UNIT - I

INTRODUCTION

1.1.1 Evolution of Energy systems.

* The first alternating current power grid system was installed in 1886 in great Barrington Massachusetts. At that time the grid was a centralized unidirectional system of electric power transmission electricity distribution and demand driven control.
* By the 1960's, the electric grids of developed countries had become very large, mature and highly interconnected with thousands of central generation powerstations.
* The Topology of the 1960's grid was a result of the strong economies of scale; large coal - gas and oil fired power stations in the 1GW to 3GW scale are still found to be cost effective.
* Power stations were located strategically to be close to fossil fuel reserves.
* sitting of hydro electric dams in mountain areas also strongly influenced the structure of the emerging

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grid. Nuclear power plants were sited for availability of cooling water.

* Finally fossil fuel fired power stations were initially very polluting and were sited as far as economically possible from population centres once electricity distribution networks permitted it.

* Through the 1970's to the 1990's growing demand led to increasing numbers of power stations.

* In some areas supply of electricity especially as peak times, could not keep up with this demand, resulting in poor power quality including blackouts, power cuts and brownouts.

* Towards the end of the 20th century electricity demand patterns were established.

* Domestic heating and air conditioning led to daily peaks in demand that were met by an array of peaking power generators that would only be turned on for short periods each day.

Modernization opportunities.

* Since the early 21st century, opportunities to take advantage

of improvements in electronic communi-cation technology to resolve the limitations and costs of the electrical grid have become apparent.

* In parallel growing concerns over environmental damage from fossil-fired power stations has led to a desire to use large amounts of renewable energy. (i.e wind power, solar power etc.)

1.1.2 Evolutions of smart Grid :-

The first official definition of smart grid was provided by the energy Energy independence and security Act of 2007 and signed to law by president George W. Bush in december 2007.

To achieve each of the following, which together characterize a smart Grid.

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

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(ii) Dynamic optimization of grid operations and resources with full cyber security.

(iii) Deployment and integration of distributed resources and generation including renewable resources.

(iv) Development and incorporation of demand response demand side resources and energy efficiency resources.

(v) Deployment of smart technologies for metering communications, concerning grid operations and status and distribution automation.

(vi) Integration of smart appliances and consumer devices.

(vii) Deployment and integration of advanced electricity storage and peak shaving technologies including plug in electric and hybrid vehicles and thermal storage air conditioning.

(viii) Provisions to consumers of timely information and control options.

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

(x) Identifying and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies practices and services.

A common element to most definitions is the application of digital processing and communications to the power grid matching data flow and information management control to the smart grid.

1.2 Concepts of SMART GRID :-

An electrical grid is an interconnected network for delivering electrical energy from the generating end to the customer end. This interconnected network is also referred as electrical grid or power grid.

1.2.1. Modules:-

The network contains four important modules namely,

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(a) Generating station
(b) substation
(c) Transmission system and
(d) Distribution system.

(a): The electrical power produced at the generating station is transmitted via high voltage transmission system.

(b) substations :-

It ~~set~~ step up the voltage for transmission or stepdown voltage for distribution.

(c) Transmission system :-

The step up voltage transfered through primary and secondary transmission lines.

(d) Distribution system.

The last module of electric grid connects consumer with the grid through distributed lines.

1.2.3. SMART GRID :-

* "A smart grid can be termed as modern grid. This modern grid enables a bidirectional flow of energy and uses

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two way cyber secure information and communication technologies.

Definition

Smart grid is defined as the integration of information and communications technology into electric transmission and distribution networks.

Conceptual Model:-

Inorder to realize this modern grid model, National institute of standards and Technology (NIST) provides a conceptual model.

Domain :-

There are seven domains presented in that model which are based on the different roles performed by smart grid. They are,

(i) Generation (ii) Transmission
(iii) Distribution (iv) operation
(vi) service provider (vii) Market and
(viii) customer.

circuit Diagram for conceptual model.

(i) Bulk Generation domain

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The bulk generation domain generates electricity in bulk quantities (more than 300 MW).

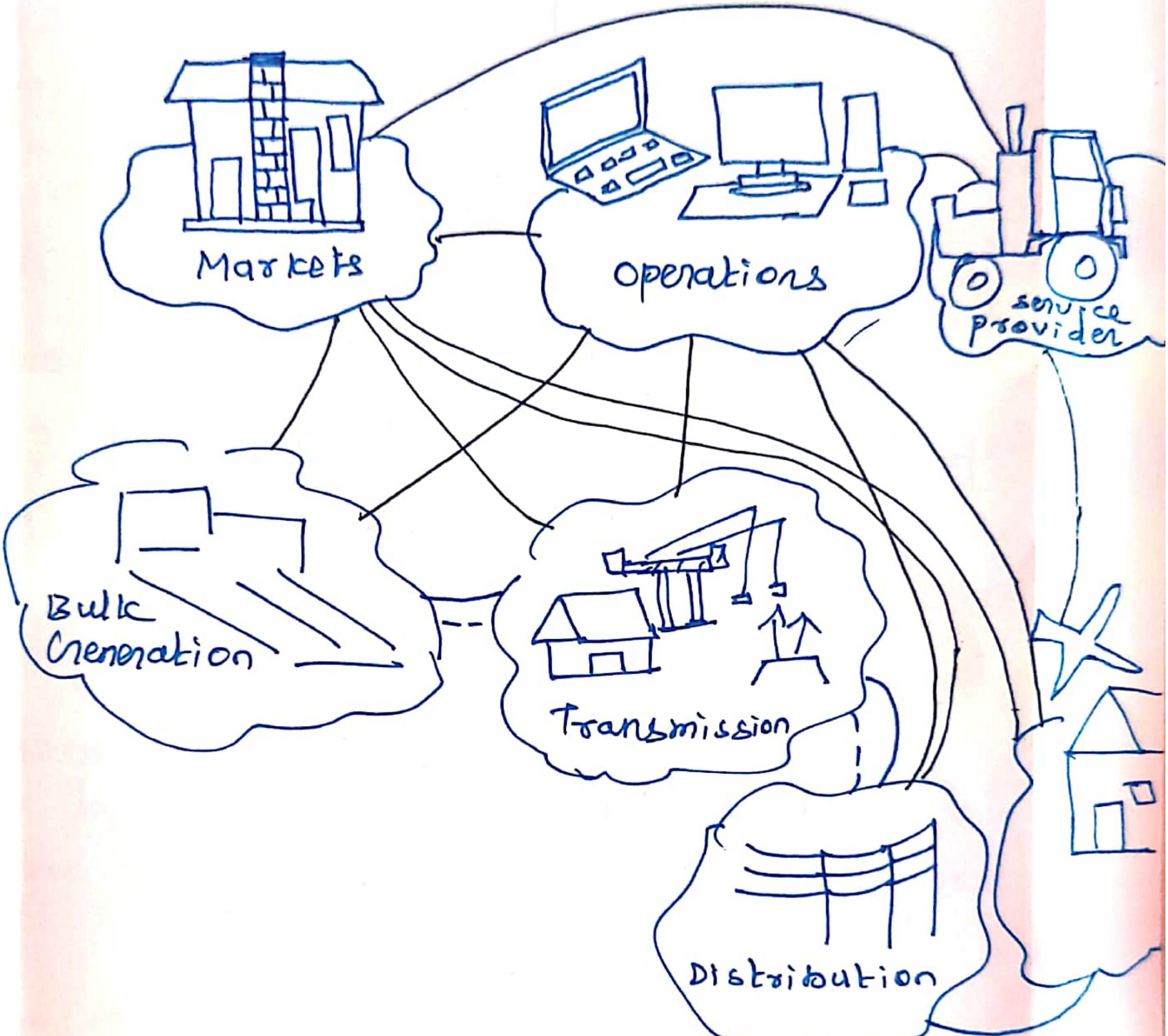

Fig. Conceptual Model of smart Grid.

* Generation domain is a location where power plants converts mechanical energy of turbine into electrical energy. Exceptional cases involved in bulk generation domain are,

(i) solar power generations
(ii) wind power generations.

(ii) Transmission domain

* The domain carries bulk electricity over long distances via transmission cables or power lines.

* The increase in voltage is done to reduce transmission loss.

* This domain needs to maintain stability on the electrical grid by balancing energy generation with energy demand across the transmission network.

(iii) Distribution Domain:-

* The generated power is provided to customer based on their demand. The distribution of electricity is initiated with distribution substations.

* It contains step down transformers which reduces the high voltage transported from the generator side.

* The customers can be either
  (a) Large industries
  (b) Small homes.

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(iii) Operations Domain :-

* The flow of electricity is managed in this domain where a supervisory network topology is deployed.

* The role of this topology is to provide the status of circuit breaker, switches and other control equipments loading conditions.

(iv) Uses:-

(a) By using this domain the real time data analysis can be performed.

(b) It is used for analyzing the faulty occurance in the system.

(c) It provides the information about faulty locations, identification, isolation and system restoration.

(v) Service provider Domain:-

* This data is used for supporting the business related data of a power system.

* It is used for providing services to electrical customers and utilities.

This domain executes.

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(i) Billing and customer service enhancement.
(ii) Maintaining and Monitoring and controlling of energy use and
(iii) Energy generation etc.

(vi) Markets domain :-
* This domain is a place where grid assets are bought and sold.
* In this domain the operator balances the supply and demand within the power systems.

(vii) Customer domain
The customers are end users of this conceptual model. the customers store and manage the use of energy.

1.3 NEED FOR SMART GRID.
The smart grid has made the energy industry to move into a new era of reliability. The following discussions will enumerate the need for smart grid in reality. They are,
(i) Curtail power theft
(ii) Enhancement of power reliability
(iii) Lack of infrastructure.

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(iv) satisfying power demand
(v) Integrating clean power
(vi) Environmental impact.

1.3.1 curtail power theft

There are several losses occur in the system. These losses are categorized as,

(a) Technical
(b) Non technical.

(a) Technical losses:-

* copper losses and core losses are some of the technical losses.

* with the support of technical modeling computation of technical losses has become simple.

(b) Non technical losses:-

* There are somany non technical losses, one such non technical loss is powr theft.

* Evaluating the non-technical losses have become complex.

solutions:-

* To address this problem, a high security, best efficiency system is highly

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demanded.

* One way to curtail power theft is to have grid accounting where the power flow can be easily tracked.

(ii) Enhancement of power reliability.

* The reliability of power defines the capability of customer to access the electricity without any disruption.

* The power flow can be made contineous by grid load balancing and distribution automation services.

* The services offered may also alert utilities from black out. This supports to react quickly to reduction in the voltage of commercially supplied power.

* Thus grid are made smarter.

(iii) Lack of infrastructure :-

* The growth of power sector can be made highly realistic only with good infrastructure.

* Exisisting power system is becoming absolute, and so improvement in grid infrastructure is required.

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(iv) satisfying power demand :-

* The increasing population has triggered power shortage challenges.

* In country like india there could get double within decade.

* Such increase in power demand can be smartly managed by the smart grid technologies.

(v) Integrating clean power.

* Fossil fuel will exhaust in next six decades which will lead to power shortage.

* so it has become essential to use renewable energy based power resources rather conventional power plants.

* The addition of renewable energy to existing grid have to address few issues.

* smart grid will address the issues related to integration of renewable energy source to the existing grid.

(vi) Environmental Impact.

* Fossil fuel based power plants has become a largest source of carbon

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* To move towards zero emission system it has become mandatory to deploy renewable energy source integration to existing grid.

1.4 Smart Grid drivers.

"smart grid drivers are forces that have emphasized the need for smart grid for overcoming the challenges faced by power sectors."

* The deployment of smart grid is based on important factors namely,

(a) Inexorable increase in energy demand
(b) Global warming
(c) Empowering customers
(d) Economic competitiveness
(e) Energy reliability and security.

(a) Inexorable increase in energy demand:-

* The growth in population and technological advancement has escalated the demand for electricity.

* As per the world energy outlook 2014 datasheet world electricity demand increases by almost 80% over the period

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2012 – 2040.

* For satisfying such hike in energy demand smart grid has become highly essential.

(b) Global warming.

* By considering the environmental impact, addressing global warming related issues have become vital.

* A major source of carbon emission is fossil fuel based power plant.

* Renewable energy based energy generation has become a good choice for energy production, where low carbon emission and low sustainability can be attained.

* To the existing system integrating renewable energy source can be managed effectively by smart grid.

* Hence deployment of smart grid can create an ecology friendly energy production system.

(c) Customer Empowerment:-

* Without compromising the individual's life styles, an effective

utilization of energy usage by customer can be triggered.

* Empowering customer so that they have more control over their energy utilization.

(d) Economic Competitiveness :-

* By including alternative energy sources a new business models can be created to alleviate the challenges of a drain of technical resources in an aging workforce.

Remedies :-

(i) The energy reliability can be increased through decreased outage duration.

(ii) By replacing manuel meter reading and field maintenance labour cost can be reduced.

(iii) Transmission and distribution system losses can be minimized by improved system planning and asset management.

(iv) Such grid management can prevent power theft and fraud which may provide better billing and protect revenues of energy sectors.

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1.5 SMART GRID FUNCTIONS.

Real time load management can be done by real time load measurements and its transfer. The entire process of smart grid can be managed and monitored under a single system called wide area network. (WAN).

The following are the important functions of smart grid. They are,

(i) Fault current limiting
(ii) Improved fault protection
(iii) Diagnosis and notification of equipment condition
(iv) Wide area monitoring, visualization and control.
(v) Power flow control
(vi) Dynamic capability rating
(vii) Automated feeder and line switching.
(viii) Adaptive protection
(ix) Automated islanding and reconnection
(x) Real time load measurement and management.

(i) Fault current limiting:-

* With the deployment of sensor based technology fault current limiting can be achieved.

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* The system reconfiguration will protect the excessive damage of system due to fault current.
* A special device called fault current limiter is employed for fault current limiting.
* Such special devices can automatically limit high through currents that occur during fault.

(ii) Improved Fault protection:-

* Fault protection is defined as the process of identifying fault its location for providing isolation and service Restoration.
* Such process must be speed enough to provide better fault protection.
* Various types of faults have been categorized using sensor based techno-logies.

(iii) Diaganosis and notification of Equipment condition:-

* To protect the system from fault condition it has become mandatory to analysis the system or equipment working condition.
* Equipment abnormality namely (i) excessive vibration (ii) Heat dissipation can be easily detected using diagnosis

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and notifications of equipment condition....

* Diagnosis and notification of equipment condition is defined as online monitoring and analysis of equipment.

(iv) Wide Area monitoring, visualization and control.

* As the grid is too wide, monitoring its performance manually is highly impossible. So a monitoring and visualization requires time synchronized sensors called phasor measurements units (PMU), communications, information processing and actuators.

* wide area monitoring and control can provide real time protective action to be made.

(v) Power Flow control :-

* Flow control requires techniques that are applied at transmission and distribution levels to influence the path that power travels.

* By using tools such as (i) FACTS (ii) phase angle regulating transformer (PAR) (iii) series capacitors (iv) very low impedance super conductors power flow control can be easily attained.

(vi) Dynamic capability Rating :-

* Dynamic capability rating is defined as the ability to carry load based on electrical and environmental conditions.

(a) The real time load carrying determination of line.

(b) Transformer in presence of line tension

(c) Temperature

(d) wind speed

can be considered as dynamic capability rating in smart grid.

(vii) Automated Feeder and Line switching:-

* Automatic isolation and reconfiguration of faulted segments of distribution feeders or transmission lines via sensors, controls, switches and communications systems can be realized using automated feeder and line switching.

(viii) Automated Islanding and Reconnection:-

* Automated islanding and reconnection is achieved by automated separation and subsequent reconnection of an independently operated portion of the T & D system from the interconnected electric grid.

Ex: Micro Grid.

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OPPORTUNITIES FOR SMART GRID IN INDIA:-

* The smart grid concept is not confined to utilities only it involves every stage of the electricity cycle from the utility through electricity markets to customers applications.
* the emerging vision of smart grid encompasses a broad set of applications including (a) Software (b) Hardware and technologies that enable utilities to integrate interface with and intelligently control innovations.
* In country like India, deployment of such modern grid provides more opportunities in the field of energy sector.

Advantages of Smart Grid :-

(a) It is a future for power grids across the globe.

(b) It can help to reduce the commercial and technical losses.

(c) Improving in grid infrastructure can also be obtained.

(d) The environmental impact of existing grid can be overcome by smart grid.

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1.6.1 Smart Grid Drivers in India:

India has few drivers very similar to global drivers of smart grid. They are, (i) short fall in power (ii) Reduction of losses (iii) Automation (iv) Integration of clean energy (v) satisfying the peak load. are few smart grid drivers in India.

* It is estimated that India's demand short fall are 12% for total energy and 16% for peak demand.

* India's aggregate technical and commercial losses are thought to be about 25-30%

* The lack of transparency in metering may still have an increase in technical losses.

* The smart grid would allow more intelligent load control.

* Integrating customer relations management (CRM) and advanced metering infrastructure (AMI) data will key enabler in India.

1.7 CHALLENGES FOR SMART GRID.

The smart grid technology platform has identified following key challenges.

(a) Government support
(b) Lack of policy and regulation
(c) compatible equipment
(d) capacity to absorb advanced technology.
(e) consumer awareness.

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(a) Government support :-

* without the support of government the industry may not have the financial capacity to find new technologies.

* Incentives for investments are to be done through government support.

(b) Lack of policy and Regulations :-

* Since smartgrid is a new technology there are no defined standards and guidelines available for the regulation of smart grid initiatives in India.

(c) Compatible Equipment :-

* The compatibility issues between existing equipment with smart grid technology must be addressed.

* The replacement of older equipment with intelligent electronics devices is highly demanded.

(d) Capacity to absorb advanced Technology:-

* The deployment of information and Communication technology on the grid faces problems due to limited experience and still in managing smart grid component.

(e) Consumer Awareness :-

The deployment of smart grid technology will not be beneficial without creating

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customer awareness.

* The end user must be educated with the importance and benefits of advanced metering and two-way communication.

* Else the features and benefits of a smart grid will not be achieved.

1.8 SMART GRID IMPLEMENTATION CHALLENGES IN INDIA :-

* Smart grid implementation means a transition towards the next generation grid through automation.

* The implementation of smart grid is not an easy task as an Indian power sector poses a number of issues such as,

(a) Power theft
(b) Inadequate Infrastructure
(c) Low metering Efficiency and
(d) Lack of awareness.

(a) Power theft :-

* In country like India power theft has grown as major issues in power sector industries.

* Usually power theft of energy happens through hooking lines.

Methods to prevent :-

(i) Insulated over head lines
(ii) replacement of LT over head wires

with insulated cables.

(iii) Replacement of conventional energy meters with digital tamper proof meters.

(iv) prepaid card for energy utilization.

(b) Inadequate Grid Infrastructure :-

* India can provide a stable environment for investments in electric infrastructure which is a prerequistic for fixing the fundamentals problems with the existing grid.

* To build a modern intelligent grid, government has to provide funds for establishing the new technology.

(c) Low Metering efficiency :-

* By improving metering efficiency, proper energy accounting and auditing can reduce commercial losses while increasing smart grid efficiency.

* usually low metering efficiency theft and pilferage are reasons for commercial losses in a grid.

(d) Lack of awareness :-

* In many developing countries a major obstruction in deployment of new technology is lack of awareness among users

* with a deployment of new technology

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It has become mandatory to educate end users regarding benefits of smart grid.

* Consumers should be made aware about their energy consumption pattern at home, office etc.

1.9 SMART GRID BENEFITS :-

The smart grid presents a wide range of potential benefits including,

(a) Optimizing the value of existing production and transmission capacity.
(b) Incorporating more renewable energy sources
(c) Enhancement in energy Efficiency.
(d) Enabling zero emission system.
(e) Improving load delivery Efficiency.
(f) Increased operational efficiency.

Benifits of smart Grid Implementation :-

Reliability :-

(i) Reliability of the system increases by deploying smart grid.
(ii) The monetory and management technologies enhance the reliability of smart grid.
(iii) Its self healing in nature during power outages ie automatic detection of faults.
(iv) The measure of reliability is observed through higher customer satisfaction

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during brownouts, black outs and surges.

(v) It can provide monetary benefits to customers, society, utilities and government.

(vi) Power theft is reduced.

(b) The technical and non technical losses of the grid can be reduced.

(c) The reduction of transmission congestion, peak load and energy consumption can extend the life of the system.

(d) smart grid is necessary for the efficient integration of renewable energy.

(e) A smart grid offers benefits to various consumers namely,

(i) Industrial
(ii) commercial and
(iii) Residential

1.10 Difference between conventional and smart grid :-

The benefits of smart grid can be highlighted by performing a comparative analysis between traditional grid and smart grid.

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Conventional grid	Smart grid
(i) Centralized system	(i) Decentralized system
(ii) Power flows in one direction.	(ii) Power flows in both the direction.
(iii) Power flows enabled	(iii) Power flow and information flow are enabled.
(iv) Power sources may or may not be located in the same geographic area.	(iv) Power sources to be located closer to their point of use.
(v) It may or may not include SCADA.	(v) It include SCADA systems.
(vi) Energy loss is more	(vi) Reduction in energy loss.
(vii) Manuel Inter operation at same points.	(vii) Fault detection and its restorations are automated.

UNIT II
SMART METERING.

2.1 Introduction to advanced Metering infrastructure (AMI).

AMI is a process of selection and deployment of a specific metering technology to the modern grid.

It can also be refferred as a new arrangement of utility processes and applications for collecting meter readings integrating customers in the daily grid operations.

2.1.1 General structure of AMI.

The fig shows the general Architecture of advanced metering Infrastructure (AMI)

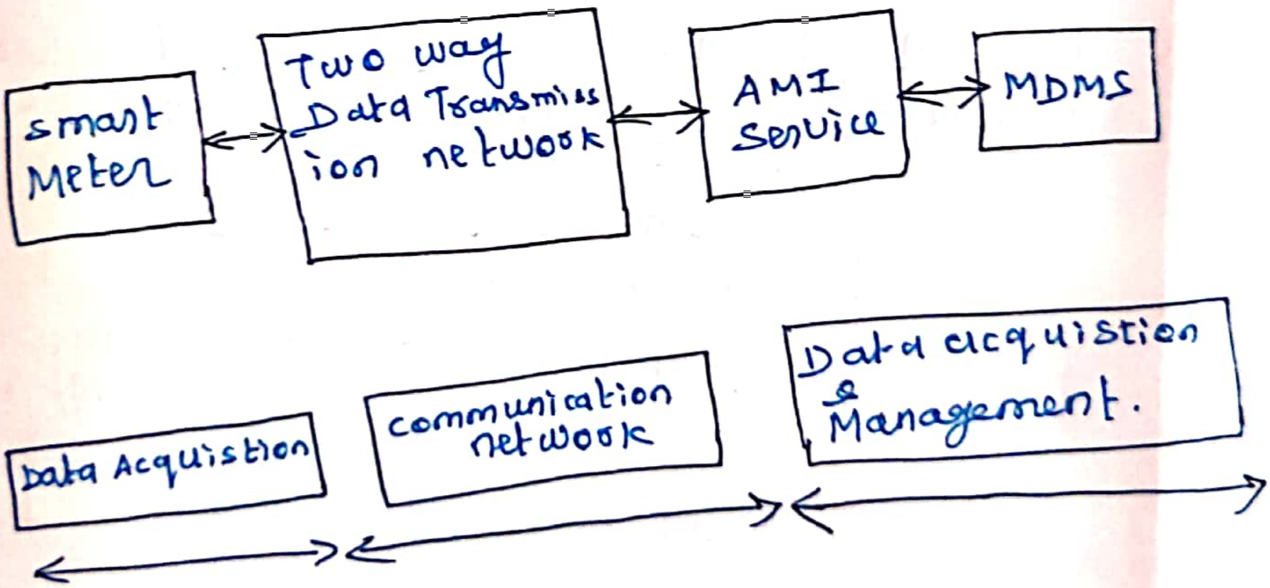

Fig. General structure of AMI

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Components of AMI Architecture are,

(a) Smart metering unit

(b) communication network

(c) Data acquisition and management.

2.1.2 Block Diagram of AMI.

* The infrastructure includes the following components in AMI are,

(a) smart meters

(b) wide area communication network (WAN)

(c) Meter data control MDC

(d) Meter data management system (MDM)

(E) Home area network (HAN)

The following figure shows general block diagram of AMI.

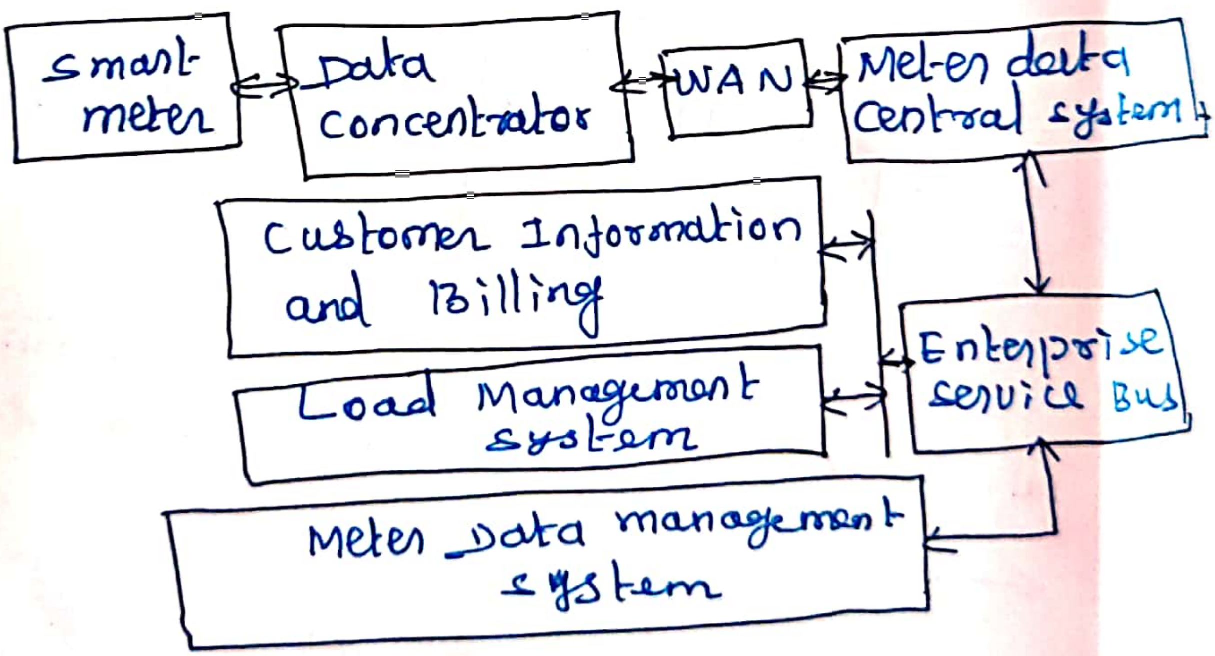

Fig. Block diagram of AMI

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(a) Smart Meters.

* It is solid state electronic electricity meter.
* It supports the measurement of electricity consumption.
* It provides smart functionalities as
(i) Hourly Electricity consumption
(ii) Time based load control
(iii) Remote connection and disconnection of delivery site, tamper detection etc.

* Smart meters can be managed remotely either on demand or on a scheduled basis.

(b) Wide area Communication Network (WAN)

→ The communication between various components of AMI platform has established through WANs.

The technology used are
(i) 3G wireless communication channels.
(ii) Broad band PLC
(iii) optical fiber
(iv) wireless radio etc.

It provides contineous communication between the data concentrators and the AMI meter data central system.

(c) Meter Data Central (MDC) :-

→ MDC is a system where data gathered from every single smart meter and concentrator are transferred to unique central database.

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→ It also interfaces with the other utility systems to furnish the required meter data to the infrastructure.

(d) Meter data management system :-

→ The validation, Estimation and editing (VEE) of meter data are done by MDM system.

→ MDM is built on top of MDC system for processing billing system.

(e) Home area network :-

→ These networks are implemented at residential consumer location.

→ The smart meters are linked to in home installed controllable electrical devices.

→ HANS manage consumers installed in home devices as displays to present.

(i) Instantaneous electricity consumption.
(ii) Time-based electricity prices.
(iii) Planned outages
(iv) Thermostats etc.

2.2 AMI BENEFITS

The benefits of AMI can be generally categorized as

(i) operational (ii) Financial
(iii) Consumer and (iv) security.

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(i) Operational Benefits:-

AMI Benefits the entire grid by

(a) Improving the accuracy of meter reads.

(b) Energy theft detection and

(c) Response to power outages.

(ii) Financial Benefits:-

→ AMI brings financial Benefits to utility by (a) Reducing equipment and maintenance cost.

(b) Enabling faster restoration of electric service during outages and

(c) streamlining the billing process.

(iii) Customer Benefits:-

→ AMI Benefits electric customers by

(a) detecting meter failures early

(b) Accomodating faster service restoration

(c) Improving the accuracy and flexibility of billing.

(iv) Security Benefits:-

(a) Enhanced monitoring of system resources

(b) Mitigates system inrusion and cyber attacks.

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2.3 AMI PROTOCOLS AND STANDARDS.

⇒ For any system, the establishment of regulation is highly important to enable interoperability.

⇒ This is done by defining protocols and standards for a system.

Standard development organization:-

The exchange of data and its usage is defined by,

(a) Institute of Electrical and Electronics Engineers (IEEE)

(b) International Electrotechnical commission (IEC)

(c) American National standard Institute (ANSI)

(d) National Institute of standards and technology (NIST)

are few development standard organization.

Interoperability standards:-

There are many types of interoperability standards available. the following are standards developed for applications specific namely,

(i) Multi media Related standards:-

⇒ It is for wireline communication and cellular communication.

(ii) Data transmission standards:-

→ Internet standards
→ Internet protocol (IP)
→ Transmission control protocol (TCP)
→ Usage based dynamic pricing (UDP)

and hyber text transfer protocol (HTTP) standards.

(iii) Application Related standards :-

→ IEC 61850
→ IEC 61968 and
→ ANSI C-12

(iv) communication and Inter operability standards.

→ It was developed by the standard development organization called IEC.
→ The standards developed by IED TC 57. are classified according to zones and communication layers have been listed below.

(a) IEC 61850 :-

→ It is associated with substation automatics integration of RES and supervisory control and data acquisition (SCADA) communication.

(b) IEC 61970 :-

→ At control centres for transmission and distribution, abstract modeling application and database integration are

Implemented.

(c) IEC 61968 :-

→ It involved in common information model (CIM) and AMI back office interface.

(d) IEC 62351

→ support and security services.

AMI Needs in the Smart Grid :-

2.4. Driving Factors

(i) The technology

(ii) Installation

(iii) operation and maintenance are the driving factors of AMI.

2.4.1 AMI Needs in smart Grid.

(i) AMI is required to ensure accurate precise and reliable data acquisition in smart grid.

(ii) The capability of communicating among different devices.

(iii) The concerns on data protection and privacy is most important.

(iv) In smart grid there may be chance of cyber attacks.

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(v) Hence there arises a need for curtailing such unauthorized controlling through cyber attacks.

Preventive measures for cyber attacks:-

(i) Authentication
(ii) Authorization
(iii) Privacy control are the preventive measures for intrusion by cyber attackers.

Robust solution for privacy control.
(a) Advanced Encryption standard (AES)
(b) public key infrastructure.
(c) Triple data encryption Algorithm (3 DES)

are few technologies deployed for privacy control.

Wireless communication Protection Technologies.
→ The wireless communication technologies are protected by
(i) IEEE 802.11 i and
(ii) IEEE 802.16e

WireLine communication system Protection:-
(a) Firewall
(b) virtual private networks (VPN)
(c) IP security methods are used in wire Line communication system.

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security Related Issues.

The parameters related security related issues are,

(a) confidentiality
(b) Integrity
(c) Accountability
(d) Authorization
(e) Availability

(vi) AMI platform improves the relationship between utilities and customers.

(vii) Offers new remote services to the customers.

(viii) Increased customer satisfaction and fidelity is observed.

2.5 Phasor Measurement UNIT (PMU)

A phasor measurement unit is a dedicated device used to estimate the magnitude and phase angle of an electrical phasor quantity in the electricity grid using time synchronization.

Structure of PMU:-

The device which provides synchronized phasor measurement is called a phasor measurement unit (PMU). Fig shows the structure of PMU.

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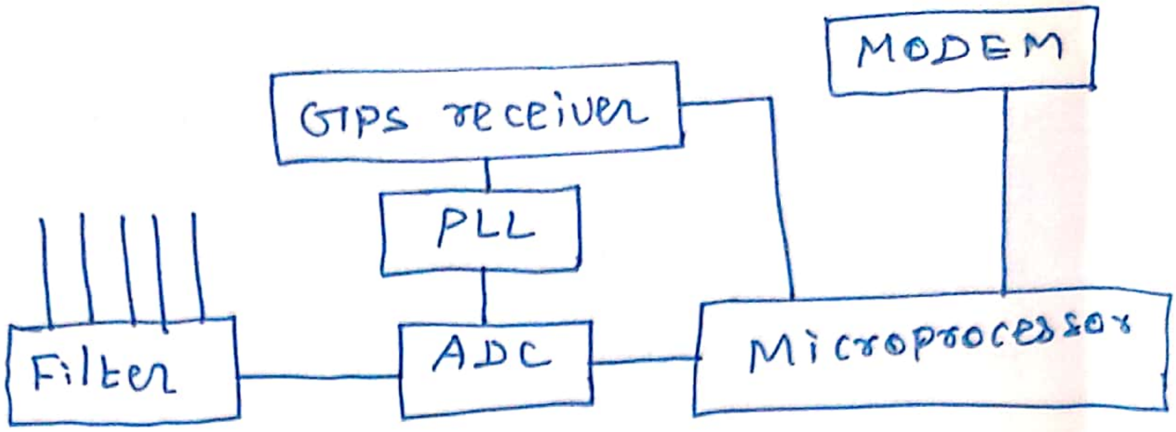

Fig. structure of PMU.

Different components of PMU are
(i) Phase locked Loop (PLL)
(ii) Microprocessors
(iii) Filters
(iv) ADC and GPS.

Synchrophasors :-

→ A phasor is a mathematical representation of a sinusoidal waveform.

→ The phase angle at a given frequency is determined with respect to time reference

→ Synchrophasor are phasor values that represent powersystem sinusoidal waveform reference to the nominal powersystem, frequency and coordinated universal time.

Functions of PMU :-

→ Phasor measurement Unit (PMU) are electronic devices that use digital signal processing component to measure AC

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waveform.

→ These AC waveforms converted into phasors according to the system frequency and synchronize these measurements under the control of GPS reference sources.

→ The analog signals are sampled and processed by a recursive phasor algorithm to generate voltage and current phasors.

PMU in a Transmission Network:-

→ PMUs are mostly installed at high voltage transformers and power generation plants.

→ In a three phase generation or transmission network, each phase is equiped with voltage and current transformer as shown in fig.

→ The voltage and current transformers are required to stepdown the voltage and current respectively.

→ These signals are transmitted to ADC of PMU.

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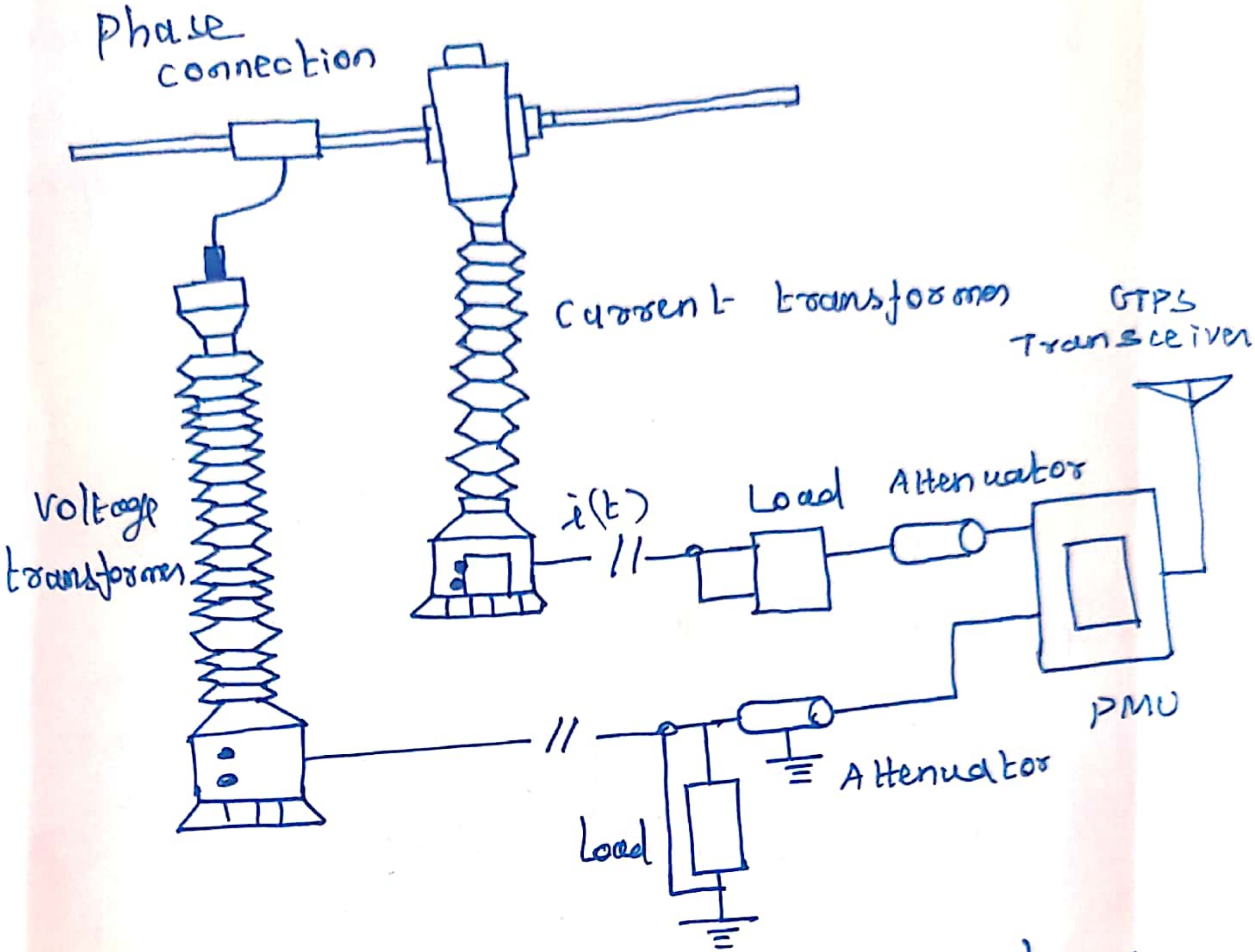

Fig : PMU in a transmission Network.

* The processed data are transmitted using satellite and GPS transceiver that operates as receiver and transmitter.

Hardware of PMU :-

* The hardware Architecture and components of basic PMU system has been illustrated in fig.
* The initial section is comprised by analog inputs where a low pass filter (LPF) is used for antialiasing of measured

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signals.

* The calculation, detection and processing blocks for measured voltage and current phasor signals are done by microprocessor controller unit.

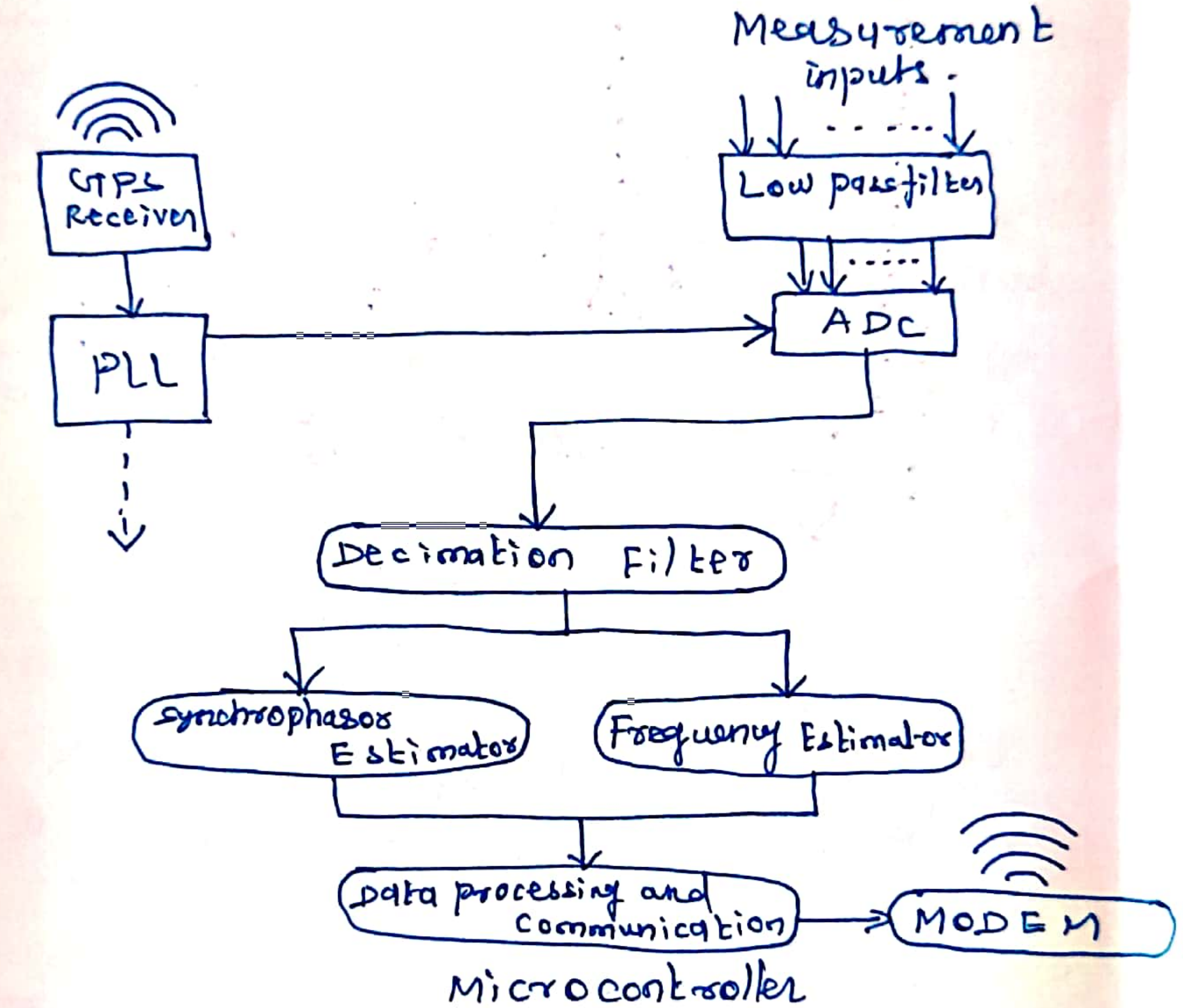

Fig. Hardware structure of PMU.

* The measured and processed data are arranged with time stamps generated by GPS signal and transmitted to receivers by modem section.

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Applications of PMU in Transmission system.

(i) wide area situational awareness and monitoring.
(ii) voltage stability and monitoring.
(iii) state estimation.
(iv) Fault location identification and protective relaying.

2.6 Intelligent Electronic Devices.

In electric power industry, circuit breakers, transformers and capacitor banks are operated by microprocessor based controllers. Such controllers are called as intelligent Electronic devices.

Block diagram of Intelligent Electronic Devices (IED)

An IED consists of three major blocks namely,

(a) signal processing Unit
(b) Microprocessor
(c) Communication Interface.

Signal processing Unit

→ It receives data from sensors and power equipment for executing the control commands on the power system.

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→ The sensed signals are used for tripping of circuit breakers based on voltage, current or frequency deviation. Commonly available intelligent electronic devices are,

(i) Protective relaying devices
(ii) On load tap change controllers.
(iii) Circuit breaker controllers
(iv) Capacitor bank switches
(v) Voltage regulators
(vi) Recloser controllers.

(b) Microprocessor and communication Interface:-

→ Since IEDs are microprocessor based devices. It has the ability to exchange data and control signals with other devices like IED or SCADA.

→ The exchange of data takes place through communication link.

Application of IED:-

(a) It has the ability to perform monitoring control and data acquisition in a power system.

(b) It is used for substation automation and integration.

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(c) It improves the reliability and operational efficiency of a power.

(d) It performs several protective and control functions.

2.7 Application of IED :-

Smart Monitoring system :-

→ The key component for grid monitoring that is based on time - synchronized measurement is WAM.

→ The improved features of WAMS are defined as wide area monitoring protection and control (WAMPAC) is shown in fig.

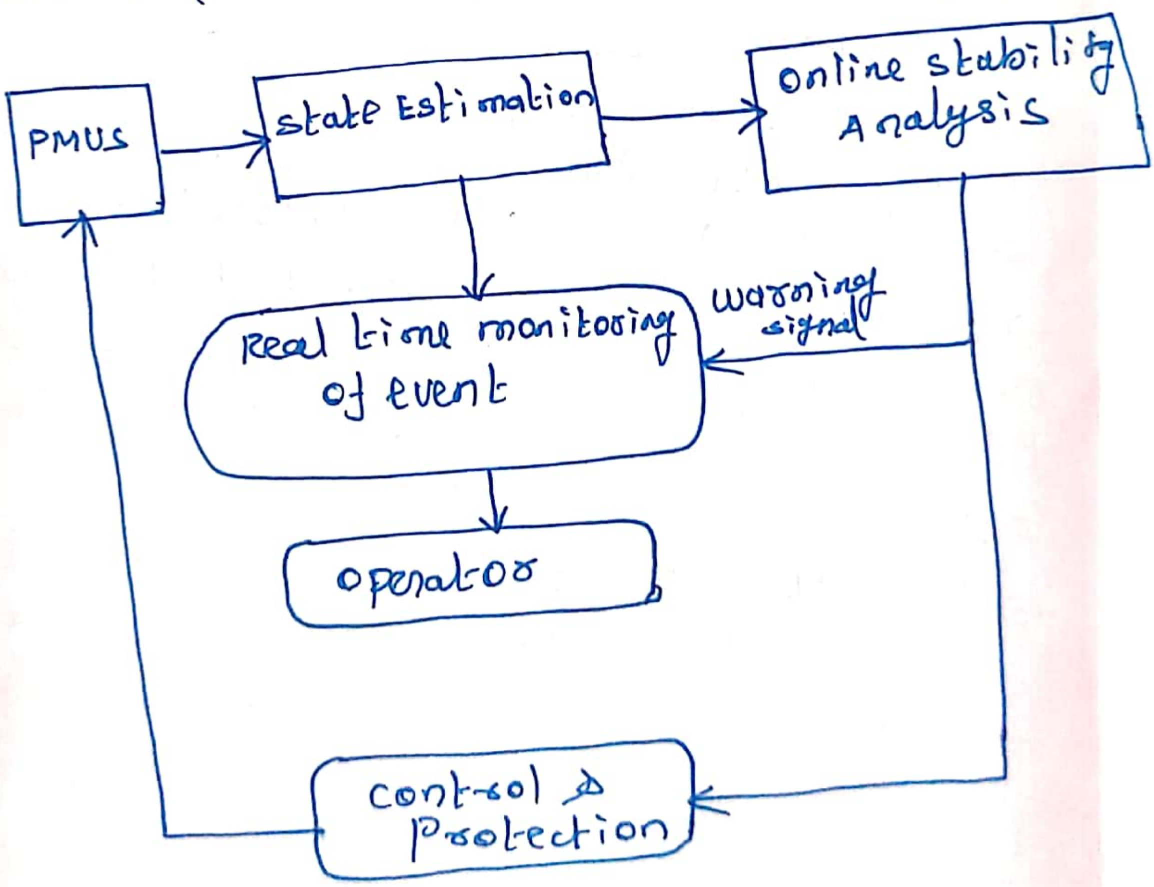

Fig. structure of WAMPAC.

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Need for monitoring of Smart Grid :-

→ To detect critical conditions

→ Diagnostic and trouble shooting.

operations :-

→ The utility network is monitored based on the fundamental bus voltages and current measurements in phasor type data.

→ such data is used to compute the phasor differences, frequency and power factor parameters.

→ The PMU measurements collected from the different part of the network and state estimation are used for online stability Assessment algorithm

→ If instability is predicted then the necessary corrective actions to correct the problem or to alert system collapse are taken.

→ Finally the control and protection commands are provided back to PMUs using a WAMPAC system.

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Integration of RES in smart Grid.

→ A large integration of RES and storage systems are required by Smart grid is shown in fig.

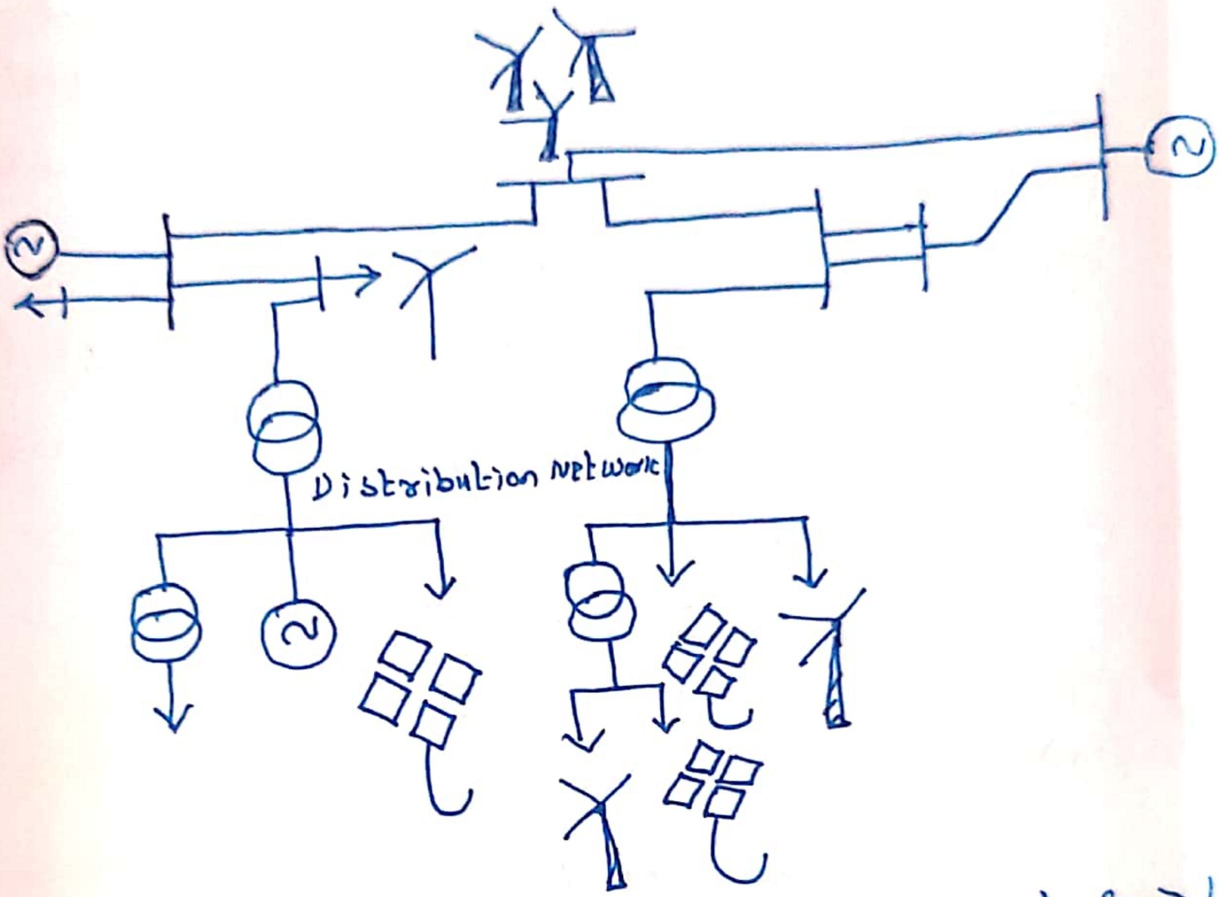

Fig: Integration of RES in smart Grid.

→ Smart grid comprises RES based systems in its infrastructure.

→ The reliable operation and distribution of generated power makes the smart grid to be self healing against power system faults

→ The integration of RES to utility network makes the system to be intermittent at times.

→ Due to this the power generation is affected.

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→ Thus for ensuring a healthy operation of grid RES integrations have to be disconnected under fault occurence.

→ The fluctuations in generations are to be managed by EMS and DMS systems.

→ At substation level an advanced monitoring system provides control signal to curtail power fluctuations caused by RES structure.

Monitoring structure of smart Grid:-

The monitoring architectures are categorized as

(i) Local monitoring
(ii) Centralized monitoring
(iii) Substation monitoring.

(i) Local Monitoring:-

→ Transformer monitoring, feeder and asset current measurements and fault passage indicators (FPI) are monitored locally by SCADA systems

→ Thus fault detection data is acquired and used for warning the system during faulty conditions.

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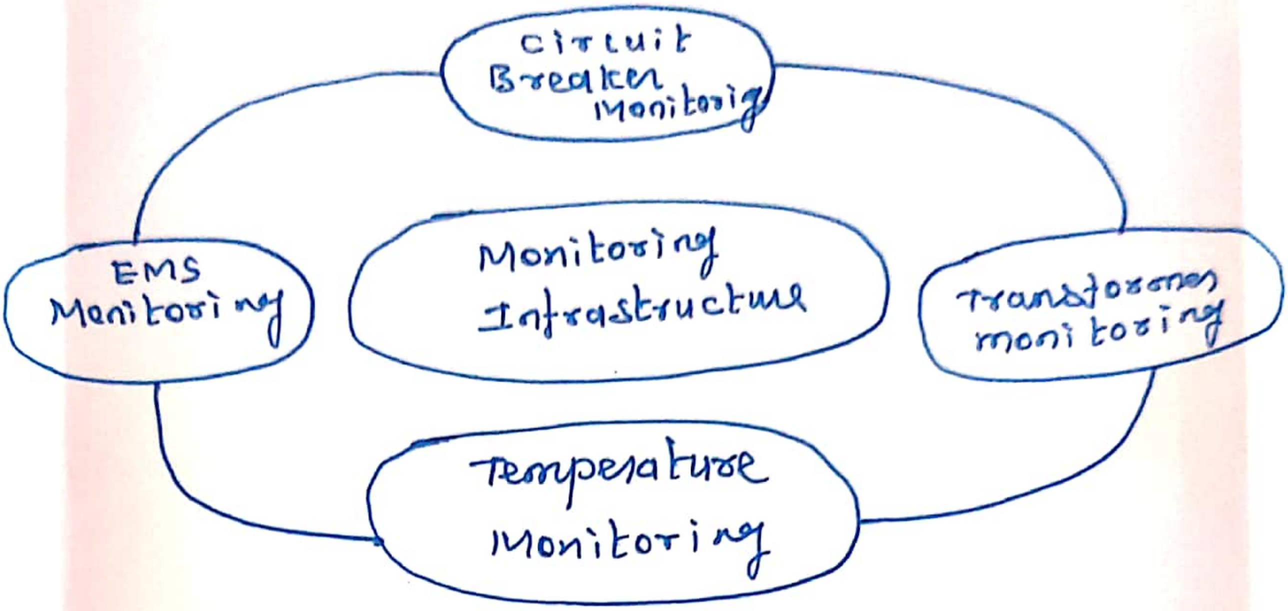

Fig. Monitoring Infrastructure of smart grid.

Centralized Monitoring :-

→ A central data base holds the acquired data for real time monitoring as well as for analyzing monitoring requirements.

Substation Monitoring :-

→ In This the smart sensors are arranged hierarchically to interact with gate ways are used for controlling the systems.

UNIT-III SMART GRID TECHNOLOGIES
(TRANSMISSION)

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3.1 TECHNOLOGY DRIVES

The following are the key factor for technology drivers.

(a) Deficiency in automated analysis.

(b) slow response caused by mechanical devices.

(c) Ignorance of situational awareness etc.

Technology Drivers Required for Smart Grid :-

To satisfy the multiple requirements of the smart grid, the following technology drivers must be developed and implemented

(i) Information and communication technology

(ii) Control and automation technologies which includes sensing and measurements.

(iii) Power Electronics and energy storage technology.

(iv) Demand side Management (DSM)

(i) Information and Communication Technology :-

→ It operates in two ways.

→ Provides connectivity between different element in the power system and loads.

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→ Broad construction for plug and play home devices, electric vehicles and micro generation.

→ It helps the customers to trade in energy market.

→ Enable customers to provide DSM.

(ii) Control and Automation Technology.

→ It includes sensing and measurement

→ It also includes

(a) Intelligent Electronic Devices (IED)

(b) phasor measurement Unit

(c) wide area monitoring, Protection and control (WAMPAC)

→ To take timely corrective action it uses

(i) control and automation system

(ii) Integrated sensors

(iii) Measurements and communication technologies.

→ smart appliances, communications controls and monitors help to increase safety, comfort convinience and energy saving.

→ Smart meters, communication, displays and relevant software will give access to customers.

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Power Electronics and Energy storage :-

It includes,

(a) HVDC Transmission and flexible AC Transmission (FACTS) - more possible long distance transmission.

(b) Unified power flow controller (UPFC), series capacitors and other FACTS devices will offer excellent control over power flows in the AC grid.

(c) It gives better performance by controlling renewable energy sources, consumer loads and energy storage.

(d) It increases the flexibility and reliability of the power system.

1. Demand side Management :-

"Demand side management (DSM) "Demand is the modification of consumer demand for energy through different methods like financial incentives and behavioral changes by means of education.

Aim of Demand side Management :-

→ To motivate the consumer to

(i) Utilize lesser energy during peak hours.

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(ii) To move the times of energy use to off peak times such as night time and week ends.

(iii) Use of energy storage units to store energy during off peak hours and discharge them during peak hours is the best example.

1. Application of DSM :-

(i) It helps the grid operators for balancing intermittent generation from wind and solar units.

(ii) It is used to produce electricity very economical manner.

Categories of DSM :-

(a) Direct Control of Load :-

→ This makes use of communication system like power line carrier to transmit control from the utility side to the customer.

→ The goal to have direct control of load, generators and storage.

2. Local Load control option :-

→ This authorizes the customers to self adjust loads to limits peak demand.

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→ Eg:- Demand activated breakers. Load interlock, timers, thermostats, occupancy sensors, cogeneration etc.

3. Distribution Load control:-
The utility controls the customer loads by sending real time prices.

Constraints of DSM:-
1. Technological constraints
2. Economic constraints
3. Social constraints
4. political and Institutional constraints.

3.2. SMART ENERGY RESOURCES.

Definition:-
"smart energy resources defined as the new set of resources available to utilities balance the supply demand equation renewable generation, energy storage and consumer demand management."

Types of smart energy sources:-
some of the most common renewable energy resources are as follows,

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(i) solar pv
(ii) solar thermal energy
(iii) wind energy
(iv) Biomass and biogas
(v) Geo thermal power
(vi) Hydro power
(vii) Fuel cells
(viii) Tidal power.

(i) solar pv system :-

→ solar pv generation has experienced an enormous growth in recent decades

→ In pv generation when solar panels are being exposed to light they will generate electric power.

→ Power generated is dependent on the conversion of the energy of the radiation of sun.

→ When solar cell is exposed to light electrons flow takes place and it causes the flow of Direct current.

(ii) Wind Energy

→ wind power is harnessed by means of wind turbines to convert the energy of the wind into electricity.

→ The kinetic energy of wind is being converted into mechanical energy and then mechanical energy is converted into electricity.

→ The wind turbine is stopped, if the power from the wind turbine is nor used.

→ The excess power generated may be used to charge an energy storage system.

(iii) Bio Mass and Bio gas :-

→ It referes to the power production from dead trees, wood chips, plant or animal matters.

→ It is used for production of chemical or heat.

→ The technologies linked with biomass conversion to electrical energy consists of (a) Utilizing energy in the form of heat

(b) converting them into other forms like combustible biogas or liquid bio fuel.

(iv) Geo Thermal power :-

→ Geo thermal power is derived from the earth through natural processes

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→ Some of the technologies that are used today includes,

(i) Binary cycle power plants.
(ii) Flash stream power plant
(iii) Dry stream power plants.

→ It offers very low thermal efficiency
→ But the capacity factor will be close to 95%.

(v) Hydro power :-

→ Hydro power utilize the energy of the moving water as the main source for electric power production.
→ when the falling water hits the blades on the rotor this will cause the rotor to turn thus producing electricity.

3.3 SMART SUBSTATION, SMART AUTOMATION:-

Smart substation is a key component of a smart grid, which uses the three layers and two networks architectural framework to enable substation information

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digitization and advanced application functions.

→ The 'three layers' refers to the equipment configurations of station control layer, bay layer, and process layer. Although the smart substation solves such issues as digital information sharing and collecting equipment reconfigurations, its overall construction concept, technology innovation, design optimization, standard setting, and economy require further improvements, particularly with respect to dispersion of many system functions within the smart substations. This problem is mainly reflected in devices related to substations protection, measurement, control and data collection.

→ Moreover, there are different types of intelligent devices in large quantities, which lead to many challenges in the commissioning, operation and maintenance of those devices.

What is substation Automation?-

Substation automation is a system to enable an electric utility to remotely monitor, control and coordinates the distribution components installed in the substation.

Benefits of substation Automation system.

-> Automatic supervision of interlocks
-> Graphical presentations of safety procedures.
-> Local & global alarm & warnings.
-> Detect fault location.
=> Equipment diagnostics
-> Intelligent interlocking system
-> Diagnostics of disturbances

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→ Functionality optimization and technology integration, wherein information is concentrated in a substation hardware, platform to achieve optimal substation protection control, thus has become a trend in substation automation.

→ This integration enables a substation to identify faults more quickly and accurately, thereby providing more reasonable protection and control strategies for the power system.

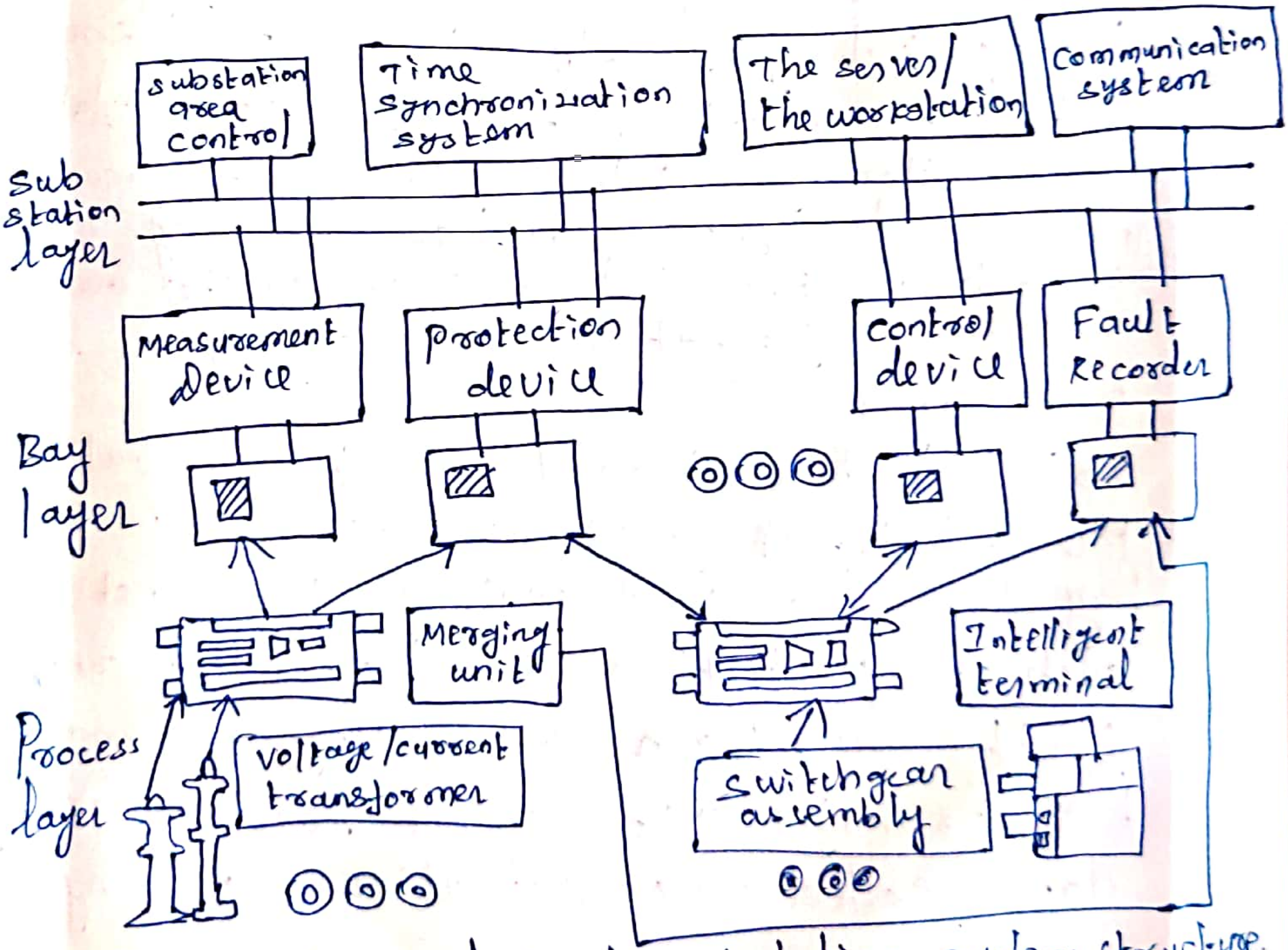

Fig: Traditional smart substation system structure.

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Substation Layer:-

→ In substation layer devices are for monitoring, misoperation, remote communication, time synchronization, condition monitoring and online decision making subsystem.

→ Substation layer mainly provides man-machine contact interface, forming all equipment operation control and management functions of the substation.

→ At present, the station control layer faces some problems which are mainly manifested, To solve this problem, we establish an integrated information platform for monitoring, interlocking, condition monitoring management systems, video security etc. to achieve the integration of the overall station information monitoring.

Bay Layer:-

→ In a traditional smart substation, the intelligent electronic devices in the bay layer are used mainly for functions such as protection, measurement, control, fault waveform recording, automatic bus transfer, low-cycle load dropping, data collection, calculation and priority control.

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→ These functions help to complete the real time data acquisition from the process layer and communication with the substation layer.

Process layer :-

→ In traditional smart substations, the intelligent terminal(IT) and the merging unit (MU) are the main equipment of the process layer.

→ IT is used for device status acquisition and remote command execution.

→ MU is mainly used for digital consolidation, processing and protocol conversion functions.

Thus, smart substations offers a better information platform for integrated technologies, but also promote the development for integrated protection and control theories as well.

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3.4 Feeder Automation :-

Electrical feeders are an important part of electrical engineering panels. Electrical panels come in different categories like control panels, PCC panels, MCC panels, etc. They have a large number of electrical components which help in managing the control of the electric power supply properly.

PCC - Power control centre
MCC - Motor control centre

→ A Feeder is an electrical distribution network system, which does the job of supplying power from a main source to various loads requiring electricity.

→ Electrical power from a main transformer or substation is fed to an electrical bus bar of a feeder panel. This busbar distributes three phase supply to various small cabinets, requiring power.

→ The electrical cabinets have control circuits in them which are used to supply power in a controlled manner to various loads like motors, lighting, industrial machinery, PLC control panels, etc.

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→ This means, each cabinet housing is connected to a corresponding electrical load and these loads get power from the busbar which has supplied mains power to their corresponding cabinets.

→ Feeder Automation Definition

Feeder automation normally involves installation of sectionalizing the devices and switches along the feeder.

Layout of Feeder automation:-

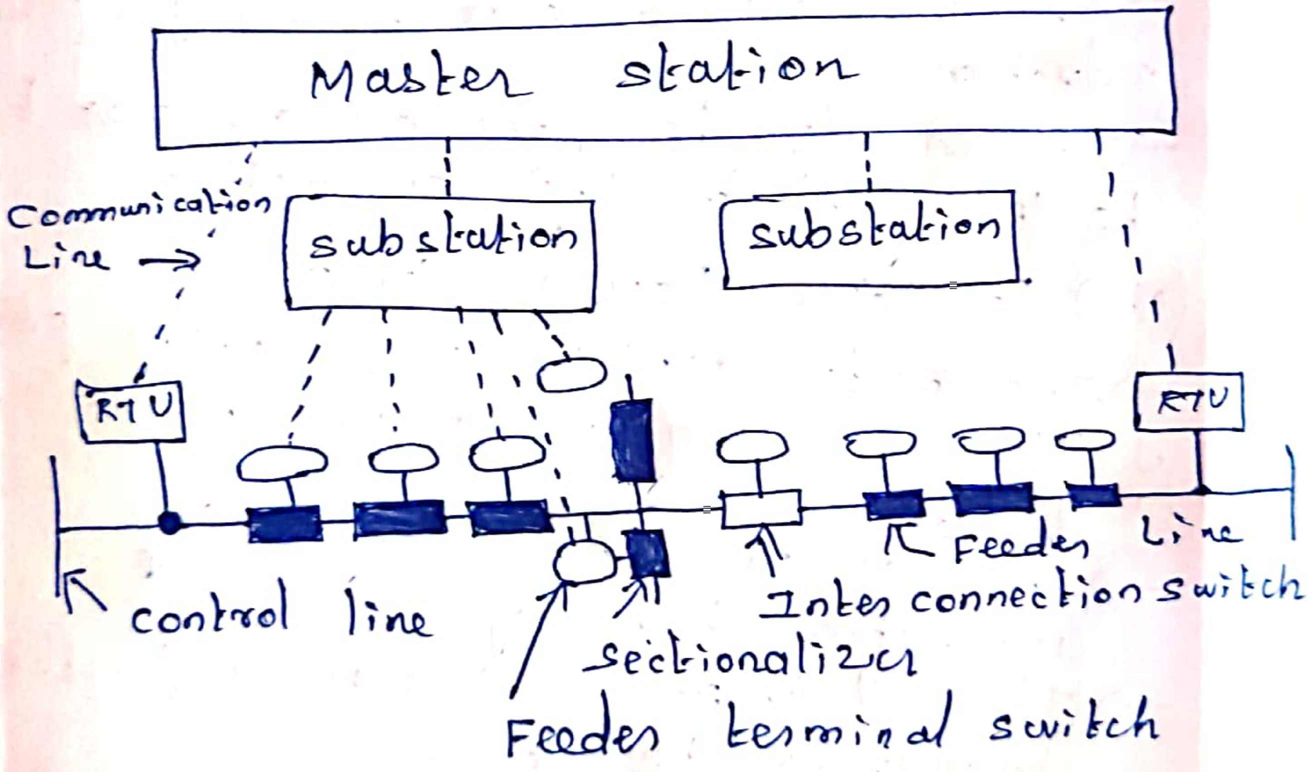

Fig. Feeder Automation Layouts.

There are three utilities are involved in feeder automation. They are,

(a) voltage Control
(b) Reactive power control
(c) Fault detection, Isolation and Restoration.

(a) voltage control

→ Utilities can have effective control of the load which can be achieved by controlling the voltage at the feeders.
→ This is done on peak times for peak load reduction.
→ It can also be done on off peak times to lessen electricity consumption.

(b) Reactive Power Control:-

→ Inorder to achieve near unity power factor, the reactive power must be very low.
→ This can be achieved by using automation technologies.
→ It will improve the power factor and reduces the losses.

(c) Fault Detection, Isolation, Restoration (FDIR)

→ It is used to ensure the reliability of the system.
→ It automatically detects the disturbance

and locates it.

→ Then the system will disconnect the faulted segment by opening the switches on either side of fault point.

Functions of Feeder Automation:-

The following are the chief function of feeder automation.

(i) Fault identification, faulty part Isolation and service restoration.

(ii) Network reconfiguration.

(iii) Load management demand response.

(iv) Active and reactive power control.

(v) Power factor control

(vi) short term load forecasting.

(vii) three phase unbalanced powerflow etc.

Advantages of feeder Automation:-

(a) Faulty points can be easily identified

(b) Quick service Restoration.

(c) Voltage profile can be improved

(d) power transfer can be improved

(e) Maintains the power factor nearly to unity.

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3.5 Transmission Systems :-

The transmission system can be categorized into three namely,

(i) Energy management system (EMS)
(ii) FACTS and HVDC
(iii) Wide area monitoring protection and control (WAMPAC)

→ The transmission systems are automated all over the world. However, due to the ever increasing power demand with the networks getting larger, the complexity of operation is challenging. The distances between bulk generation and load centers are widening, and at the same time the challenges of integrating large-scale renewables has added additional constraints to the transmission system. SCADA systems are not enough for effective monitoring in times of worst contingencies.
→ So the focus is turned on phasor Measurement Units (PMU) and the Broader Wide-Area Monitoring and Control systems (WAMS). Because they ensure security and allow the transmission network to operate closest to its capacity. Smart transmission has become the integrated

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part of smart grid technology.

→ with the invention of more advanced technologies, such as FACTS and HVDC, transmission system will have efficient power flow control and enhanced stability.

→ Transmission network expansion projects will concentrate on renewable generation to densely populated regions of the country. Also monitoring and control requirements for the distribution system will increase.

→ The centralized functions and decisions are available at the Energy Management System (EMS) and Distribution Management System (DMS). From EMS and DMS, data moves to substations and feeders. This significantly improves responding nature of the transmission and distribution system.

→ To ensure system-wide reliability, efficiency, and security, the distributed intelligence in the substations and feeders in the field operate in line with each other.

→ As the number of sensors increase, smart grid technologies will lead to a huge volume of real time and operational data to be managed effectively.

→ Intelligent devices carry out real-time pricing and consumer demand management. This kind of advanced data analytics and forecasting of the electricity will help the consumers to have real time consumption of electric power.

3.5.1 Energy Management System (EMS)

→ The energy management system is a very important function necessary to increase energy efficiency and to provide the excellent coordination between multiple energy sources. It also plays a very important role in smoothening the problems related to power quality, grid failure and plugged integration of ~~hyd~~ hybrid vehicle.

Typically an EMS should have the following:-

1. Monitoring and controlling of complete system including the parameters of the power system with its interconnections is absolutely necessary.
2. Capturing the real time analog and digital data from the field quickly.
3. Measured data must be validated properly.

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4. Control commands should be sent to the field devices and other associated systems whenever the need arises.

5. operating the system within safe limits by tracking the instantaneous load generation balance and ensuring system security

6. Ability to take preventive action with the awareness of potential risks.

7. The ability to start restoration after an emergency in the system or a state change.

→ Thus, the objectives of EMS is to provide stable, reliable, secure and optimal power to consumers efficiently and economically. The EMS frame work is shown in fig. which includes the transmission operation management in coordination with generation operation management.

→ Every major energy control center will have a dispatcher training simulator as depicted in figure. Here the operators will analyze past disturbances and generate real-life scenarios for study purposes.

Each subsystem in EMS has the functionalities

Generation operation management

1. Load forecasting 2. Unit commitment

3. Hydrothermal coordination (HTC)
4. Real time economic dispatch and reserve monitoring (ED)
5. Real time automatic generation control (AGC)

Transmission operations management:

Real time:

1. Network configuration / topology processor (TP)
2. state estimation (SE)
3. Contingency Analysis (CA)
4. optimal power flow and security constrained optimal power flow (OPF, SCOPF)
5. Islanding of power systems.

Study Mode simulations,

1. Power flow (PF)
2. short circuit analysis (SC)
3. Network modeling.

Energy Services and Event Analysis:-

1. Event analysis
2. Energy scheduling and accounting.
3. Energy service providers.

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Dispatcher Training Simulator (DTS)

Dispatch of information:-

→ The power system operations are performed in three time frames. The real time operations are the most critical ones. In this the operator is assisted by the EMS functionalities to take appropriate control actions.

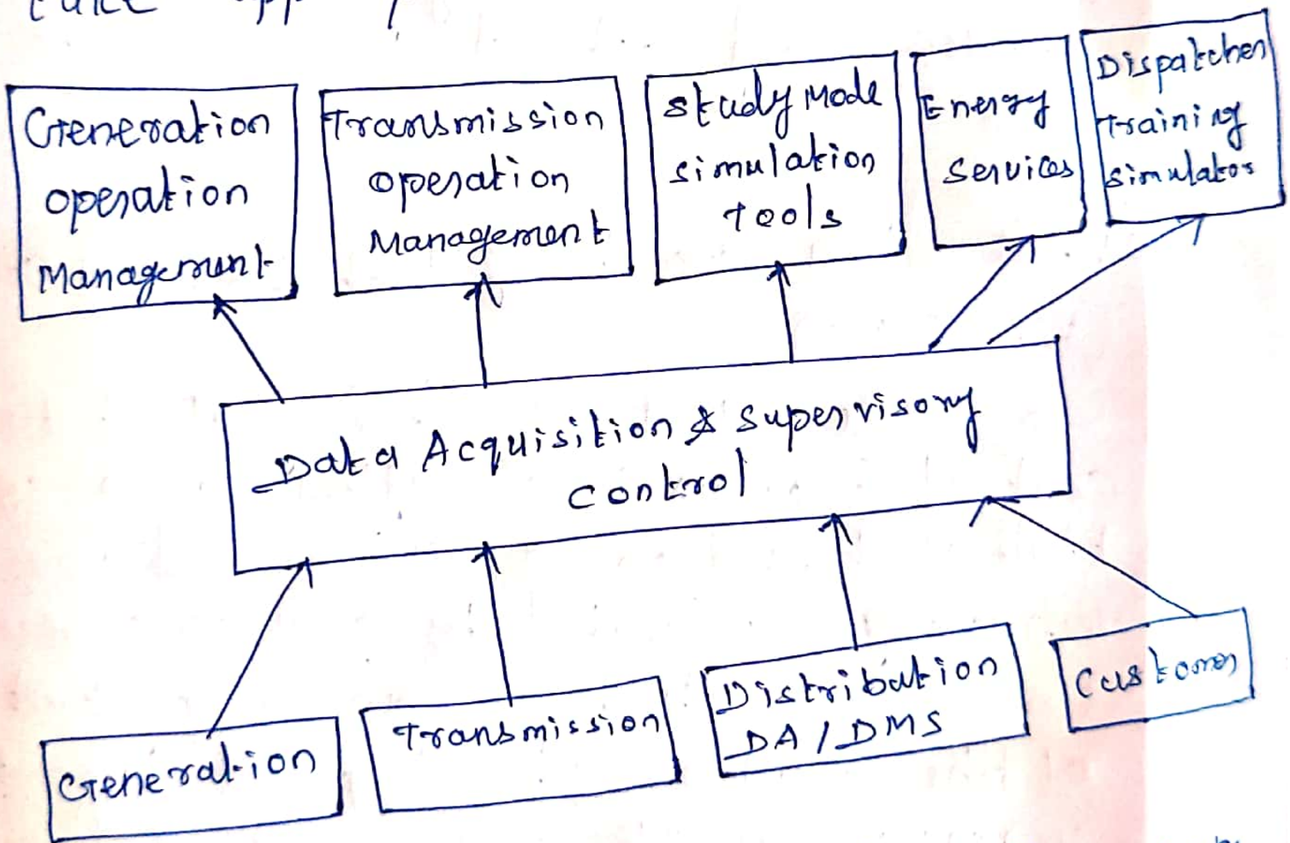

Fig. Energy Management system Frameworks.

→ A series of post-event analyses are done to calculate the energy transactions and cost of production. This will help to asses the causes of system contingencies.

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→ These important functionalities will be classified in three time frames namely real-time operations, pre-real time and post-real-time analysis.

→ It is to be noted that some of the EMS functionalities are performed offline in study mode, as well as real time mode like contingency analysis, power flow analysis, and optimal power flow to help the operator.

3.5.2 Wide-Area Monitoring Protection and Control (WAMPAC)

→ Wide area monitoring, Protection and Control (WAMPAC) is defined as a system that is based on synchronized Measurement Technology represented by Phasor Measurement Units (PMU) which is an important part of the solution. The typical layout of WAMPAC with many PDCs (phasor data Concentrator) is shown in the Fig.

→ WAMPAC is nothing but time synchronized measurements. Their locations are completely scattered and over spread in an electric power grid.

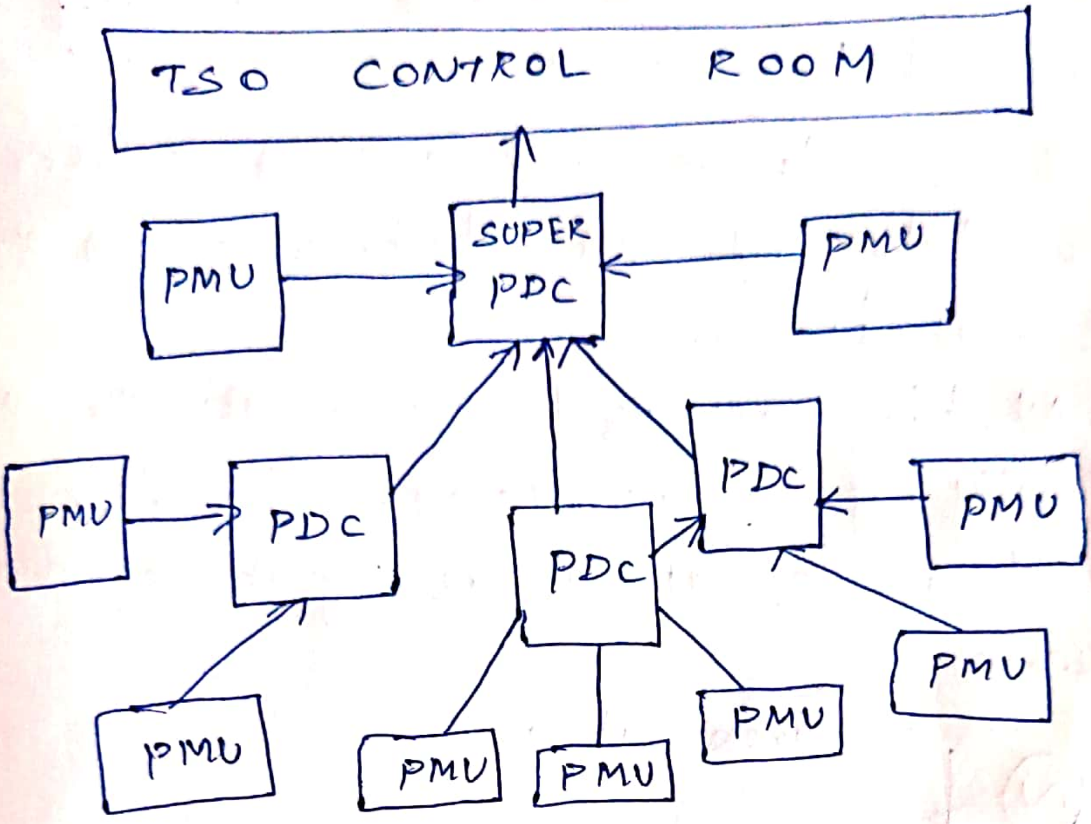

Fig: Typical layout of WAMPAC.

→ WAMPAC systems are configured upon the synchronized sampling of power system currents and voltage signals as shown in fig.

* A common timing signal which originate from GPS synchronizes them with the power grid. The sampled signals are converted into phasor or vector representations of the grid's voltage and current measurements at fundamental frequency.

* An accurate GPS time reference compares these synchronized signals effectively and

thoroughly across the electrically connected power system.

* Bus voltage and current phasor indicate the state of an electric power grid in real time.

* All the processed information's are finally given to TSO (Transmission system operator) as input for necessary action.

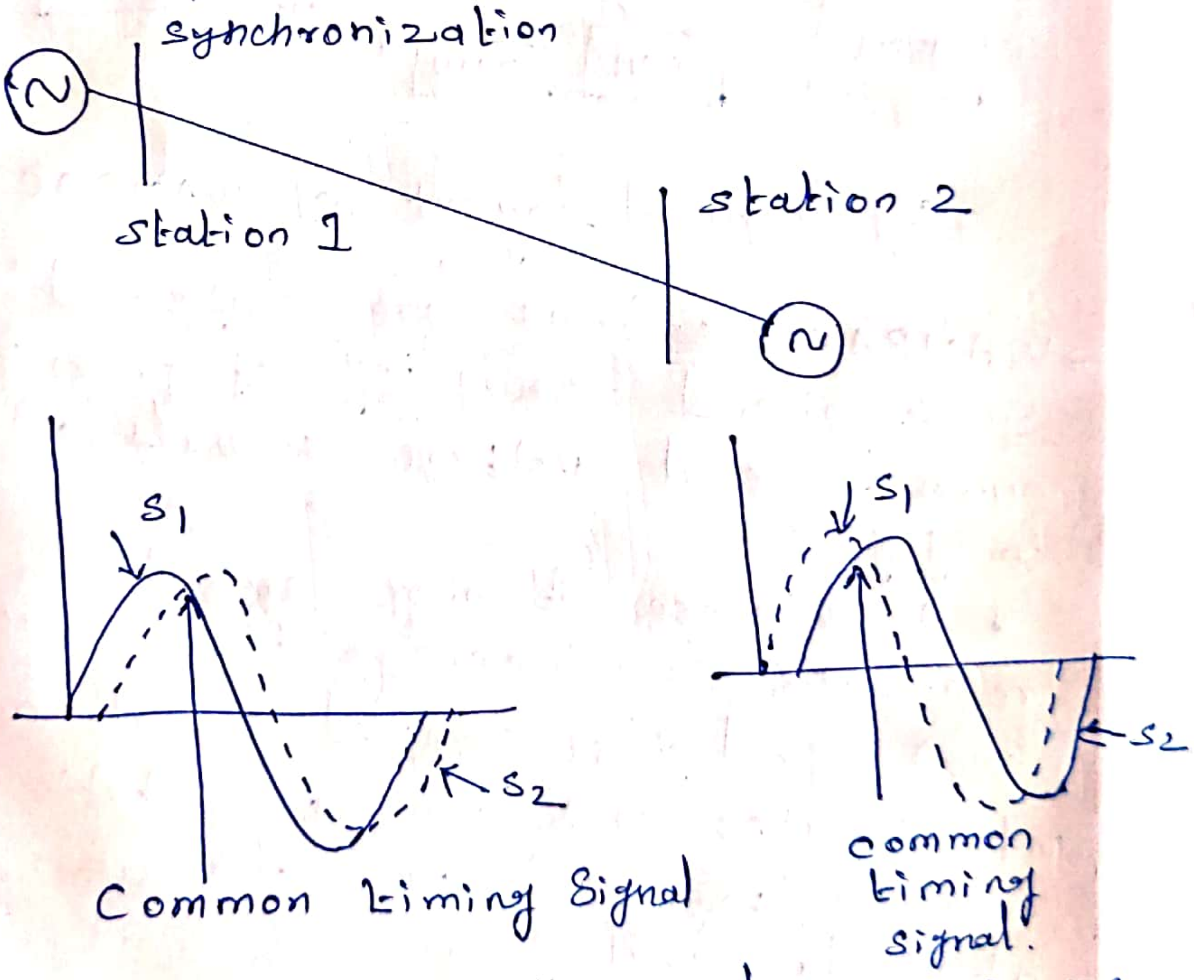

Fig: synchronized sampling of power system signals.

Phasor Measurement Unit (PMU)

→ The PMU is also known as a synchrophasor. It is the basic building block of a WAMPAC system. The diagramatic representation of PMU is shown in the fig.

→ The power system signals are obtained from voltage and current sensors. These signals are sampled by the PMU and converted into phasors.

→ They are generally used in the design, control and protection of power systems for bulk power transmission.

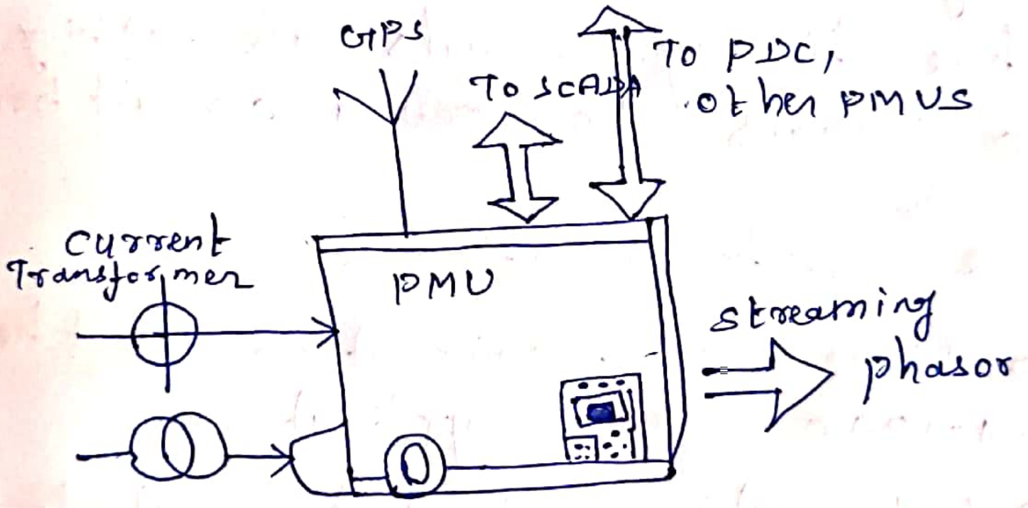

Fig: Phasor Measurement Unit (PMU)

→ When the timing pulse is obtained from the GPS, then the phasor is time tagged and then streamed into the wide area communications network.

→ GPS timing pulse interrelates with the phasor angle information. Because of this interrelationship, the information will be physical significance. It must be compared with other phasor angle measurements from the same system.

→ The condition of the system and other valuable information like oscillatory disturbances will be informed by the difference in the phasor angle.

→ Many of the PMUs output will have binary modeles for transmitting binary signals

→ These binary signals are nothing but trip signals to open a circuit breaker.

Time synchronization :-

→ Time synchronization is the heart of WAMPAC based applications.

→ Information about the details of protection, controlling and monitoring the electrical network will be taken care by each PMU. Normally, it takes nanoseconds to microseconds for time synchronization requirements.

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The typical time synchronization is depicted in fig.

→ A common source clock signals controlls all methods across the network. This control action is carried out by satellite through the communication network or using synchronization networks that operate independently. Because of this temporary loss of the synchronization signal is totally avoided in the signal transmission processes.

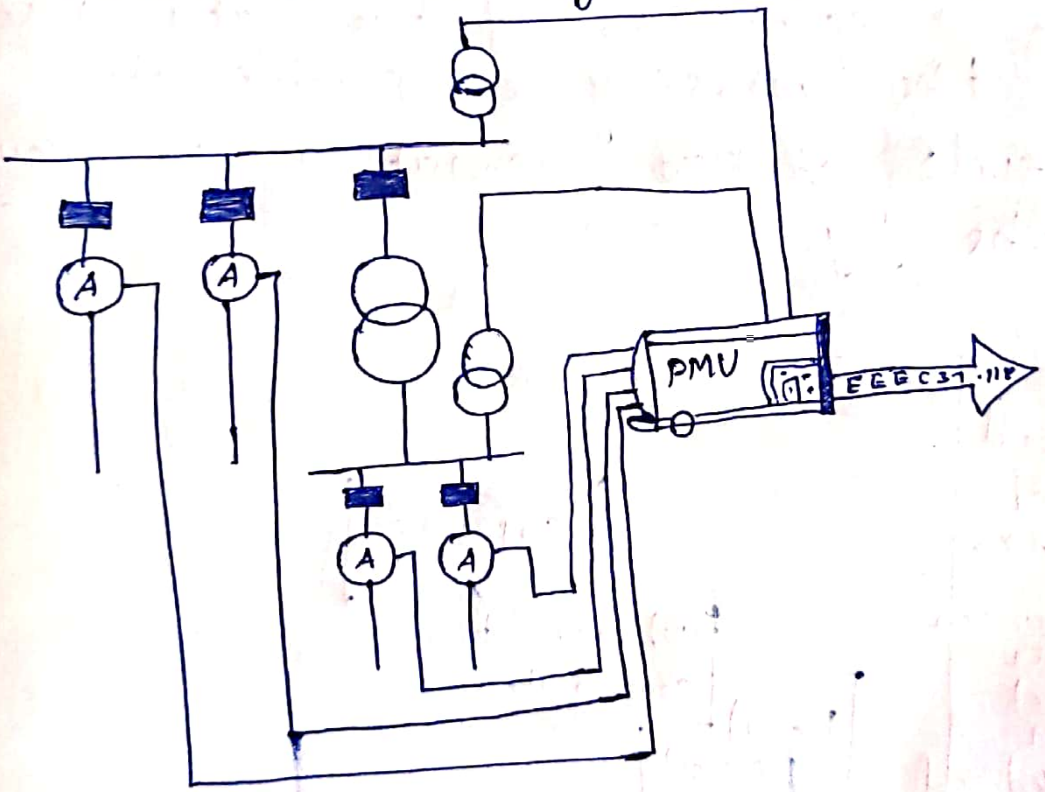

Fig: Time synchronization.

Phasor Data Concentrator (PDC)

→ A phasor data concentrator collects phasor data from multiple PMUs or other PDCs and aligns the data by time tag. It formulates a synchronized dataset, and then transfers the data to application processors

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→ For application that process PMU data from the grid, it is essential that the measurements are time aligned and grounded on their original time tag to create a system wide, synchronized snapshot of grid conditions.

→ A PDC also performs data quality checks that will ensure the integrity or completeness of the data. Also it flags all the missing or problematic data. Levels of PDC operation is shown in the fig.

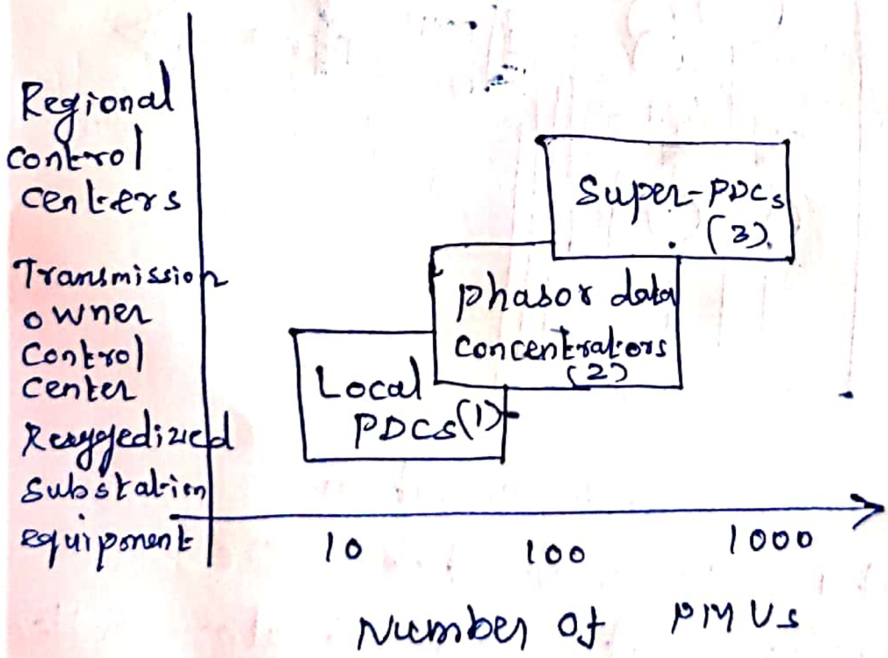

Fig: Levels of PDCs

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There are levels of PDCs

1. Local or substation PDC Level
2. Control center PDC Level
3. super PDC level.

→ PMUs make use of various data formats, data rates and communications protocols, for streaming data to the PDC.

→ The PDC supports such kind of different formats in the input side. In addition to that, it must be able to sample the input streams to a standard reporting rate and process the different datasets into a general format output stream.

1. Local or substation PDC :-

A local PDC is generally placed near the substation. It communicates with various PMUs to collect and manage information within the substation or other substations which are located closely with each other.

→ The collected information is time synchronized dataset. This data set will be sent to higher level concentrators at the control center.

→ It is widely used for local substation control operations.

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2. Control center PDC.

→ It collects data from individual utility's PMUs and substation PDCs, If needed, it also collects data from neighbouring utility PDCs.

→ In a time synchronized manner they will be sending multiple output streams to different applications like visualization, alarms, storage and EMS applications.

3. Super-PDC

→ A super-PDC works on a larger, regional scale. It takes the responsibility for collecting and correlating phasor measurements, from several hundreds of PMUs and multiple substations and/or control center PDCs.

→ It additionally takes responsibility to exchange data between utilities by channeling the PMU. Not only it supports applications such as EMS, visualization, wide area monitoring system (WAMS), and SCADA applications, but also it collects enormous amount of data, normally several terabytes per day.

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The following are the chief advantages of WAMPAC :-

1. Reliability, stability and security is maintained against large disturbances.
2. Large number of intermittent generating sources like solar, wind etc. are managed properly.
3. Power quality is maintained to better level.
4. Transmission efficiency is increased.

The main works carried out by WAMPAC are the following.

1. Monitoring of voltage phase angle difference.
2. Monitoring of thermal limits of the line.
3. Voltage stability monitoring.
4. Monitoring of power system damping
5. Online monitoring of system loading.

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UNIT - IV

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4.1 DMS (Distribution Management System)

A DMS is a collection of applications incorporated to monitor and control the whole distribution network efficiently and reliably. It works as a decision support system to help the control room and field operating engineers with the monitoring and control of the electric distribution system. It helps to enhance the reliability and quality of service in terms of reducing outages. while minimizing outage time, it maintains acceptable frequency and voltage levels. These are the key achievements of a DMS. Inorder to support proper decision making activities, DMS shall have the following functions:

4.1.1. Network connectivity Analysis (NCA)

→ Distribution network normally encompasses over a large area and serves power to different customers at different voltage levels. Network Connectivity analysis is an operator dependent functionality which helps the operator to fix or locate the preferred network or component in a quicker way. NCA does the necessary investigation and provides display of the feed point of different network loads.

→ The network is modeled depending upon the condition of all the switching devices such as circuit breaker (CB), Ring Main Unit (RMU) and isolator. In addition to that the NCA further helps the operator to know the operating state of the distribution network which indicates the loops and parallels in the network.

4.1.2. State Estimation(SE):-

→ Power system state estimation is a method where data are telemetered from network measuring points to a central computer which can be formed into a set of reliable data for control and recording purposes.

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→ In power networks, state estimation absorbs observable data from the field and gives a model of what is actually happening. It is achieved by processing the data to indicate inaccurate readings or to estimate missing data.

→ In a distribution network, the data quality that is telemetered will be imperfect because of the presence of noise. Problems in electronic devices and in the communications networks suggest that prior to conducting an analysis, preprocessing of data is compulsory to eliminate the bad data points.

4.1.3 Load Flow Applications (LFA)

→ Load flow study is an essential tool which involves application of numerical analysis to the power system. The chief aim of power flow study is to obtain the details of voltage magnitude, phase angle, real power and reactive power information for each bus in the

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power system for specified load conditions.

→ Load flow is highly nonlinear problem with a lot of constraints. So numerical methods are applied to obtain a solution which lies within acceptable tolerance.

→ Load flow or power flow studies are significant for future planning and expansion of power systems as well as in determining the optimal operation of existing systems.

4.1.4 Load shedding Applications (LSA)

→ Distribution load shedding and restoration schemes plays a significant role in control and emergency operation in any utility.

→ It not only reveals the emergency situation but also performs necessary predefined control actions, like opening, closing of non critical feeders.

→ It determines the sources of injections and performs a tap control at transformers.

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4.1.5 Load Balancing via Feeder

→ Load balancing via feeder reconfiguration is an important application for utilities where they have multiple feeders feeding a congested area.

→ The Feeder load Management (FLM) is required to permit the operator to manage energy delivery in the electric distribution system and identify problem sensitive areas.

→ The Feeder load management observes the vital signs of the distribution system and indicates areas of concern so that the distribution operator is warned in advance and can effectively focus his attention where it is most needed.

→ It permits for quicker correction of existing problems and makes possibilities for problem avoidance. This will result in both improved reliability and excellent energy delivery.

→ Feeder reconfiguration is also used for loss minimization.

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4.1.6. Distribution Load Forecasting (DLF)

→ Distribution Load forecasting (DLF) offers a structured interface for creating, managing and analyzing load forecasts.

→ DLF provides data aggregation and forecasting capabilities that is created not only to address today's requirements but also to address future requirements. DLF has the capability to produce repeatable and accurate forecasts.

4.2 VOLT / VAR CONTROL (VVC)

VVC governs two important objectives namely distribution substation switching and feeder voltage regulation equipment with the help of capacitor bank.

→ The first one is to reduce the VAR flow on the distribution system and the second one is to maintain voltage at the customer delivery point within required limits.

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Components of VVC are as follows.

4.2.1.1 VAR control, VAR compensation, pf correction:-

→ substation and distribution feeder Capacitor banks are utilized to reduce the VAR flow, which will improve the power factor on the distribution feeder during all load levels.

→ The distribution system losses are reduced because of optimal VAR flow.

4.2.2. Conservation voltage Reduction (CVR)

→ The distribution feeder voltage regulators and substation transformer load tap changers (LTC) are controlled by CVR.

→ Because of this customer delivery voltage is minimized within specified and safe margins point during peak periods of load at the customer service.

→ sometimes during base loading period CVR may also be incorporated to enhance voltage stability.

4.2.3 Integrated Volt/VAR control (IVVC)

→ IVVC is the integration of VAR flow and CVR to minimize losses in the distribution feeder. It also controls the voltage profile of feeder. This will reduce system losses and may improve the quality of voltage supplied to the customer.

→ It also include capacitor bank troubleshooting is minimized.

4.2.4 Volt / VAR optimization (VVO)

→ VVO deals with the capability to optimize the objectives of VAR loss minimization and reduction in load with voltage constraints by means of optimization algorithms.

→ These objectives are restrained by various constraints through decision making process either in a centralized way or decentralized way.

→ At every level of transmission and distribution system electrical losses, cannot be avoided due to the presence of electrical impedance which includes both resistance and reactance of the equipment.

→ Generally VAR flow happens in the system due to flow of current through equipment on the system which is inductive in nature, such as transformers and transmission lines, and also by the nature of load.

→ To reduce the VAR flow in the system, capacitance in the form of capacitor banks are connected to the system.

4.2.5 Volt/VAR optimization and the Smart Grid :-

→ As the power system is faced by complexities differing radically, VVO helps the distribution organizations to function their systems with their limits. These complexities include increase in renewable generation placed at distribution voltage levels. The essential data sharing between the enterprise applications is enabled by smart grid.

→ The very fast growth of renewable generation and energy storage system in the future years with smart grids will introduce huge challenges. The tendency to reach overvoltage conditions will increase because of them in the distribution system.

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4.3 Fault Detection, Isolation and Service Restoration.

→ Fault Detection Identification and Restoration (FDIR) is one of the important technologies to identify occurrence, record the occurrence and determine the fault location.

→ Finally it helps in the restoration process.

→ FDIR system is tightly connected with the DMS so that measured values from the shunt capacitors, reclosers, and sectionalizers are available to find the location of the fault.

→ In addition to that, automatic operation of switches, reclosers and sectionalizers is made possible which further reduces the time length of the outage.

Characteristics of FDIR.

1. The chief benefits of the incorporated FDIR is power system reliability increases. The peak load or annual energy consumption is not affected.
2. When the FDIR is coordinated with reclosers, sectionalizers, DMS and OMS, it becomes to increase the

reliability of a distribution feeder.

3. Only when the power system is having low reliability, coordination of FDIR is mandatory.

→ Generally, two technology components are needed to provide FDIR capabilities these are software algorithms and field devices.

→ Field devices have sensors and switches. The sensors search for issues on the network, while switches are utilized to control the power flow in the network.

→ Algorithms are the mathematical tools that guide the switching operations when isolating equipment on the network.

→ A larger degree of automation may be introduced by making use of reclosers with RTUs, with communication infrastructure between them as shown in the fig. In this scheme, an agent is brought into picture who gathers data from all the intelligent devices in the system.

→ During normal operation, the Agent surveys all the RTUs and IEDs to stabilize the system status.

→ When there is a fault at the location shown, IED1 senses the fault current, opens the CB and give information to the Agent.

→ The Agent, in turn sends instructions to RTU1 to RTU 4 to open them and requests current and voltage data from them in real time.

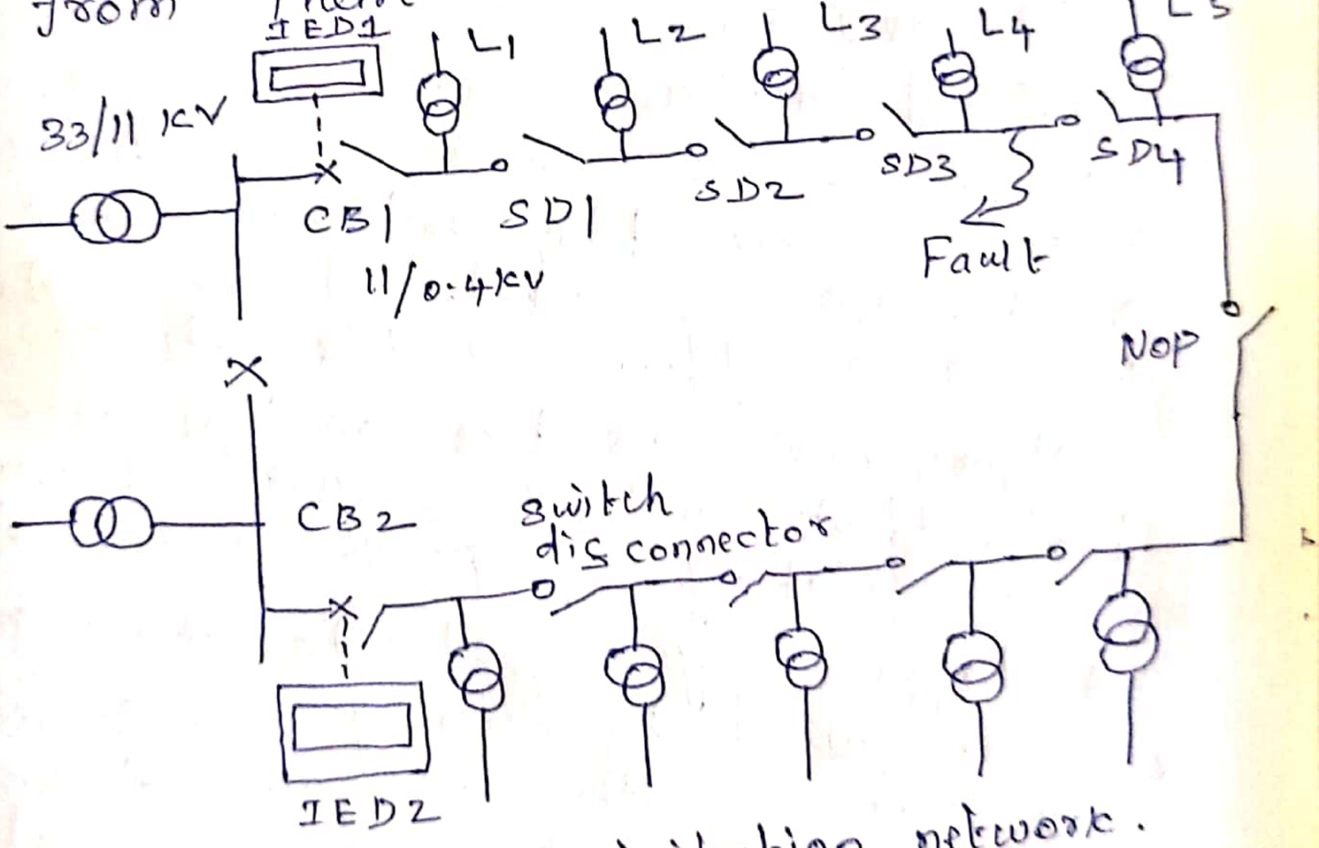

Fig: 11 KV Distribution network.

A possible automatic restoration method works as follows.

1. A command is sent to IED1 to close CB1.
2. Next level command is sent to RTU1

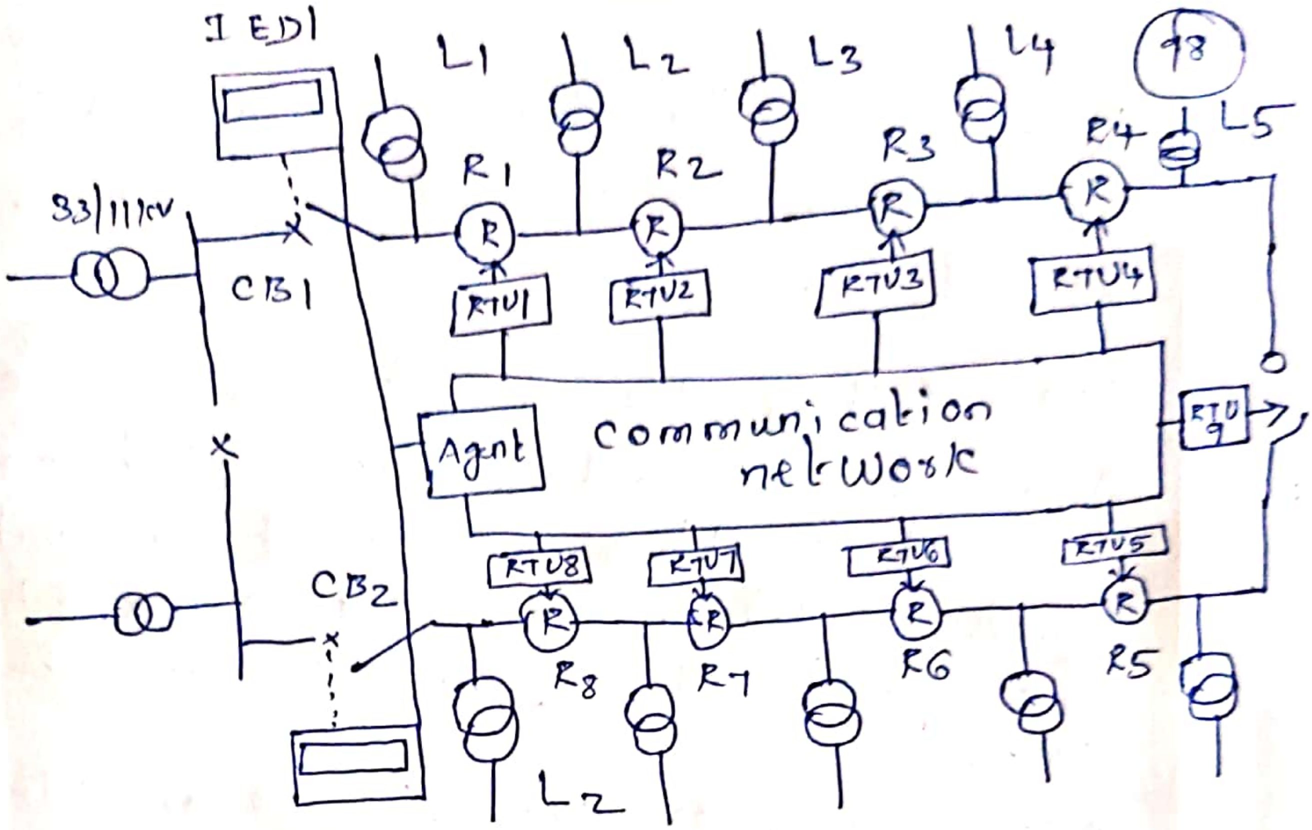

Fig: 11 KV Distribution network with reclosers and sectionalizers.

to reclose R_1. If the fault current exceeds, a trip is initiated but as there is no fault current, R_1 remains closed. Similarly a set of commands sent to RTU2, 3 and 4 to reclose R_2, R_3 and R_4.

→ When R_3 is closed, fault current flows, thus causing R_3 to trip and lock-out.

→ Then a command is sent to RTU 9 to close the normally open point. Finally, a command is sent to RTU 4 to close R_4. As the fault current flows, a trip command is initiated for

R_4. R_5 and R_4 thus isolate the fault and supply is restored to loads L_1, L_2, L_3 and L_5.

4.4 Outage Management System (OMS)

→ Conventional outage happens because of bad weather and heat, excavations, defects in the power station, power lines damages and defects in the distribution system.

→ Other reasons for outage may include a short circuit in the line, the overloading of electricity mains, equipment failures, or vehicles hitting utility poles.

→ Recent computer-based OMS makes use of connectivity models and graphical user interfaces. This includes operations like trouble call handling, outage analysis and prediction, working crew management and reliability reporting.

→ Outage management was initially carried out by receiving calls from the customers and did not have a connectivity model of the system. This will include the connection points of all customers

A typical OMS is shown in fig.

Network data from GIS (Geographic Information system) are given to the

OMS database by means of a network data interface.

→ The interface first generates the database with all network data. This will include connectivity information, system components, protection and switching device types and their locations, and information about distribution transformers. This is called as the bulk network data load or bulk load.

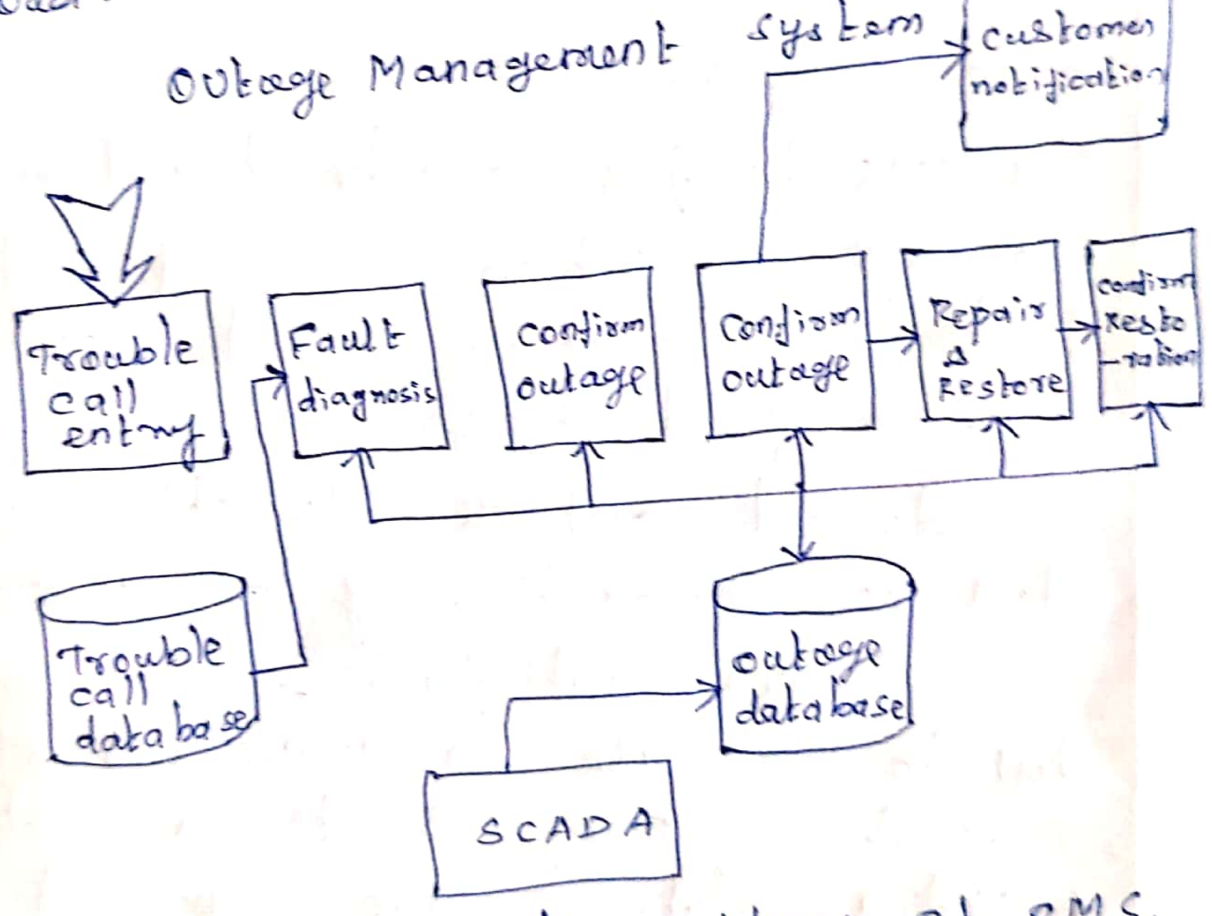

Fig: Information flows of OMS.

→ The interface will be periodically run to exchange the subset of data that has changed since the last update. This process is called as the incremental network data update or incremental update.

→ outage management systems are usually integrated with SCADA systems which will automatically report the monitoring of circuit breakers operation.

→ This will reduce estimated restoration times without demanding radio communication with the control center.

OMS Benefits.

The OMS benefits can be listed as below,

1. outage duration is reduced due to faster restoration based upon outage location predictions.
2. Reduced outage duration minimizes due to prioritizing of outage clearing.
3. Customer satisfaction is improved due to increase in awareness of outage restoration progress to the customers.
4. Media relations are improved by providing accurate outage and restoration information.
5. Frequent occuring of outage is reduced due to efficient outage management.

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4.5 High-Efficiency Distribution Transformer:-

→ India is currently experiencing 23% transmission and distribution losses. we struggle to reduce these losses which are made possible by incorporating energy efficient equipment.

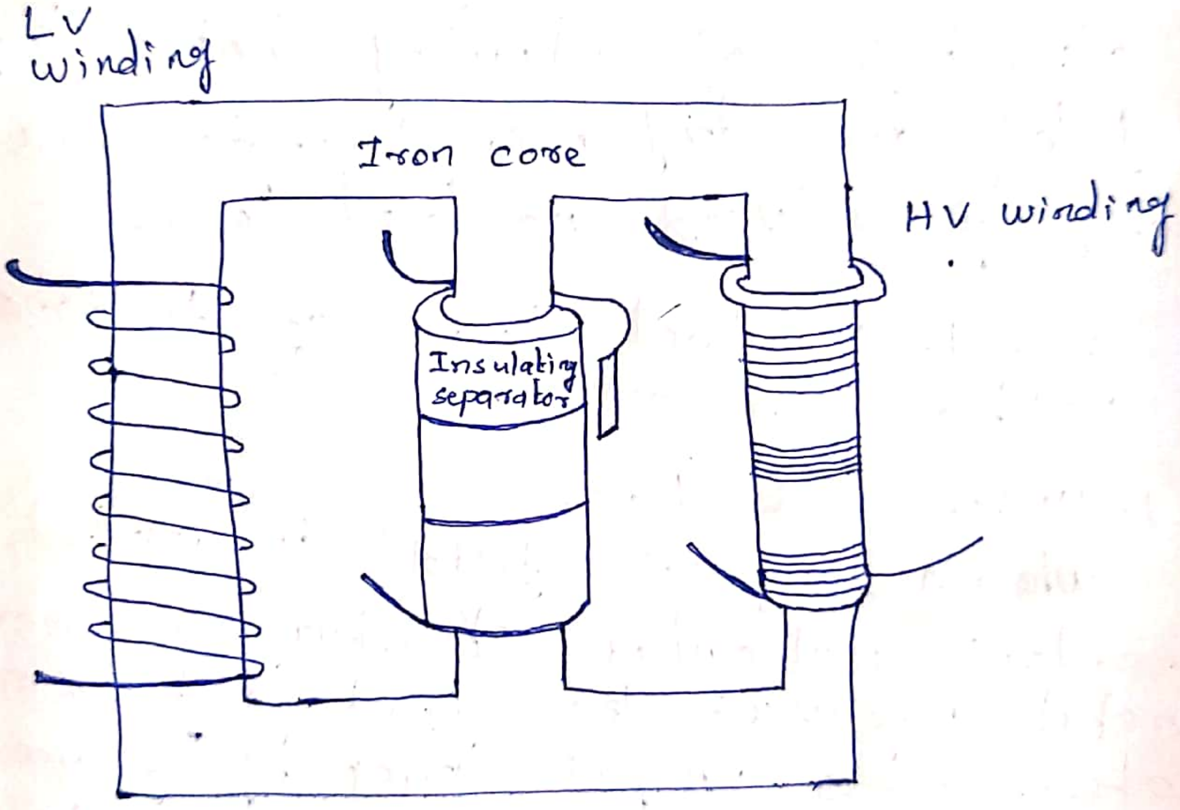

Fig: High efficiency Distribution transformer.

→ Because of the presence of a large number of distribution transformers in electric power system and their long lifetime, even small increase in the efficiency of these units will end up in very good energy savings.

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→ A significant increase in energy efficiency of distribution transformers is obtained by minimizing no-load loss (iron or core loss) of the transformer.

→ The use of amorphous metal in distribution transformers has an advantage of allowing both liquid filled and dry type transformers with highly reduced no-load loss.

4.5.1. No Load losses of Amorphous Ribbon or core.

1. Hysteresis Loss:

When a magnetic field is applied, the random molecular structure of amorphous metal produces less friction than silicon steel. This unique property of amorphous materials allows ease of magnetization and demagnetization. This will significantly lessen hysteresis losses.

2. Eddy current Loss:-

→ Amorphous metals are of very thin laminations and have high resistivity this will reduce the eddy current losses as compared to silicon steel.

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→ When compared with standard liquid filled transformers, the amorphous metal core transformers have a significant no-load loss reduction upto 70 %.

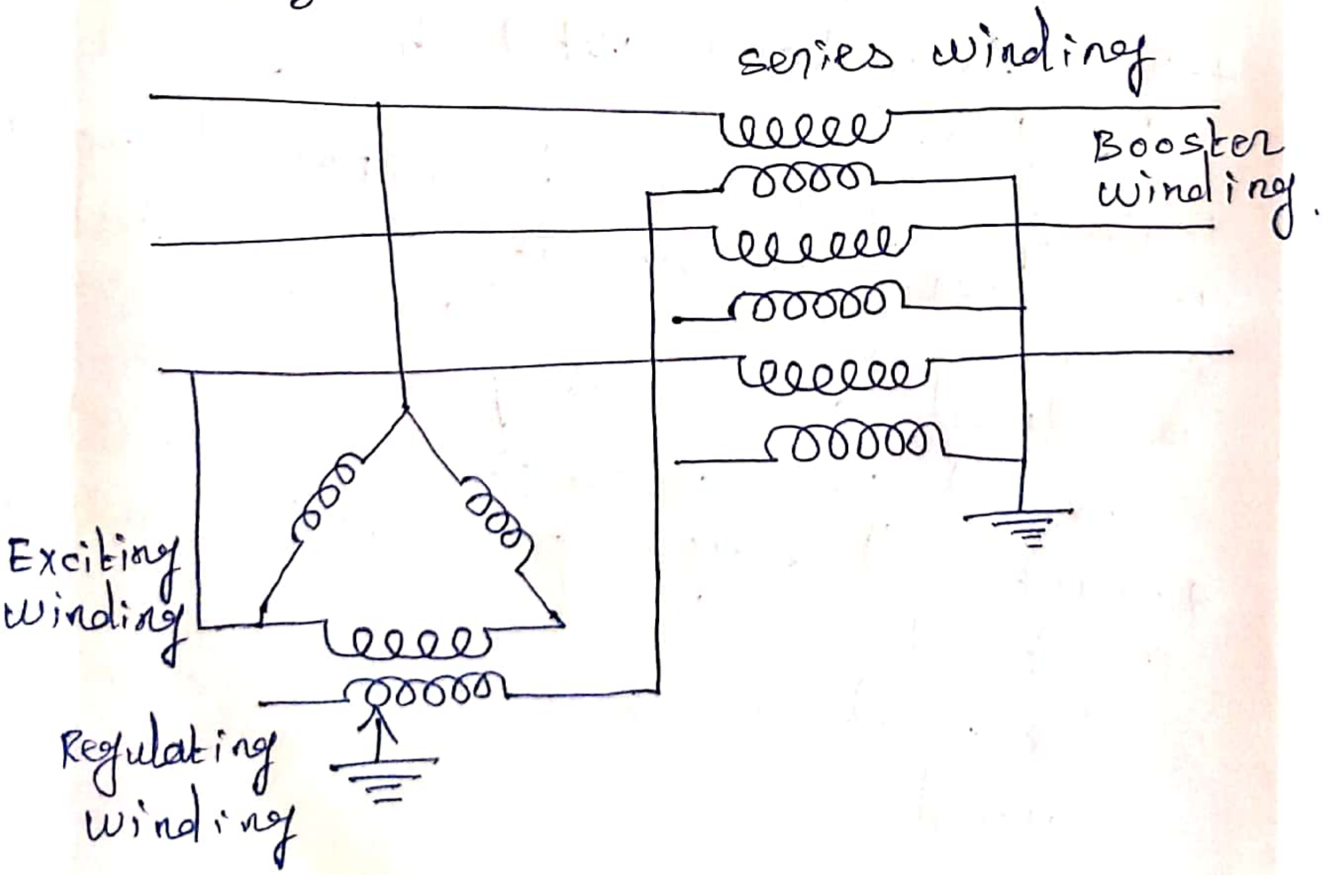
→ An amorphous metal transformer is a unique kind of energy efficient transformer installed on electric grids. The magnetic susceptibility of these materials is very high and it has very low coercivity and high electrical resistance. The high resistance and thin foils will produce low losses.

4.5.2. Amorphous Metal transformer Benefits.

1. Energy saving can be improved up to 75 % over conventional silicon steel core
2. CO, SO emission of hazardous gasses is reduced significantly.
3. Fossil fuel consumption is reduced.
4. Fast and easy repair due to modular construction
5. Temperature rise in the core is reduced.

4.6 Phase shifting Transformer (PST).

Phase shifters are largely used in power systems for controlling the magnitude and direction of the active power flow. The typical representation of PST is shown in figure. By injecting a voltage in series with the line the control of the magnitude and direction of real power flow on the line is achieved. This will also change the phase angle of the receiving end voltage.



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→ A variable series voltage is obtained by a tap changer which acts on the regulating winding. It is then injected by the booster winding across the series winding.

→ A typical pst will be capable of providing variable phase angle shift up to 20°. However, changing the phase angle of the injected voltage through the taps takes time because of the slowly operating nature of phase shifting transformers.

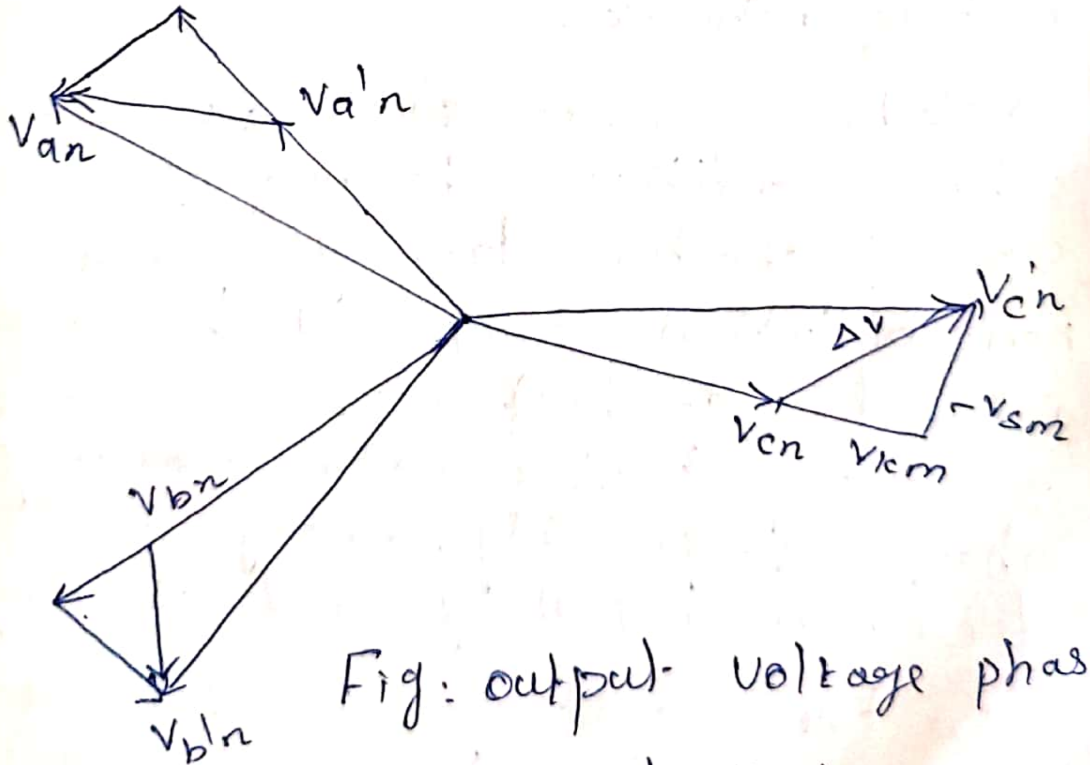

Fig: output voltage phasor of PST.

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4.7 Plug in Hybrid Electric vehicles:- (PHEV).

→ One of the serious challenges this world is facing is environmental concern regarding the consumption of fossil fuels. consequently, consumption of more renewable resources and promotion of a clean transport system such as the use of plug in Hybrid Electric vehicles has become the new energy policies. However, the invention of PHEVs in the automobile industries raises concerns about power system stability in the network.

→ Electric vehicles (EVs) are suitable for urban conditions because of its lower speed, shorter driving range and non pollution compared to conventional internal combustion engine (ICE) vehicles. In urban traffic, the working conditions change frequently among acceleration, deceleration, parking and starting.

→ In the coasting mode, the assistant braking function of the ICE is utilized to decelerate the vehicle, and the driving feeling associated with the speed and the deceleration change during the process is important for the driver to avoid traffic accidents.

→ Moreover, recovery of braking energy is the main energy-saving method for an EV. For EVs, the assistant braking which can be achieved by motor braking not only can improve the driving feeling in coasting mode, but also recover part of the braking energy.

4.7.1. Layout and Main Parameters of the Developed EV.

→ It is mainly composed of a driving motor, a main reducer, a differential, four wheels, a motor controller, a brake controller and the battery pack.

→ When the vehicle is in coasting mode the relationship between the rotation speed of the driving motor $n_{mot}(t)$ and the speed of the EV $V(t)$ is expressed by $n_{mot}(t) = \frac{V(t)}{R} \times i$,

where

$R \rightarrow$ dynamic rolling radius of the driving wheels.

$i \rightarrow$ transmission ratio of the EV transmission system.

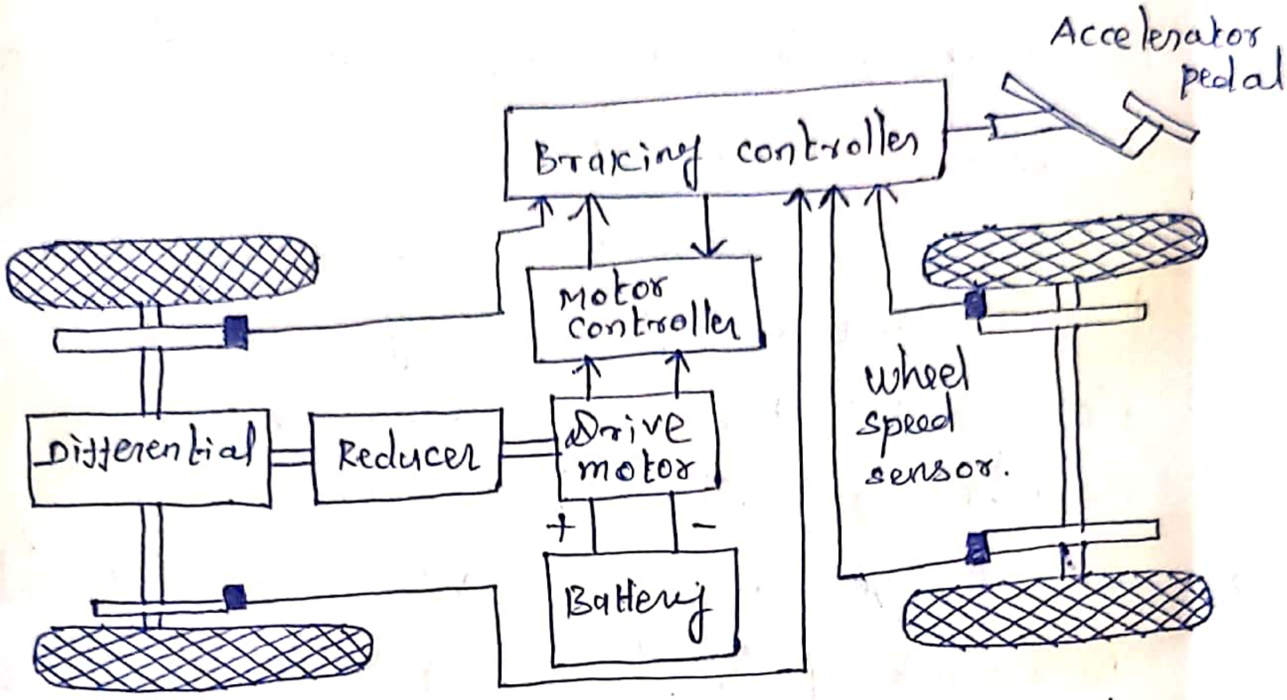

Fig. Layout of the developed EV.

The demanded torque of the driving motor Treq(t) can be expressed as,

$$T_{req}(t) = f(n_{mot}(t))$$

The load signal (Ls) of the driving motor is,

$$Ls(t) = \frac{T_{req}(t)}{T_{motmax}(n_{mot}(t))} \times 100\%$$

Where, T_{motmax} is the maximum torque of the driving motor.

For a disk brake, the braking torque M_B generated under a certain

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pressure P_B can be expressed by,

$$M_B = 2 P_B \times A_B \times \eta_B \times \mu_B \times r_B \times C_B$$

where

P_B → Pressure of the hydraulic

A_B → Brake piston surface,

η_B → Efficiency.

μ_B → Friction coefficient

r_B → Effective friction radius

C_B → specific brake factor.

4.7.2 Merits of plug. in Hybrid Electric vehicle.

1. The fuel consumption is reduced from 30% to 60% reduces fuel consumption.

2. Due to the application of battery and charging abilities of PHEV, green house gases produced by the vehicle are minimized.

3. Since battery is largely used for the movement of the vehicle, fuel consumption cost is reduced.

4. PHEV has several energy generators and motors which are smaller in size and lesser in weight. Therefore this reduces fuel consumption without interfering with the performance of the vehicle.

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UNIT- V

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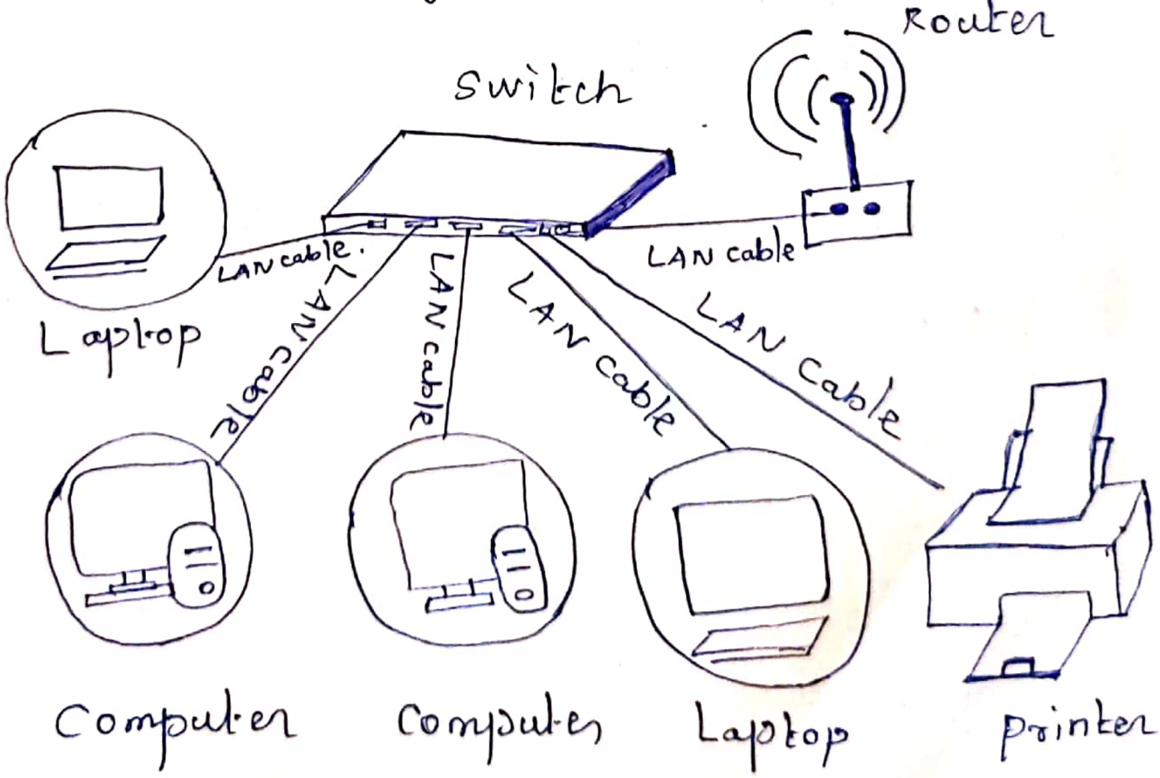
5.1 Local Area Network (LAN)

A local Area network (LAN) is a connected environment spanning one or more buildings - typically in a one-kilometer radius - that links computing devices within close proximity of each other by using ethernet and wi-Fi technology. LAN is among the most foundational components of the global networked landscape, both at consumer and enterprise levels.

A local Area Network (LAN) is a group of computers or ther devices interconnected within a single, limited area, typically via Ethernet or wi-Fi.



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5.1.1 Function of Local Area Network.

→ The function of local Area Networks is to link computers together and provide shared access to printers, files and other services.

→ Local area network architecture is categorized as either peer-to-peer or client-server. on a client-server local area network, multiple client devices are connected to a client server, on which application access, device access, file storage and network traffic are managed.

→ Applications running on the local Area network server provide services such as database access, document sharing, email, and printing.

→ LAN can interconnect with other LANs via leased lines and services, or across the internet using virtual private network technologies. This system of connected LANs is classified as a wide local Area network or a metropolitan area network.

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5.12 Types of Local area network,

client - server LAN
Peer to peer LAN
Token ring LAN
Token bus LAN
Wired LAN
wireless LAN
cloud - managed LAN

1. Client - server LAN

In a client server LAN environment, a single server connects to multiple devices known as clients. This LAN type may be faster in small perimeters, but in a large perimeter, it places too much pressure on the central server.

2. Peer to Peer LAN:-

In a Peer to peer LAN, there is no centralized server, and all connected devices have access to each other, regardless of whether they are servers or clients. The advantage of a peer to peer LAN is that devices can freely exchange data with one another.

3. Token Ring LAN:-

In the former, all devices are arranged in a ring when they are connected. A token is assigned to every connected device based on its requirements.

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4. Token bus LAN

In a token bus LAN, connected nodes are arranged in a treelike topology, and tokens are transferred either left or right. Typically, it provides better band width capacities than a token ring LAN environment.

5. Wired LAN

It uses electronic waves to transfer data across optical fiber (or cable varients) instead of tokens. wired LAN is extremely reliable and can be very fast, depending on the performance of the central server.

6. Wireless LAN:-

Wireless LAN is commonly used in home environment to connect computing devices, wearable, smart appliances etc. This type of LAN users radiofrequency for data transfers, which can make it susceptible to security risks.

7. Cloud Managed LAN:-

cloud-managed LAN is a specific type of wireless LAN where a centralized cloud platform is used to manage network provisioning, policy enforcement, access control, and other aspects of network performance and security.

5.2 Home Area Networks (HAN)

→ To manage the energy consumption, storage, and generation devices, home energy management systems (HEMS) have been deployed. It includes a wide spectrum of devices, including lights, appliances, heaters, air conditioners and local generation facilities.

→ HANs are wireless networking technologies that are defined by zigbee standards. A zigbee standard is a suite of high level communication protocols. For the purpose of remote monitoring and control external devices are connected to HAN.

→ The energy consumption / supply into and out of the systems are monitored by HEMS. To turn ON/OFF of devices can be controlled based on the need of energy efficiency. Further HEMS may control their operation, turning them on and off as needed and managing their energy efficiency. The smart meter can also be connected into the HAN and thus HEMS can access the meter measurements.

→ Such access can be executed by smart phones which are outside from home. Internet access can be accomplished by

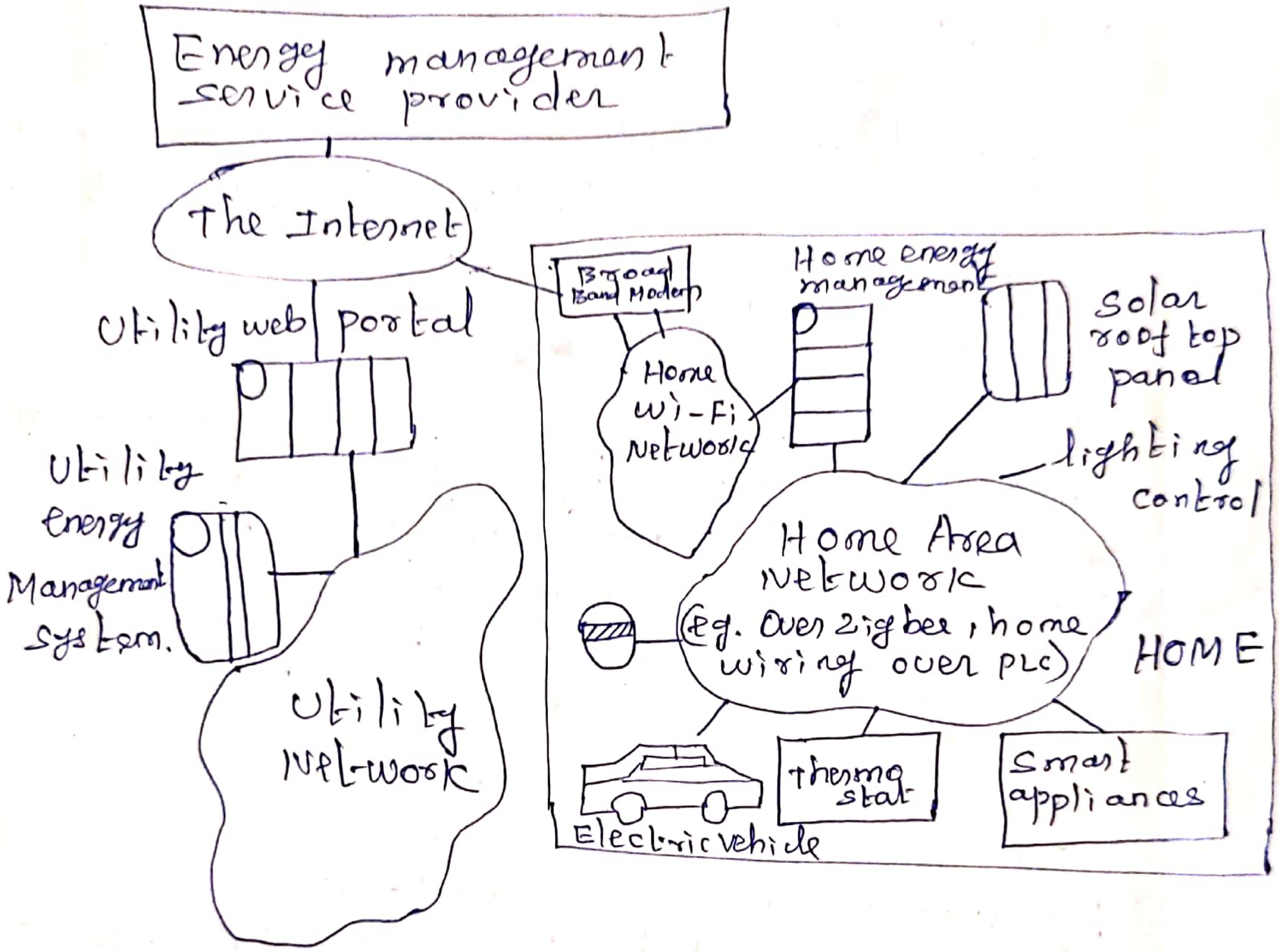

Fig: Home Area Network.

connecting HEMS to home wi-Fi network.

→ Apart from these, the utility Energy Management System (UEMS) can report information related past consumption, consumption predictions and variation to HEMS.

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5.3 Wide Area Network (WAN)

→ A smart grid communications infrastructure allows utilities to communicate with one another in regional grids, as well as with customers and distributed power generation and storage facilities.

→ A multi-tier network integrates communications throughout the distribution grid and uses an infrastructure wide network or wide area network. 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 as well as with other distribution assets such as capacitor banks, transformers, and reclosers.

→ Many utilities will want to take full advantage of the investment in this WAN infrastructure to run other enterprise networking applications, including wireless communications, site security with video surveillance etc.
Each application running on the utility's WAN has its own set of requirements.

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5.3.1 Applications of WAN

→ Integrated communications will enable the grid to become a dynamic.

→ optimize system reliability.

Structure of WAN :-

→ A wide area network (WAN) is a network containing huge information. WANs can assist communication, information sharing between devices from around the globe through a WAN provides.

→ For smart grid applications, the WAN provides a two-way communication link, which acts as backbone for reliable operation of system.

→ The WAN covers the transmission and distribution domains between 10 and 100 km range.

→ In smart grid, transmission substation LAN, utility LAN and public internet are connected via WAN.

→ The transmission substation LAN comprises of all connected transmission substations which use protection and control devices in order

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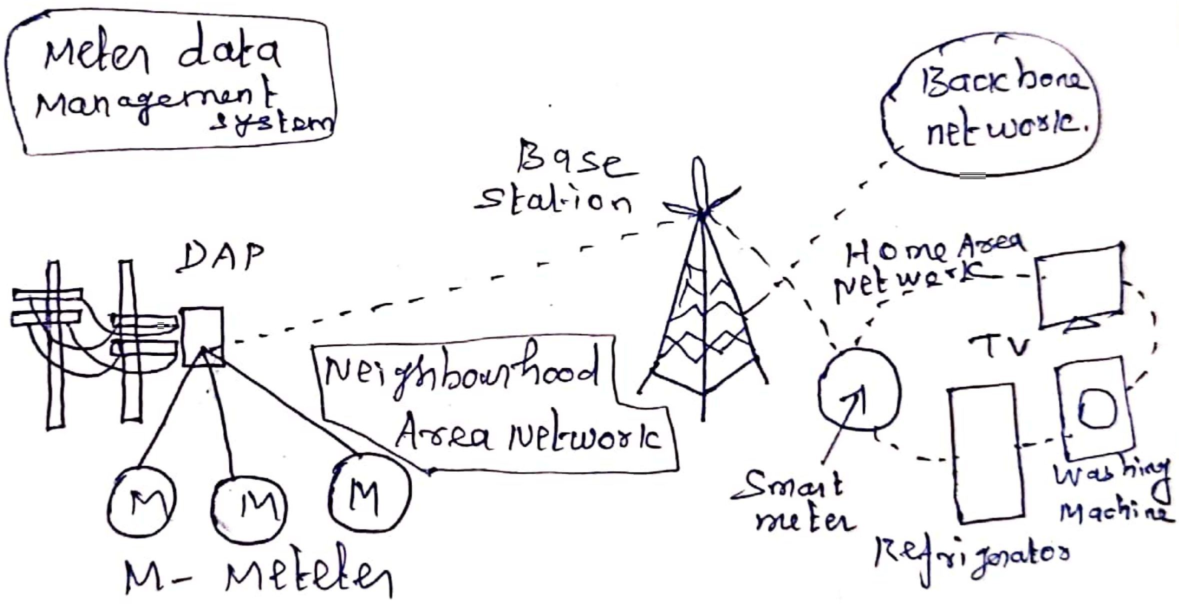
to achieve substation automation functionality.

→ The utility LAN is used to manage, monitor and control data flows by the utilities.



DAP - Data Aggregate point.

→ It would be used to provide services such as field device automation, metering, demand response and load control. The wide area network connected to the public internet, allows third parties to partake in smart grid activities using a secured communications channel.

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5.4 Computing Technologies for Smart Grid Applications (web service to cloud computing).

A robust, affordable and secure supply of power through smart-grid is accomplished through reliable and efficient communication system. cloud computing (cc) model is an emerging area through which the computational requirements of smart grid applications can be easily met out.

5.4.1 Benefits of cloud computing in smart grid :-

The following are the needs of cloud computing in power system

- → supports in recovery of black out condition in a power system.
- ⇒ Monitoring and scheduling functions can be performed in power system.
- → Reliable evaluation of the power system.
- ⇒ Instant information sharing aids in quick power restoration process.

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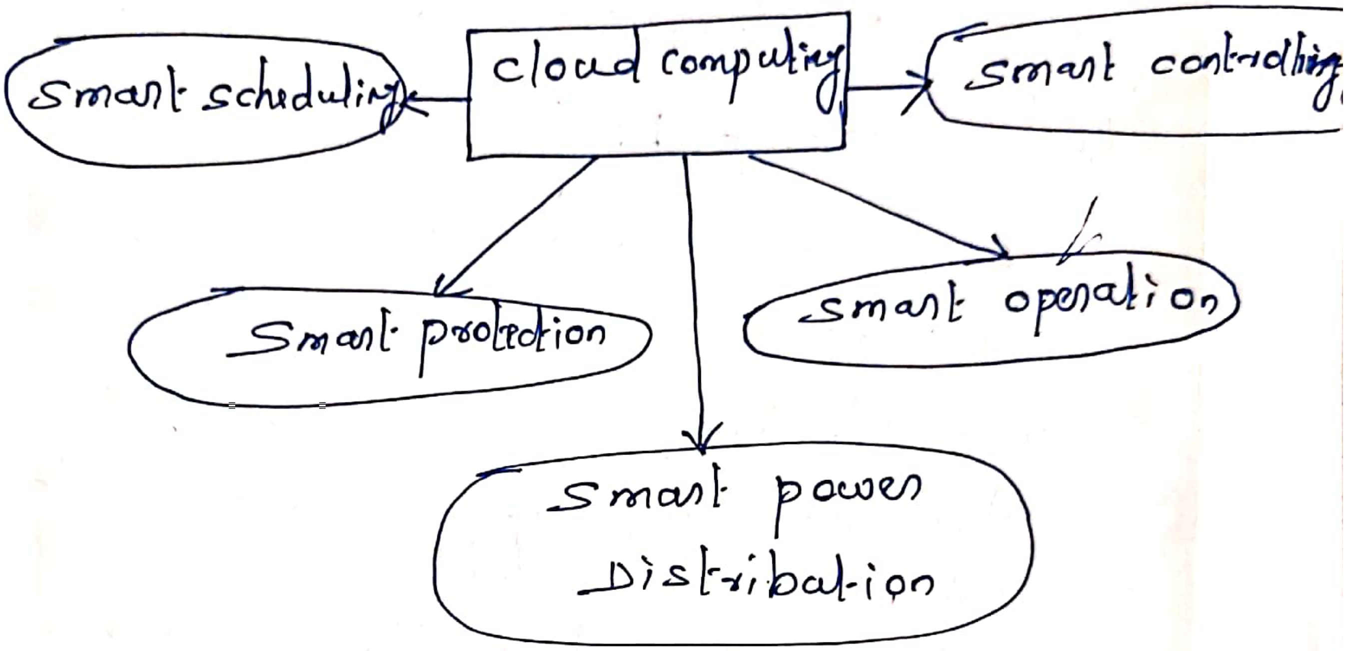

Fig: Function of cloud computing.

→ Reduced system complexity
→ Reduced implementation and maintenance costs.

5.4.2 cloud computing Architecture.

Based on demand, the device retrieves the software and information shared through network.

a. Infrastructure as a service (Iaas)
b. platform as a service (Paas)
c. Data as a service (Daas)

are the three types of cloud computing

architecture. Using the power of cloud computing, the requirements of smart grid can be attained easily. Real time response is important for smart grid applications for addressing immediate demand response.

→ When a request is sent from client through cloud platform, then a response is sent to client in real time. Self healing system is highly essential in a smart grid. Such self healing process can be done by cloud computing which provides instant response to customers.

→ Thus, there should be no internet outages to provide consistent transmission. Such contineous transmission is handled by cloud computing through two or more IP address assignment to a client. This multi IP address assignment to client is known as multi homing.

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5.4.3 characteristics of cloud computing.

→ Communication between the machine and cloud software is done via Application Programming Interface (API)

→ Maintenance and virtualization are properties of cloud computing.

→ For running an application and performing computation, there is no need for software installation.

→ cloud computing offers an easy access to services from anywhere and at any time.

→ Large number of users located in a pool have the access to shared resources.

→ To increase the system performance cloud computing platform uses web services.

→ Losses can be prevented by using private cloud platforms. This will improve the reliability of smart grid.

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5.4.4. challenges in using cloud computing for smart Grids.

The following are major challenges to be faced by cloud computing in smart grid applications.

a. Location of data:-

Business enterprises are unaware of location of server that stores and processes smart grid information. This is because of placement of cloud servers in any location. This, identifying the data location has become highly important. This is defined by cloud service providers (CSP)s, which can be used for meeting out the requirements of data management in smart grid.

b. Mixing of data:-

Many multi-user applications in CSPs create security and scalability issues for enterprises. Therefore, security methods like data encryption algorithms

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must be applied on CSPs for ensuring reliability and confidentiality in smart grid applications.

c. Inefficient cloud security policy:-

Weaker security policies applied to CSPs may create disagreements between smart grid utilities. This can be addressed by deploying service level agreements into effect between each others. Thus security in smart grid can be ensured at proper level.

d. Redundant Data Management and Disaster Recovery.

Under emergency situation, recovery of smart grid utilities is crucial because cloud computing distributes data to multiple servers in different geographical location. Thus assuring reliability for smart grid application becomes a problem. In such situation, CSP can go for out-sourcing of services

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to address recovery related problems.

structure of the hierarchical model of the intelligent cloud of power system is shown in fig.

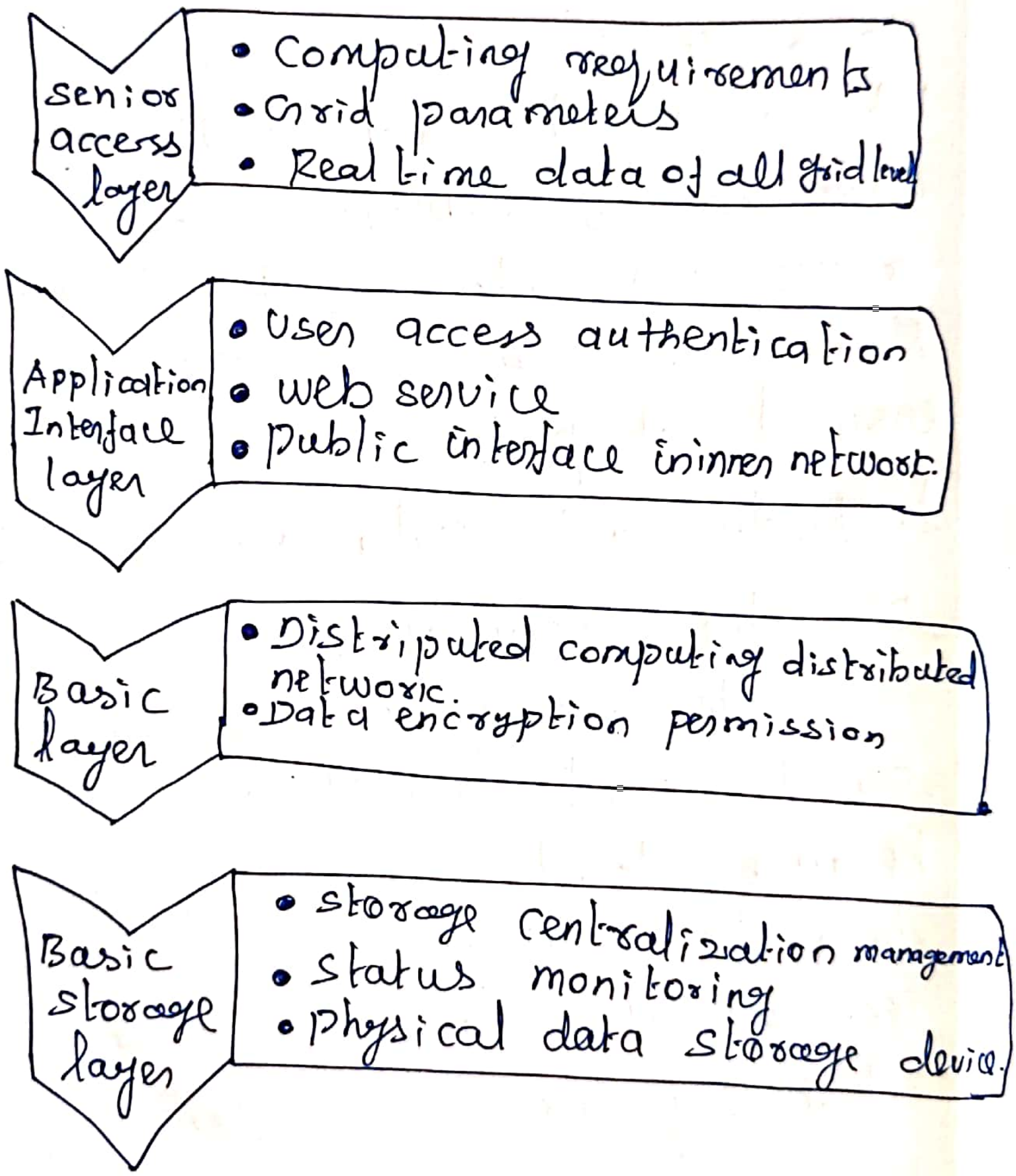

Fig: cloud computing in smart Grid Applications.

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In this structural model, basic storage layer becomes the fundamental element of the smart grid. Here storage devices are interconnected through network in a smart grid. While the basic management layer incorporates integration of all devices in cloud atmosphere.

5.5. Broad Band over Power Line (BBPL).

Power line communication (PLC) offerens a cost effective solution by data transmission in the existing electrical network. When compared to digital subscriber Line (DSL) and fiber optic communication technologies, PLC eliminates installation of additional wires such as twisted pair or coaxial cables to interconnect devices. Since every home appliance is connected to power line, it is easy for PLC to monitor electricity, demand response and load control.

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Types

1. Narrowband power line communication (NB-PLC) → 3-500 KHz.
2. Broad band power line communication (BB-PLC) → 2-100 MHz

5.5.1 BB-PLC Technologies.

Home plug AV_2 is the latest BB-PLC technology that offers a peak rate of more than 1 Gbps. This is attained by using advanced signal processing technologies such as Multiple Input Multiple output (MIMO) and pre-coding. But these technologies introduce increase in system complexity, power consumption and capital cost.

5.5.2 NB-PLC Technologies

To meet the requirements of long-range and outside-the-home applications NB-PLC technologies are deployed. It provides low complexity, low power consumption and high reliability.

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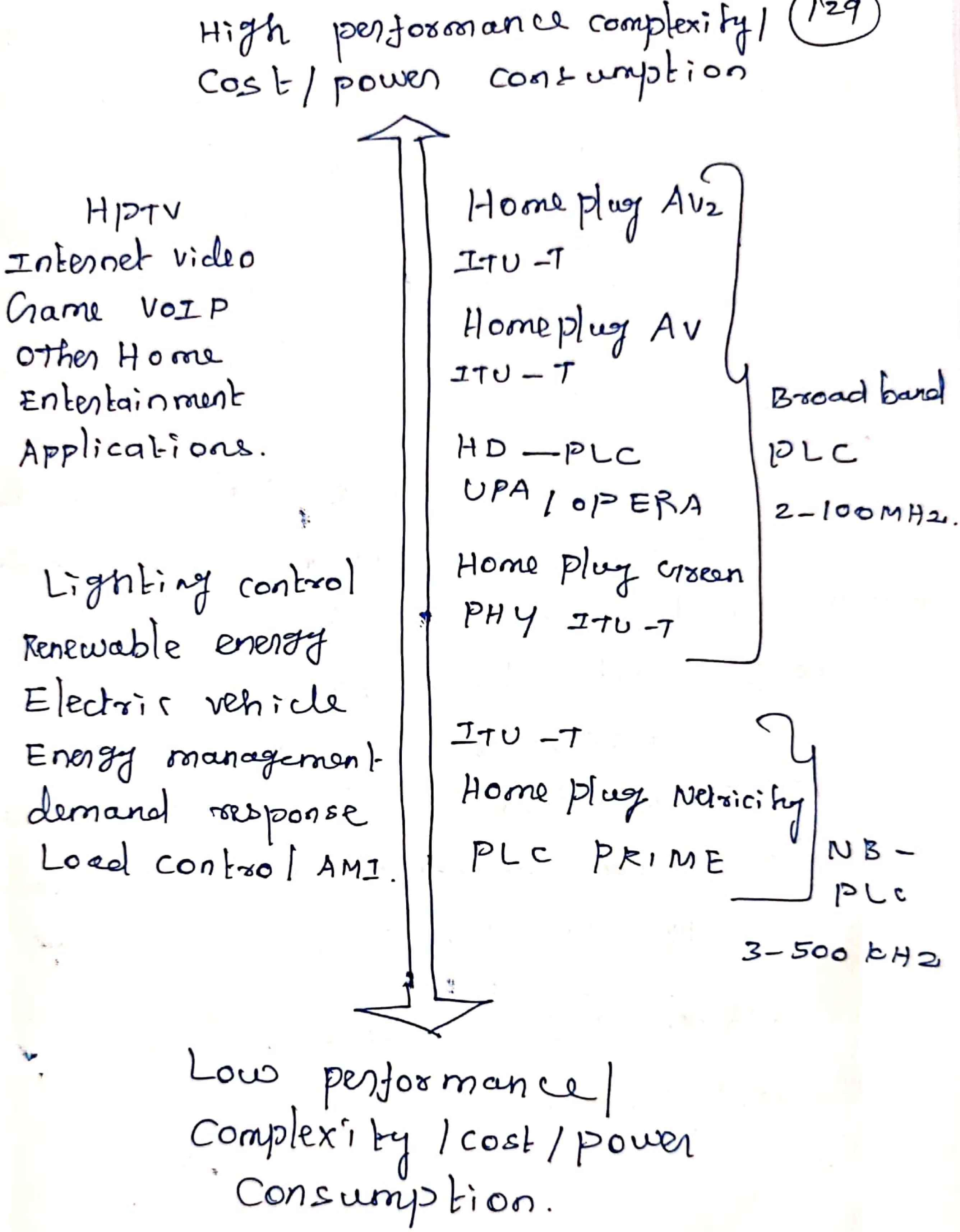

Fig: Classification of PLC Technologies.

5.5.3 Challenges of PLC Technologies:-

→ when PLC signals reach a receiver over more than one path, fading occurs. This is due to the existence of multiple branches between transmitter and receiver.

→ In such multiple path, the data transmission experiences delay.

5.5.4 The following are the issues observed:-

→ physical characteristics of the transmission medium.

→ Power line cables were not designed to carry communication signal.

→ Multi path fading

→ Frequency selective fading

→ Interference.

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5.6. Cyber security Requirements.

The three level cyber security objectives namely availability, integrity and confidentiality are used for defining the requirements cyber security in smart grid.

The following are cyber security requirements in a smart grid.

5.6.1. Attack Detection and Resilience operations.

In smart grid, an open communi-cation network over large geographical areas is observed. Monitoring each and every node in such a wide area is little tedious. By consistent testing and comparison of communication network, the network traffic status can be monitored. This supports the detection and identification abnormal incidents due to attacks. The presence of attacks can be overcome by self-healing ability of the network.

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5.~~3~~6.2. Identification, Authentication and access control.

→ The smart grid infrastructure incorporates millions of electronic devices and users in it. In such structure verifying the identity of a device or user is done by identification and authentication.

→ This can be considered as a prerequisite for granting access to resources in the smart grid information system.

→ The objective of access control is to ensure that access of resources is done by the appropriate personnel only. Enforcement of strict access control can prevent unauthorized users from accessing sensitive information and controlling critical infrastructures.

→ For ensuring the authentication of data access, it is mandatory satisfy certain requirements. For implementation of such initiative, smart grid must allow data encryption and authentication.

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5.6.3 Secure and Efficient communication protocols.

→ In distribution and transmission systems, message delivery requires both time-criticality and security. In the design of communications protocols and architectures for smart grid, optimal tradeoffs are required to balance communication efficiency and information security.

→ Inorder to fully achieve efficient and secure information delivery for critical power infrastructures, smart grid imposes strict security requirements than the internet.

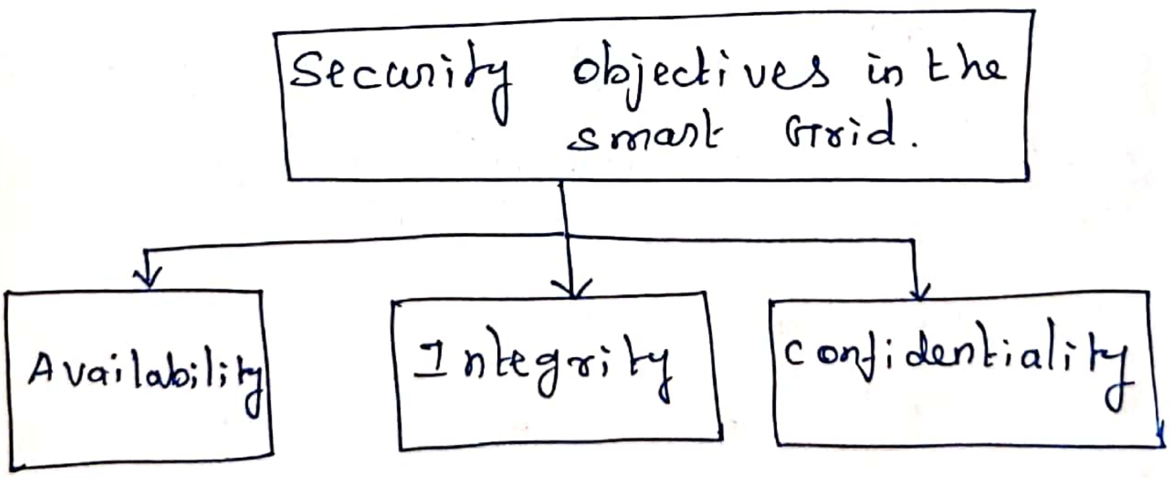

Fig: three high-level security for the smart Grid.

5.6.4 Network security threats in the smart grid.

As security challenges mainly come from malicious cyber attacks via communication networks, it is essential to understand potential vulnerability in the smart grid under network attacks.

Attack classification:-

Attacks targeting availability,

It is also called denial-of-service (DOS) attacks, attempt to delay, block or corrupt the communication in the smart Grid.

Attacks targeting Integrity:-

It aim at deliberately and illegally modifying or disrupting data exchange in the smart grid.

Attacks targeting confidentiality:-

It ~~used~~ Intend to acquire unauthorized information from network resources in the smart grid.

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5.7 Role of Big Data and IOT,

→ The role of IOT in smart grid is crucial. Internet of things is in large part the enabler of smart grid as its technological and infrastructural components are largely IOT-based.

→ The data on energy consumption comes from sensor-enabled IOT devices, appliances and hubs that control a smart house or any other connected space.

5.7.1 IOT-based Process Automation:-

Smart grid IOT technology is widely used to automate processes and increase efficiency in the supply chain.

5.7.1 IOT-based Process automation.

→ Adopt automated metering to monitor energy usage in real-time and dynamically respond to changing demand.

→ Use environmental data and IOT technologies in renewable energy to optimize power production and maximize the use of green sources of energy.

→ Monitor grid load and adopt data-driven

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strategy to minimize the risks of outages or overloads.

5.7.2 Applications.

⇒ Predictive Maintenance.

Predictive maintenance is one of the most important use cases for smart grid IOT applications for power plants, energy distributors and utilities.

Using intelligent grid technology for monitoring and energy grid management.

→ Real time data analytics and visualization:-

The role of big data in smart grid operation is very significant. Big data applications enable automation, management problem detection and prediction in a smart energy grid.

→ Advanced Algorithm :-

Applications based on machine learning are already common in the IOT market, It helps better understand and use big data, identify trends, make predictions. Therefore the use of advanced algorithms to analyze IOT data created in the smart grid supply chain is another way to make it more efficient.

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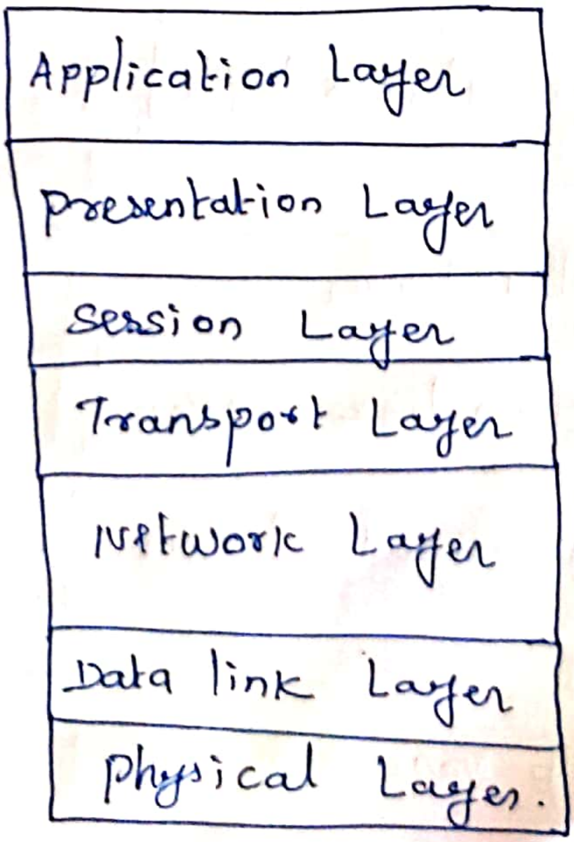
5.8 IP based Protocols.

A smart grid is made possible by applying sensing, measurement and control devices with two way communications to electricity production, transmission, distribution and consumption parts of the power grid.

Internet Protocol (IP) Layers.

While internet architecture uses the definitions and language used by the ISO open system Interconnect Reference. The structure of the internet reference model is shown in figure.



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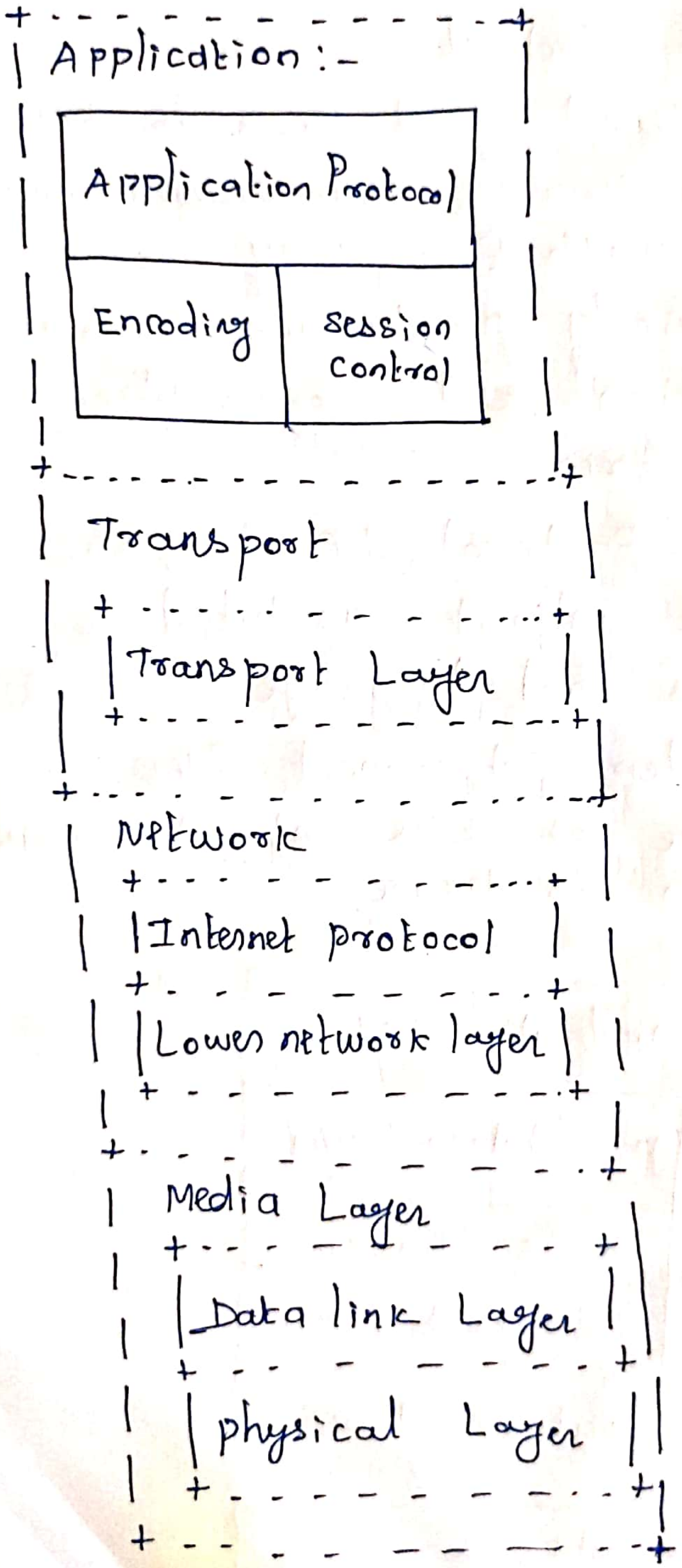

Fig. IP various layers.

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Application Layer:-

→ In the internet model, the application, presentation, and session layers are compressed into a single entity called the application.

→ An application protocol encodes its data in some way and that it manages sessions in some way doesn't imply a hierarchy between those processes.

→ Rather, the application views encoding, session management, and a variety of other services as a tool set that it uses while doing its work.

Transport:-

→ In the internet protocol stack, the transport is the lowest protocol layer that travels end-to-end unmodified, and is responsible for end-to end data delivery service.

→ In the internet the transport layer is the layer above the network layer. The ability to multiplex several applications on one IP address.

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→ In addition, the responsibilities of a specific transport layer protocol typically includes the delivery of data in a stated sequence with stated expectations regarding delivery rate and loss.

Network :-

→ The main function of the network layer is to identify a remote destination and deliver data to it.

→ In connection-oriented networks such as Multi-protocol Label switching or asynchronous Transfer Mode (ATM), a path is setup once, and data is delivered through it.

→ In connectionless networks such as Ethernet and IP, data is delivered as datagram.

Internet protocol :-

This the layer that allows diverse networks such as Ethernet, 802.15.4 etc. to be combined in to a uniform IP network.

Lower network Layer :-

The network layer can recursively subdivided as needed. This may be accomplished by tunneling, in which an IP datagram is encaptulated in another IP header for delivery to decaptulator. IP is frequently carried in virtual private networks across the public internet using tunneling technologies.

⇒ Media Layer: physical and Link.

At the lowest layer of the IP architecture, data is encoded in messages and transmitted over the physical media. The specifications are from IEEE, ITU and other sources.

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