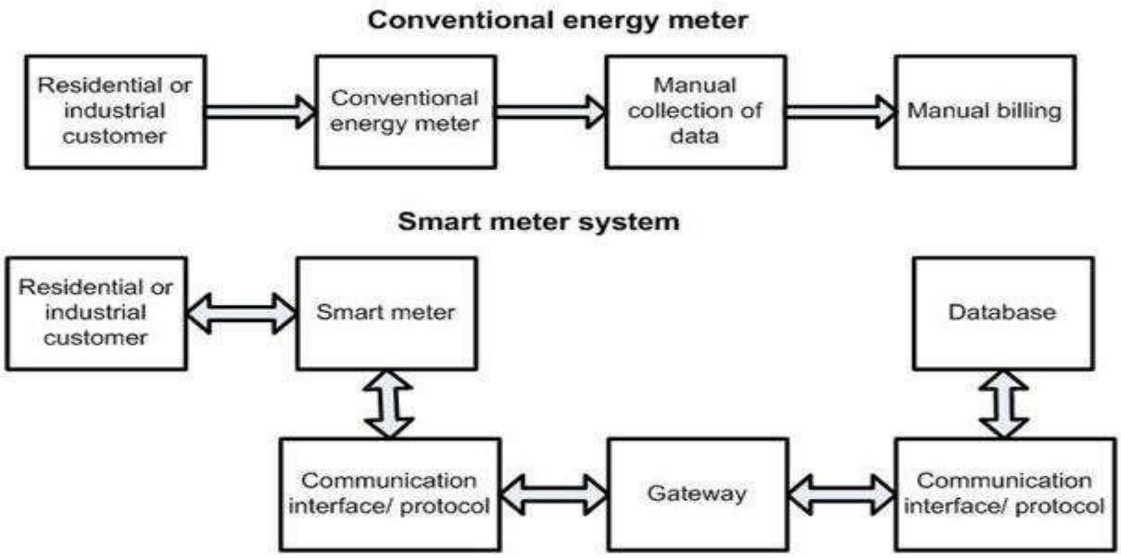
Intelligent electronic devices (IEDs) are Microprocessor-Based devices with thecapability to exchange data and control signals with another device (IED, Electronic Meter, Controller, SCADA, etc.) over a communications link. IEDs perform Protection, Monitoring, Control, and Data Acquisition functions 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.

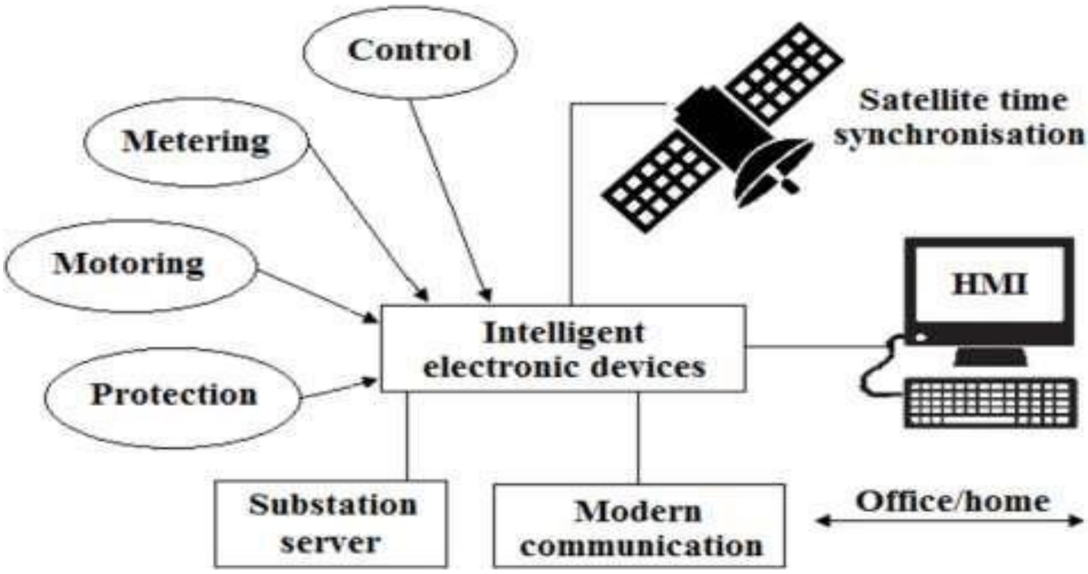
IEDs receive measurements and status information from substation equipment and pass it into the Process Bus of the Local SCADA. The substation systems are connected to the Control Centre where the SCADA master is located and theinformation is passed to the EMS Applications

IEDs are a key component of substation integration and automation technology. Substation integration involves integrating protection, control, and dataacquisition 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. Automation involves the deployment of substation and feeder operating functions and applications ranging from SCADA andalarm processing to integrated Volt/Var Control (IVVC) in order to optimize the management of capital assets and enhance operation and maintenance (O&M) efficiencies with minimal human intervention. 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.

Comparison Conventional Metering Vs. Smart Metering:

Sl.No.	**Smart Metering**	**Conventional Metering**
1.	Digital with Alpha Numeric Display	Analog with Spinning Dials
2.	Will Measure how much and when electricity is used (Hourly with date and Time Stamping)	Measurement only for how much Electricity is used over a Billing Period (One or Two Months)
3.	Automated Meter Reading: Meters send data Electronically to Distribution Companies through a Wireless Network	Manual Meter Reading: Distribution comp [any Staff Physically visit rate payer premises to record data
4.	Two Way communication between meters and distribution companies	No Communication capability





Functional architecture of IED:

Power system monitoring and control is basically carried out by SCADA systems primarily based on the data that collected and fed from RTUs situatedin substations. In substation switchyard, RTUs are wired to the CB links and each change in the CB status contact is provoked in form of alarm to the operators. The RTUs also collects analog measurement data obtained through instrument transformers (CTs and VTs) and connecting transducers. If the measured analog value is above the threshold value, it is reported either as an operator measurement or an alarm. The data recorded by RTU cannot be accessed locally by the consumer; it will be only accessible after it has been sentto a centralized location. In addition to this, the SCADA system design is notthe most robust one; there is a possibility of errors in the readings because of malfunctioning of transducers, CB contacts, RTUs or SCADA communication equipment. Comparatively slow scanning rate of SCADA for measurements (1e10s) is another performance concern. The SCADA systems fail to track dynamic changes occurring for intervals shorter than the SCADA scan time.The limitations in capabilities of SCADA can be overturned by inclusion of IEDs. IEDs are microprocessor-based devices with ability to exchange data and control signals with another device over communication link. This new unit provides real-time synchronization for event reporting. IEDs can be regarded as the eyes and ears of any remote power management systems. IEDs are installed to improve monitoring, control, protection and data acquisition capabilities of the power system. Besides their main function, IEDs are capable to record various types of data. Redundancy and amount of data coming from a substation can be improved in this way. If designing of IEDs are with interface to global positioning system (GPS), further improvement in data usage can be achieved with automating system disturbance analysis. IEDs receive data from power equipment and sensors and can issue control commands, such as tripping CBs, if they sense any abnormality in current, voltage or frequency or lower/raise voltage levels in order to maintain the desired level. Common types of IEDs consist of CB controllers, capacitor bank switches, voltage regulators, protective relaying devices, recloser, controllers, LTC controllers etc. By a setting file this is normally controlled. Usually, one of the most time-consuming roles of a protection tester is the testing of setting files.

UNIT-5: HIGH PERFORMANCE COMPUTING FOR SMART GRID APPLICATIONS

Introduction:

High-performance computing is typically **used for** solving advanced problems and performing research activities through **computer** modeling,simulation and analysis. HPC systems have the ability to deliver sustained **performance** through the concurrent useof **computing** resources.

The power grid is becoming far more complex as a result of the grid evolution meeting an information revolution. Due to the penetration of smart grid technologies, the grid is evolving as an unprecedented speed and the information infrastructure is fundamentally improved with a large number of smart meters and sensors that produce several orders of magnitude larger amounts of data. How to pull data in, perform analysis, and put information out in a real-time manner is a fundamental challenge in smart grid operation and planning. The future power grid requires high performance computing to be one of the foundational technologies in developing the algorithms and tools for the significantly increased complexity. New techniques and computational capabilities are required to meet the demands for higher reliability and better asset utilization, including advanced algorithms and computing hardware for large-scale modelling, simulation, and analysis. This chapter summarizes the computational challenges in smart grid and the need for high performance computing, and present examples of how high-performance computing might be used for future smart grid operation and planning.

Local Area Network (LAN) in Smart Grid:

A local area network is a data communication network, typically a packet communication network, limited within the specific network. A local area network generally provides high-bandwidth communication over inexpensive transmission media. The information flow is between smart meters and sensors.

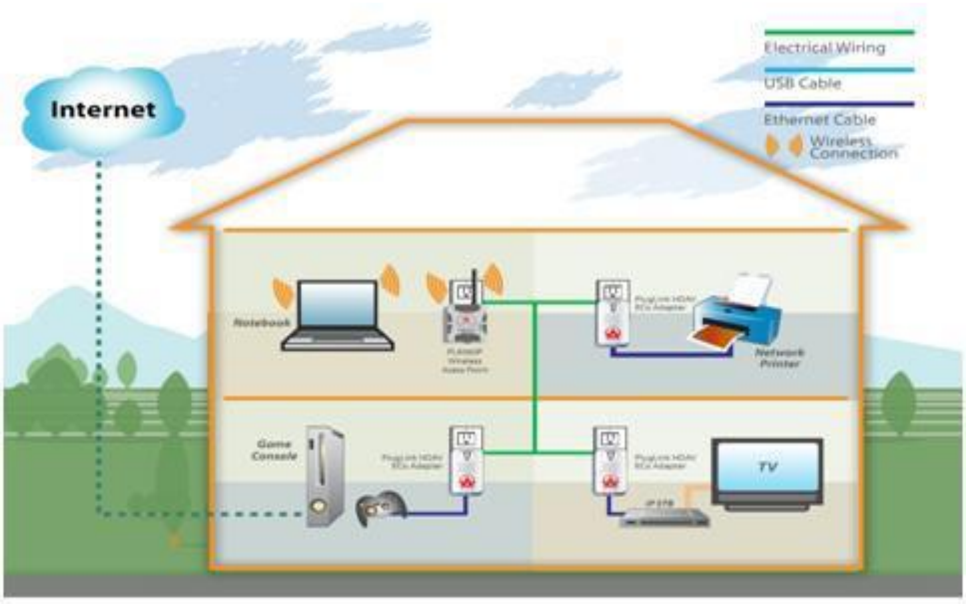
For this data exchange LAN technology is used. PLC which used existing power cable and Zigbee can be ideal communication technologies for LAN in the smart grid. Wi-Fi provide high data rate but it consumes more electric power than other. Bluetooth is limited for implementing HAN because of its limited capability

The Technologies of LAN for the Smart Grid can be detailed as,

Technology	Data Rate	Coverage Range	Band Licensed	Cost
Ethernet	10 – 100 Mbps	100 M	Free	High
PLC	10 – 100 Mbps	10 – 10 M	Free	Medium
Wi-Fi	5 – 100 Mbps	30 – 100 M	Free	Low
ZigBee	0.02 – 0.2 Mbps	10 – 75 M	Free	Low
Bluetooth	0.7 – 2.1 Mbps	10 – 20 M	Free	Low

House Area Network (HAN) in Smart Grid:

A home area network is a dedicated network connecting device in the home such as displays, load control devices and ultimately "smart appliances" seamlessly into the overall smart metering system. It also contains software applications to monitor and control these networks.



Home area network

Building Blocks of HAN:

The HAN is a subsystem within the Smart Grid dedicated to demand-side management (DSM), and includes energy efficiency and demand response which are the key components in realizing value in a Smart Grid deployment.
A few examples of demand-side management applications are:
a) Behavioural energy efficiency
b) Technology-enabled dynamic pricing
c) Deterministic direct load control

The latest application of Home Area Networks is installation of smart meters with an in-home display to monitor and manage the power consumption within the networked area. It also allows remote monitoring and control of electric appliances like thermostats etc. "Smart" meters have the capacity to connect wirelessly with the home appliances that contain RF antennas on the same frequency (usually 2.4-2.5 GHz). The meters can, thus, control appliances and generate detailed data on power consumption of each appliance.

Benefits of Home Area Network:

- Home Area Network empowers the consumers and allows the smart grid infrastructure to benefit the home owners directly.
- HAN allows the Smart Grid applications to communicate intelligently by providing

centralized access to multiple appliances and devices.

- Utilities can effectively manage grid load by automatically controlling high energy consuming systems with HAN and Smart Grid infrastructure.
- Home Area Networks provide energy monitoring, controlling and energy consumption information about the appliances and devices and hence support energy usage optimization by allowing the consumers to receive price alerts from the utility.

Challenges:

There exist various challenges to HAN, some of them are:

1) One of the major challenges is to integrate various technology solutions, so that smart services such as comfort, automation, security, energy management, and health can be offered seamlessly.
2) Interoperability is another key concern among the technology solutions that needs to be resolved in order for any technology to be acceptable by the market.
3) Consumer privacy and security is an issue that needs to be address.

Disadvantages of Home Area Network (HAN):

1. **Expensive –**

Set up of HAN is a little bit expensive because it requires smart devices and appliances to work in the network. For example, it requires Laptops, Smart Television, Smart Washing machines, smartphones, etc.

2. **Slow Connectivity –**

When all the users of the home use shared Home Area Network, they may face slow internet speed. For example, when anyone is downloading a high volume file by taking a high amount of internet during that others may feel slow down in internet speed.

3. **High Security –**

It requires high security otherwise if an attacker targets any device and enters the home network then they may steal important data from the laptop also as all the devices are connected to each other and work on a shared network.

WAN (Wide Area Network for Smart Grid):

The WAN connects several subsystem and smart meters with control center which is far from subsystem and customer side network. For example, several meter data collectors, mobile meter readers, and substation automation devices might send information to the utility offices over a WAN. However low data rate and significant signal attenuation limit its usage for WAN. The dedicated copper or fiber-optic cable support reliable and secure communication however it is very costly to deploy new cable for long distance. Cellular communication like as WiMAX, 3G and LTE is also considered for WAN in the smart grid since the same can support wide area communication between control centre and subsystems.

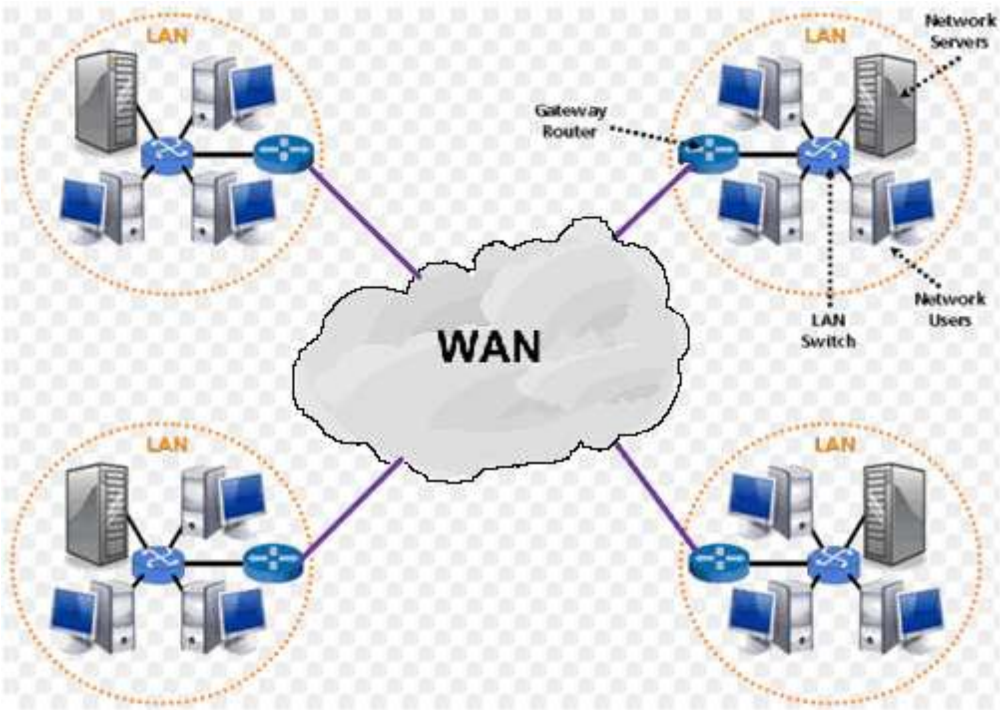
To be fully effective, the utility's WAN will need to span its entire distribution footprint, including all substations, and interface with both distributed power generation and storage facilities such as capacitor banks, transformers, and re-closers. The utility's WAN will also provide the two-way network needed for substation communication, distribution automation (DA), and power quality monitoring.

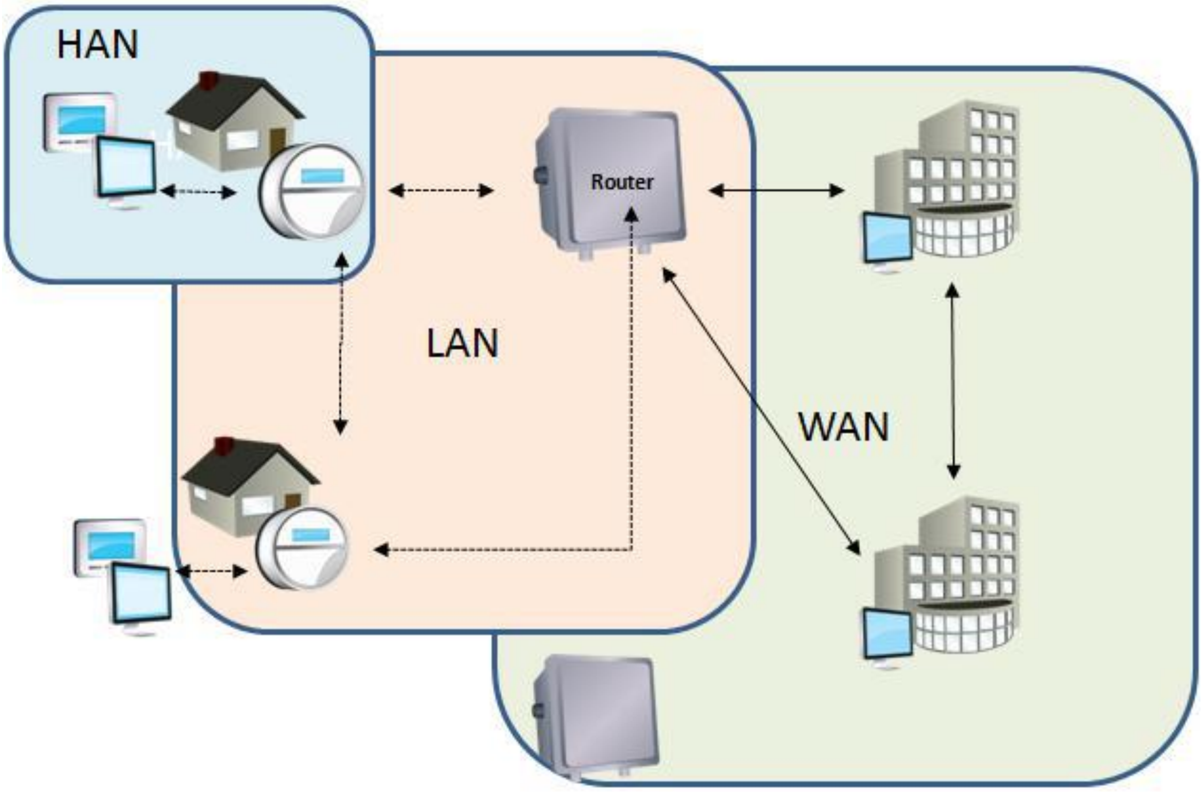
It also supports aggregation and backhaul for the advanced metering infrastructure (AMI) and any demand response / demand-side management applications. Each application running on the utility's WAN has its own set of requirements. Some applications like Supervisory Control And Data Acquisition (SCADA), automatic restoration and protection, and VoIP will require prioritization for real-time or near-real-time response and satisfactory Quality of Service (QoS). Some applications like AMI backhaul and video surveillance will consume considerable bandwidth, requiring broadband data rates end-to-end. And others like substation load management and crew communications will require both high bandwidth and fast response times.

Integrated communications will enable the grid to become a dynamic, interactive medium for real-time information and power exchange. When integrated communications are fully deployed, they will optimize system reliability and asset utilization, enable energy markets, increase the resistance of the grid to attack, and generally improve the value proposition for electricity.

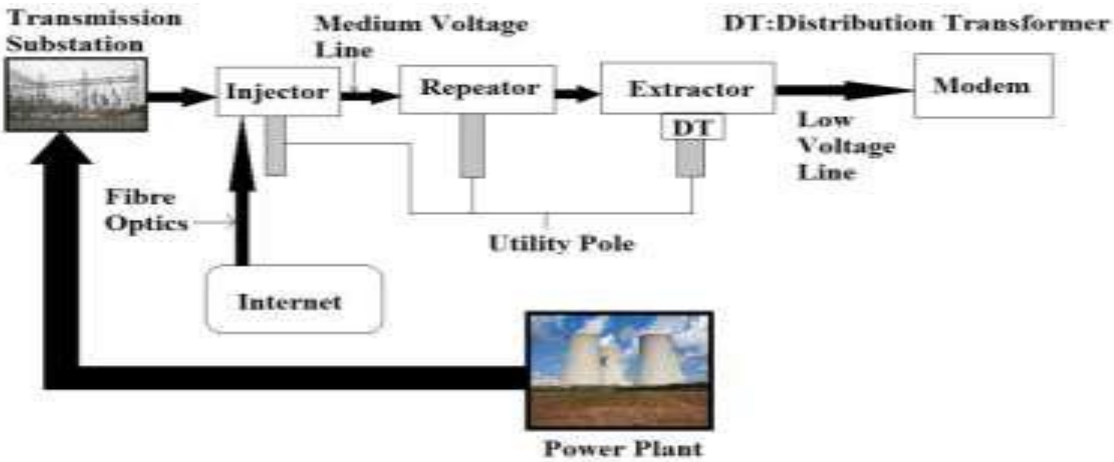
Example of WAN:

- The Internet
- 4G Mobile Broadband Systems
- A network of bank cash dispensers.





Broadband Over Power Line:

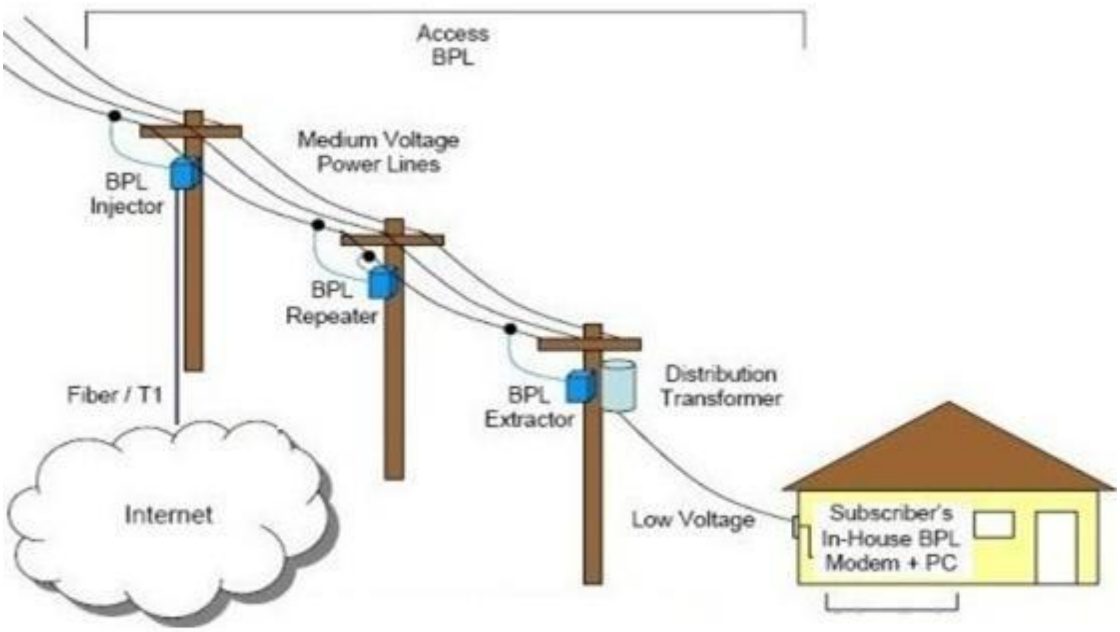


ARCHITECTURE OF BPL

Broadband over power line (BPL) is a technology that allows data to be transmitted over utility power lines. BPL is also sometimes called Internet over power line (IPL), power line communication (PLC) or power line telecommunication (PLT). The technology uses medium wave, short wave and low-band UHF frequencies and operates at speeds similar to those of digital subscriber line (DSL).

Initially it was hoped that BPL would allow electric companies to provide high-speed access to the internet across what providers call "the last mile." In this scenario, the service provider would deliver phone, television and internet services over fiber or copper-based long-haul networks all the way to the neighborhood or curb and then power lines would bring the signals into the subscriber's home. The BPL subscriber would install a modem that plugs into an ordinary wall outlet and pay a subscription fee similar to those paid for other types of Internet service. No phone, cable service or satellite connection would be required.

Proponents of the technology speculate that even if BPL is not accepted as a viable way to deliver high-speed Internet access, it may find a place in helping consumers to manage their energy consumption. High-speed data transmission between electrical plugs in a building would allow devices such as thermostats, appliances and smart meters to communicate with each other.



IP based Protocols:

The Internet Protocol (IP) is the method or protocol by which data is sent from one computer to another on the Internet. Each computer known as a host on the internet has at least one IP address that uniquely identifies it from all other computers on the Internet. When you send or receive data (for example, an e-mail note or a Web page), the message gets divided into little chunks called packets. Each of these packets contains both the sender's Internet address and the receiver's address. Any packet is sent first to a gateway computer that understands a small part of the Internet. The gateway computer reads the destination address and forwards the packet to an adjacent gateway that in turn reads the destination address and so forth across the Internet until one gateway recognizes the packet as belonging to a computer within its immediate neighborhood or domain. That gateway then forwards the packet directly to the computer whose address is specified.

Because a message is divided into a number of packets, each packet can, if necessary, be sent by a different route across the internet. Packets can arrive in a different order than the order they were sent in. The Internet Protocol just delivers them. It's up to another protocol, the Transmission Control Protocol (TCP) to put them back in the right order. The reason the packets do get put in the right order is because of TCP, the connection-oriented protocol that keeps track of the packet sequence in a message

The most widely used version of IP today is Internet Protocol Version 4 (IPv4). However, IP Version 6 (IPv6) is also beginning to be supported. IPv6 provides for much longer addresses and therefore for the possibility of many more Internet users. IPv6 includes the capabilities of IPv4 and any server that can support IPv6 packets can also support IPv4 packets.

Basics of Web Service:

A web service is any piece of software that makes itself available over the internet and uses a standardized XML messaging system. XML is used to encode all communications to a web service. Web services are XML-based information exchange systems that use the Internet for direct application-to- application interaction. These systems can include programs, objects, messages, or documents. Web services are self-contained, modular, distributed, dynamic applications that can be described, published, located, or invoked over the network to create products, processes, and supply chains. These applications can be local, distributed, or web-based. Web services are built on top of open standards such as TCP/IP, HTTP, Java, HTML, and XML.

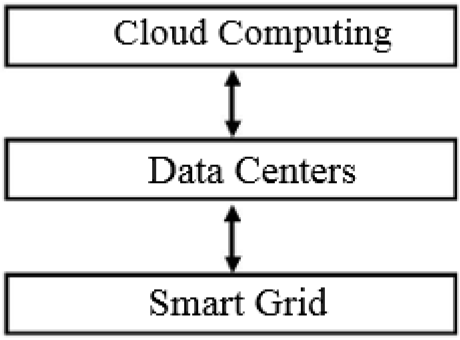
A web service is a collection of open protocols and standards used for exchanging data between applications or systems. Software applications written in various programming languages and running on various platforms can use web services to exchange data over computer networks like the Internet in a manner similar to inter-process communication on a single computer.

To summarize, a complete web service is, therefore, any service that:

- Is available over the Internet or private (intranet) networks
- Uses a standardized XML messaging system
- Is not tied to any one operating system or programming language
- Is self-describing via a common XML grammar
- Is discoverable via a simple find mechanism

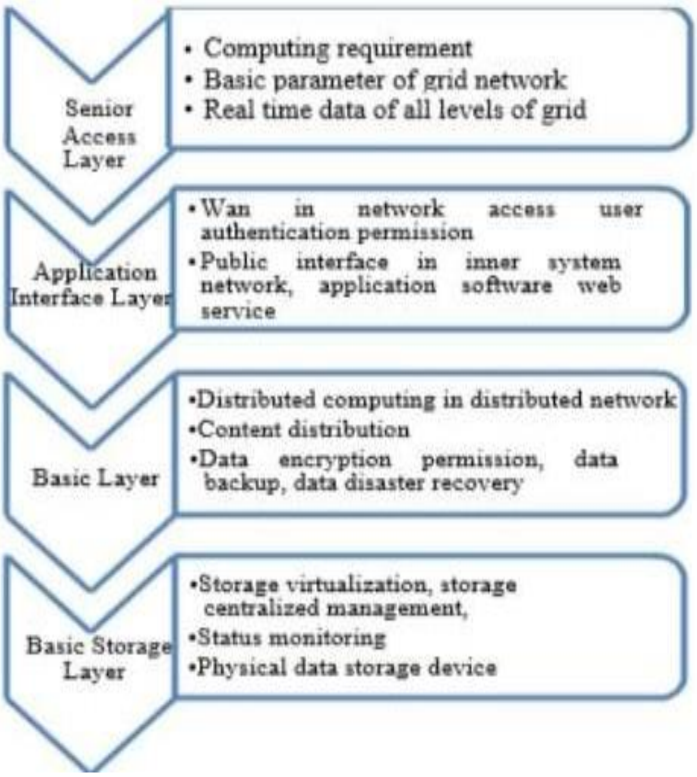
Concept Of Cloud Computing:

Being an emerging technology, development in field of virtualization, storage and connectivity are combined to create a new environment for cloud computing. Cloud computing has given a new definition to IT industry. In the last few years, cloud computing has shown an exponential growth in the IT industry. Leading industry sources define cloud computing as a new segment of computation in which numerous quantities of scalable IT enabled processes are delivered to external customers using internet technologies. This leads to revamp the business of IT industry and will bring changes in many of IT organization in the process of delivering the business services that are enabled by IT.



Relationship between cloud computing systems and smart grid and distributed data centers.

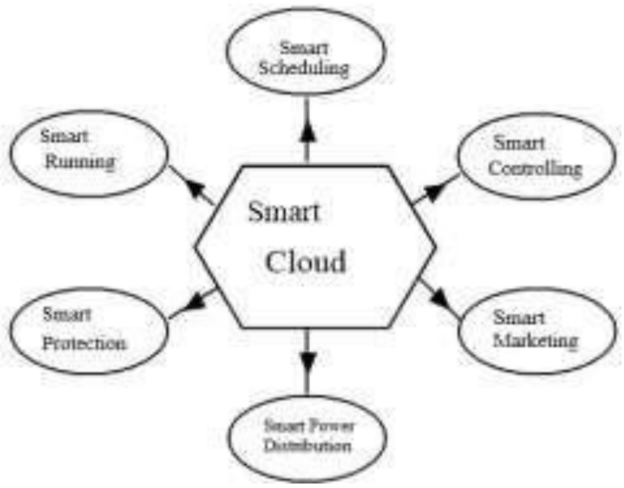
The cloud computing of electrical power system assimilates all networks with computer application software of inner network of power system to work united with help of cluster application, distributed computer system. All levels of network of electric power system can be reached through software interfaces. Structure of the hierarchical model of the intelligent cloud of power system. Basically, in structural model, the basic storage layer becomes the fundamental element of the Smart power system. As different locations are omnipresent, so storage devices are interconnected through network in power system. On the other hand, basic management layers assimilate the integration of all the devices in the cloud atmosphere.



Structural and hierarchical model of intelligent cloud of Power System

Need of Cloud Computing in Smart Grid:

Various applications require the need of cloud computing in electric power system. Primarily, cloud computing helps the power system to recover in the blackout condition. Secondly, monitoring and scheduling of the power system can be performed with the help of cloud computing. It also enables to have reliability evaluation of the power system. Recovery of power system after blackout proves to be a complicated nonlinear optimization problem. Promotion of the information sharing and cooperation between different participants is possible through power restoration process. An increase in calculation efficiency is observed by distributed computing. Further, an optimal complex interconnected recovery plan can be put into action due to shared computing platforms. These platforms provide better sharing and cooperation. The various functions of cloud computing in power system



Functions of cloud computing in Power system

The need of Cloud Computing:

Cloud Computing is the term referring to the delivery of hosted services over the internet. Cloud computing is a model for delivering information technology services in which resources are retrieved from the internet through Web based tools and applications rather than a direct connection to the server.

Any smart grid infrastructure should support real-time, two-way communication between utilities and consumers, and should allow software systems at both the producer and consumer ends to control and manage the power usage.

Cloud computing is an emerging technology advocated for enabling reliable and on- demand access to different computing sources that can be quickly provisioned and released in a cost-effective way to the service providers.

Using cloud infrastructure, a customer can gain access to their applications anytime, and from anywhere, through a connected device to the network.

In order to balance the real-time demand and supply curves, rapid integration and analyzation of information that streams from multiple smart meters simultaneously is required that necessitates the scalable software platform. Cloud platforms are well suited to support huge data and computationally-intensive, always-on applications.

Cloud platforms serve as essential components due to the various benefits they offer,

- Cloud acts elastically to avoid costly capital investment by the utility during the peak hours.
- Customers can be benefited from the real-time information by sharing the real-time energy usage and pricing information.
- Some data can be shared with a third party by using cloud services, after meeting the data privacy policies for developing intelligent applications to customize consumer needs.
- To manage large amounts of data, cloud computing is the best way for smart grids due to its scalable, economical and flexible characteristics.

Implementation of Cloud Computing in Power System:

The working of electric power system involves generation, transmission, distribution and usage of power simultaneously. On the other hand, electric power system has a feature that it can't store energy in larger amount. Thus, in production of the electric power, the control should be real-time, reliable and must consist of hierarchical management, hierarchical control, and distributed processing.

The above mentioned control can be achieved through cloud computing. The cloud computing can divide lengthy calculation into small segments with the help of intranet. After fragmentation, it is delivered to a system consisting of many servers. Servers perform computation and analysis of the information and pass it to the end users. So, due to cloud computing, huge information can be handled within a short span of time which resembles it to the supercomputer's grade service. As distributed computing is finding place in electrical power system which make its operationanalogous to internet. The cloud computing platform is categorized in to cloud computing control center and computing resources integration platform. With cloud computing, resource allocation as per application can be done and can access to storage resources on demand. Integration of the running grid nodes or computation on a single computer system is possible. Alternatively, cloud computing avoids improving the computational ability of the node or computer. It automatically gets enhanced through the clouds at every point in overall system.

Cyber Security for Smart Grid:

Smart Grid has transformed the electric system into a two-ways: a) flow of electricity and b) information. The information technology (IT) and telecommunications infrastructures have become critical to the energy sector. Therefore, the management and protection of systems and components of these infrastructures must also be addressed by an increasingly diverse energy sector.

To achieve this, a security system should be so designed which comprises of the following.

- Requirements of the system

- Plans that could be formulated and implemented.
- Risks involved in maintaining the security systems and smart methods to eradicate the risks.
- Strategy to be evolved.
- Study and analyse for future improvement.

Requirements:

The requirements are being developed using a high-level risk assessment process. These requirements are implicitly recognized as critical in all of the particular priority application plans.

Plans:

The critical role of cyber security in ensuring the effective operation of the Smart Grid by,

- Increasing the use of digital information and controls technology to improve reliability, security and efficiency of the electric grid.
- Dynamic optimization of grid operations and resources, with full cyber- security. A robust, resilient energy infrastructure in which continuity of business and services is maintained. This can be achieved through secure and reliable information sharing, effective risk management programs.

Risks involved:

Deliberate attacks, such as from disgruntled employees, industrial espionage, and terrorists. Inadvertent compromises of the information due to user errors, equipment failures. Natural disasters. Vulnerabilities might allow an attacker to penetrate a network, gain access to control software, and alter load conditions to destabilize the grid in unpredictable ways.
Additional risks to the grid which could bring vulnerabilities:

- Increasing the complexity of the grid
- Increase exposure to potential attackers and unintentional errors;
  - Interconnected networks can introduce common vulnerabilities;
  - Increasing vulnerabilities to communication disruptions and introduction of malicious software that could result in denial of service or compromise the integrity of software and systems;
  - Increased number of entry points and paths for potential adversaries to exploit; and
  - Smart Grid has additional vulnerabilities due to its complexity, large number of stakeholders, and highly time-sensitive operational requirements.

Strategy to be evolved:

Implementation of a cyber-security strategy requires the development of an overall cyber security risk management framework. This framework is based on existing risk management approaches developed by both the private and public sectors. This risk management framework establishes the processes for combining impact, vulnerability, and threat information to assess the risk. Because the Smart Grid includes systems and components from the IT, telecommunications and energy sectors. The goal is to ensure that a comprehensive assessment of the systems and components of the Smart Grid following the risk assessment

In a typical risk management process, assets, systems and networks are identified; risks are assessed, and specified. Security controls are selected, implemented, assessed for effectiveness. Then the same are monitored. The risk assessment process for the Smart Grid will be completed when the security requirements are specified. These requirements will not be allocated to specific systems, components, or functions of the Smart Grid. The output from the Smart Grid risk management process should be used in these steps.

Study and analyse for future improvement:

The approach taken herein is to more quickly identify fruitful areas for solution development, A list of evident and specific security problems in the Smart Grid that are amenable and should have open and interoperable solutions are created. General problems such as poor software engineering practices, key management, etc. are not included. From the above a catalogue of design patterns that serve as a means of identifying and formulating requirements is developed and documented. This document is to be treated as an interim work product with some apparent redundancies, but in the next iteration of the groups analysis process these will be worked out for improvement.