RAJIV GANDHI COLLEGE OF ENGINEERING AND TECHNOLOGY, PUDUCHERRY

QUESTION PAPER ANALYSIS – January 2023

Sub.Name	Smart Grid	Branch	EEE
Year	IV	Semester	VII
Name of Faculty	S.Sivakumar	Sub.Code	EE 19

Question No.	Marks allotted	Materialization			
		Within syllabus	Available in QB	Asked in Unit Test/ Model Exam	Total Marks based on appearance in Unit Test/ Model Exam
1	2	Yes	No	No	0
2	2	Yes	Yes	Int-1- 11b	2
3	2	Yes	Yes	Int-1- 6	2
4	2	Yes	No	No	0
5	2	Yes	Yes	Int-2- 9	2
6	2	Yes	Yes	Int-2- 8	2
7	2	Yes	Yes	Model - 10	2
8	2	Yes	Yes	Model - 17a	2
9	2	Yes	Yes	Model- 9	2
10	2	Yes	Yes	No	0
11	11	Yes	Yes	Int-1- 12a	11
12	11	Yes	Yes	Int-1- 11a	11
13	11	Yes	Yes	Int-1- 14 b & Model- 14 a	11
14	11	Yes	Yes	Int-1 - 16a	11
15	11	Yes	Yes	Int-2- 15	11
16	11	Yes	Yes	Int 2- 14a	11
17	11	Yes	Yes	No	0
18	11	Yes	Yes	Model- 17 a&b	11
19	11	Yes	Yes	No	0
20	11	Yes	Yes	Model- 20	11

B.Tech. DEGREE EXAMINATION, JANUARY 2023
Seventh / Eighth Semester
Electrical and Electronics Engineering
Elective:SMART GRID
(2013-14 Regulations)

ANSWER KEY

1. **How Indian Power Grids are classified.**

   Indian Grid is a synchronous interconnection of Eastern, Northern, Northeastern, Southern and Western Regional grids.

2. **What are the three main layers in Smart Grid architecture? (IT-1)**
   a. Smart Devices Interface Component
   b. Storage Component
   c. Transmission Subsystem Component
   d. Monitoring and Control Technology Component

3. **Define Phaser Measurement Unit used in Smart Grid. (IT-1)**

   A Phasor Measurement Unit is a device –(microprocessor based unit) which reports the magnitude and phase angle of an analog and /or derived phasor with respect to the global time reference, as per the synchrophasor standards (IEEE 1344, IEEEC37.118).

4. **What is the role of high-efficiency distribution transformers in Smart Grid technologies?**

   High-efficiency distribution transformers in smart grid create economic benefits for the society. Besides reduced greenhouse gas emissions, they improve reliability and give potentially longer service life by bringing down temperature rises through energy-efficiency improvements.

5. **What is the need to have AMI Protocols?**

   The main objective of AMI is to enable two way communications between smart energy meter and Head End System (HES) to enable remote reading, monitoring & control of electrical energy meters (consumer, feeder, DT meters etc.) to serve as repository of record for all raw, validated and edited data.

6. **List out the display forms of a Smart meter. (IT-2)**

   Voltage, Current, Maximum Demand, Power factor, Kvah, Kwh

7. **Highlight any two factors that decides the various types of protocols for Smart Metering**
   i. Openness

ii. Interoperability
iii. Scalability
iv. Adaptability
v. Security

8. What are the benefits of adopting mobile communication?

Mobile Communication plays an important role in Smart Grid, as one of the most significant differences between traditional grids and Smart Grid are the two-way communication and the potentials this enables (i.e., distributed smart sensors, distributed power generation, real time measurements and metering infrastructure, monitoring systems.

9. What are the advantages of Super capacitors over SMES. (Model)

i. Power density
ii. Recycle ability
iii. Environmentally friendly
iv. Safe
v. Light weight

10. List out any two functions required for cyber security in Smart Grid

i. Confidentiality,
ii. Integrity
iii. Availability

PART B (5X11 = 55 Marks)

UNIT-I

11. How Smart Grid differs from the Conventional Grid. Explain the goals and functions of Smart Grid. (11) **- (IT-1)**

CONVENTIONAL GRID (TODAY 'S GRID) VERSUS THE SMART GRID

As mentioned, several factors contribute to the inability of today ' s grid to efficiently meet the demand for reliable power supply. Table compares the characteristics of today ' s grid with the preferred characteristics of the smart grid**.**

The traditional power grid is basically the interconnection of various power systems elements such as synchronous machines, power transformers, transmission lines, transmission substations, distribution lines, distribution substations, and different types of loads. They are located far from the power consumption area and electric power is transmitted through long transmission lines.

The smart grid is a modern form of the traditional power grid which provides more secure and dependable electrical service. It is, in fact, a two-way communication between the utility and the electricity consumer.

4 Marks

The smart grid is capable to monitor activities of the grid-connected system, consumer preferences of using electricity, and provides real-time information of all the events. The key components of smart grid include smart appliances, smart substations, smart meters, and advanced synchrophasor technologies.

This article covers the key differences between the Traditional Power Gird and the Smart Grid on the basis of technology, power distribution & generation, sensors, monitoring, restoration operation, equipment, control, and customer choices

2 Marks

SL.No	Preferred Characteristics	Conventional Grid (or) Today ' s Grid	Smart Grid
1	Active Consumer Participation	Consumers are uninformed and do not participate	Informed, involved consumers —demand response and distributed energy resources
2	Accommodation of all generation and storage options	Dominated by central generation — many obstacles exist for distributed energy resources interconnection	Many distributed energy resources with plug - and – play convenience focus on renewables
3	New products, services, and markets	Limited, poorly integrated wholesale markets; limited opportunities for consumers	Mature, well – integrated wholesale markets; growth of new electricity markets for consumers
4	Provision of power quality for the digital economy	Focus on outages — slow response to power quality issues	Power quality a priority with a variety of quality/price options — rapid resolution of issues
5	Optimization of assets and operates efficiently	Little integration of operational data with asset management— business process silos	Greatly expanded data acquisition of grid parameters; focus on prevention, minimizing impact to consumers
6	Anticipating responses to system disturbances (self- healing)	Responds to prevent further damage; focus on protecting assets following a fault	Automatically detects and responds to problems; focus on prevention, minimizing impact to consumers
7	Resiliency against cyber attack and natural disasters	Vulnerable to malicious acts of terror and natural disasters; slow response	Resilient to cyber attack and natural disasters; rapid restoration capabilities

5 Marks

(OR)

12. Write short notes on Smart Grid road map for India (11) (IT-1)

SMART GRID ROADMAP FOR INDIA

"Transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders" In order to achieve this vision, stakeholders are advised to formulate state/utility specific policies and programs in alignment with following broad policies and targets which are in line with MoP's overarching policy objective of Access, Availability and Affordability of Power for All: **2 Marks**

A) Distribution (Including Distributed Generation)

1. Appropriate policies and programs to provide access to electricity for all with uninterrupted life line supply (8 hours/day minimum, including the evening peak) and electrification of 100% households by 2017 and continuous improvement in quality and quantum of supply.

2. Enabling programs and projects in distribution utilities to reduce AT&C losses to below 15% by 2017, below 12% by 2022, and below 10% by 2027.

3. Integrated technology trials through a set of smart grid pilot projects by 2015; and based on outcome of the pilots, full rollout of smart grids in pilot project areas by 2017; in major urban areas by 2022 and nationwide by 2027.

4. Modernization of distribution sub-stations and conversion of sub-stations in all urban areas (starting with metro cities) to Gas Insulated Substations based on techno-commercial feasibility in a phased manner through innovative financing models.

5. Development of Microgrids, storage options, virtual power plants (VPP), solar photovoltaic to grid (PV2G), and building to grid (B2G) technologies in order to manage peak demand, optimally use installed capacity and eliminate load shedding and black-outs.

6. Policies for mandatory roof top solar power generation for large establishments, i.e., with connected load more than 20kW or otherwise defined threshold.

7. Microgrids in 1000 villages/industrial parks/commercial hubs by 2017 and10,000 villages /industrial parks/commercial hubs by 2022, which can island from the main grid during peak hours or grid disturbances – 3 **Marks**

B) Transmission

1. Development of a reliable, secure and resilient grid supported by a strong communication infrastructure that enables greater visibility and control of efficient power flow between all sources of production and consumption by 2027.

2. Implementation of Wide Area Monitoring Systems (WAMS, using Phasor Measurement Units, or PMUs) for the entire transmission system. Installation of a larger number of PMUs on the transmission network by 2017 or sooner, as guided by the results of initial deployments.\ Indigenization of WAMS technology and PMU development and development of custom made analytics for synchrophasor data by 2017.

3. Setting up of Renewable Energy Monitoring Centre's (REMCs) and Energy Storage Systems to facilitate grid integration of renewable generation.

4. 50,000 Kms of optical fiber cables to be installed over transmission lines by the year 2017 to support implementation of smart grid technologies.

5. Enabling programs and projects in transmission utilities to reduce transmission losses to below 4% by 2017 and below 3.5% by 2022.

6. Implement power system enhancements to facilitate evacuation and integration of 30 GW renewable capacity by 2017, 80 GW by 2022, and 130 GW by 2027 – or targets mutually agreed between Ministry of New and Renewable Energy (MNRE) and MoP. **– 3 Marks**

C) Policies, Standards and Regulations

1. Formulation of effective customer outreach and communication programs for active involvement of consumers in the smart grid implementation.

2. Development of state/utility specific strategic roadmap(s) for implementation of smart grid technologies across the state/utility by 2014. Required business process reengineering, change management and capacity building programs to be initiated by 2014. State Regulators and utilities may take the lead here.

3. Finalization of frameworks for cyber security assessment, audit and certification of power utilities by end of 2013.

4. Policies for grid-interconnection of captive/consumer generation facilities (including renewables) where ever technically feasible; policies for roof-top

solar, net-metering/feed-in tariff; and policies for peaking power stations by 2014.

5. Policies supporting improved tariffs such as dynamic tariffs, variable tariffs, etc., including mandatory demand response (DR) programs, starting with bulk consumers by 2014, and
extending to all 3-phase (or otherwise defined consumers) by 2017.

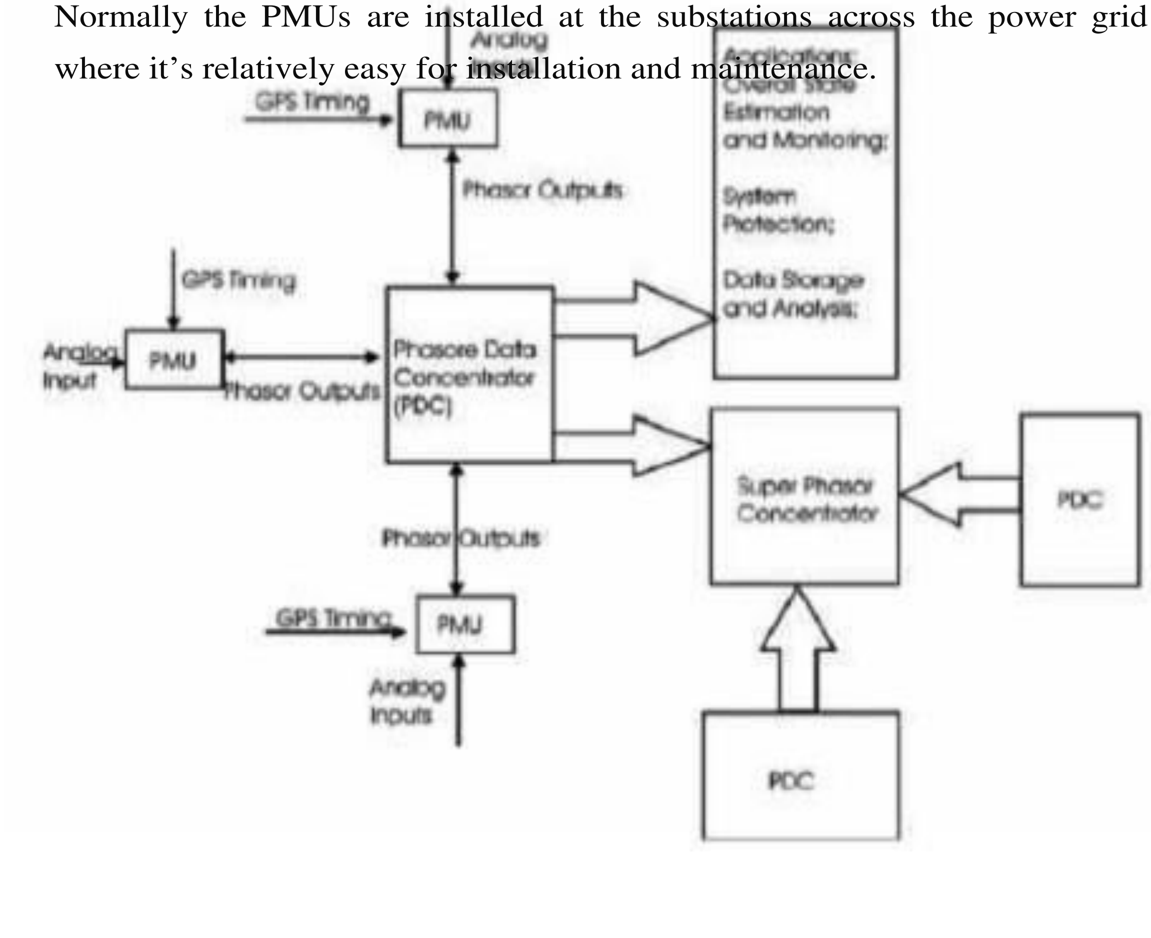
6. Policies for energy efficiency in public infrastructure including EV charging facilities by 2015 and for demand response ready appliances by 2017. Relevant policies in this regard to be finalized by 2014. **– 3 Marks**

UNIT-II

13. Discuss the need and benefits of Wide Area Monitoring System in Smart Grid(11) **(IT-1)**

WIDE AREA SYNCHROPHASOR MEASUREMENT (OR) MONITORING SYSTEM

Figure shows a typical wide area phasor measurement system. Normally the PMUs are installed at the substations across the power grid where it's relatively easy for installation and maintenance.



4 Marks

For wide area measurement system, PMUs measure voltage and current phasors and send them to a phasor data concentrator where the time stamped voltage and current data are processed. As the core component of the measurement system, the PDC collects data from a number of PMUs or other PDCs (A super PDC). The PDC correlates phasor data by its time tag and sample number resulting in a wide area measurement set synchronized in time other functions of the PDCs include performing quality checks on the data and inserting appropriate flags to indicate data quality as well as buffering the data stream internally and spooling it out to other utility applications. – **2 Marks**

Following are some of the benefits of WAMS technology:

(i) The Operators are additionally provided with online information at the right time for improved power system operation.

(ii) With real time information on angular separation between the buses and its voltages, transmission load ability in lines may be increased considerably, Therefore more power can be transmitted on existing lines and construction of new lines can be deferred and also resulting in better utilization of the existing transmission system/assets.

(iii) Early detection of critical conditions in the grid and accordingly taking corrective operational measures to avert grid disturbance.

(iv) Detection of power system oscillation by Synchrophasor technology would enable tuning of PSS/ voltage stabilizer and thereby healthy operation of the machines for a longer period.

(v) Improved knowledge of the power system conditions and corrective actions prevents excessive or unnecessary load shedding.

(vi) The relay operation characteristic can be validated in real time.

(vii) According to the behaviour of the real time system dynamics measure & monitored by the technology, Defence Plan/ Islanding scheme(s) can be designed to avert grid collapse.

(viii) The technology will provide more intelligence on network security and help to improve and maintain the robustness of the grid.

(ix) Objectives of secure, safe, reliable and smart grid operation will be achievable through WAMs technology. **– 5 Marks**

(OR)

14. Explain in detail about the Syhnchoro phasor Application in Smart Grid. (11) (IT-1)

PRINCIPAL APPLICATIONS AND BENEFITS OF SYNCHROPHASOR TECHNOLOGY

1.Situational awareness and wide-area monitoring:

The network of PMUs enable grid operators to see the bulk power system across an entire interconnection, understand grid conditions in real time, and diagnose and react to emerging problems. Analysts believe that synchrophasor-enabled visibility could have prevented the 2003 Northeast and the 1996 Western blackouts. As synchrophasor data quality improves, those data are being integrated into some existing control room visualization tools based on EMS and SCADA data, gaining acceptance for synchrophasor-enhanced wide-area monitoring.

-3 Marks

2.Real-time operations:

Synchrophasor data is being used to improve state estimator models for better understanding of real-time grid conditions. It is being used to detect and address grid oscillations and voltage instability, and integrated with SCADA and EMS data to drive real-time alarms and alerts. Analysts are looking at PMU data to expedite resolution of operating events such as fault

location, and quickly diagnose equipment problems such as failing instrument transformers and system imbalances.

More advanced applications use PMU data as an input to Special Protection Systems (SPS) or Remedial Action Schemes (RAS), and can trigger automated equipment controls. PMU data can be used to monitor and manage system islanding and black-start restoration. ERCOT is using PMUs to verify customers' performance in demand response events. **– 3 Marks**

3.Power system planning:

Good dynamic models allow a better understanding of how power systems respond to grid disturbances; better prediction enables better system planning with better grid and financial asset utilization. Synchrophasor data are particularly useful for validating and calibrating models of power plants, FACTS devices and other grid equipment, letting generators and grid operators comply with NERC Modeling standards with better results at lower cost. These data are also being used to improve system models, calibrating state estimators and dynamic system models and simulations. The Western Interconnection of North America has been a leader in using synchrophasor data for planning applications.

-3 Marks

4. Forensic event analysis:

Phasor data is invaluable for post-event analysis of disturbances an blackouts. Because synchrophasor data is time-stamped, it can be used to quickly determine the sequence of events in a grid disturbance, and facilitate better model analysis and reconstruction of the disturbance.

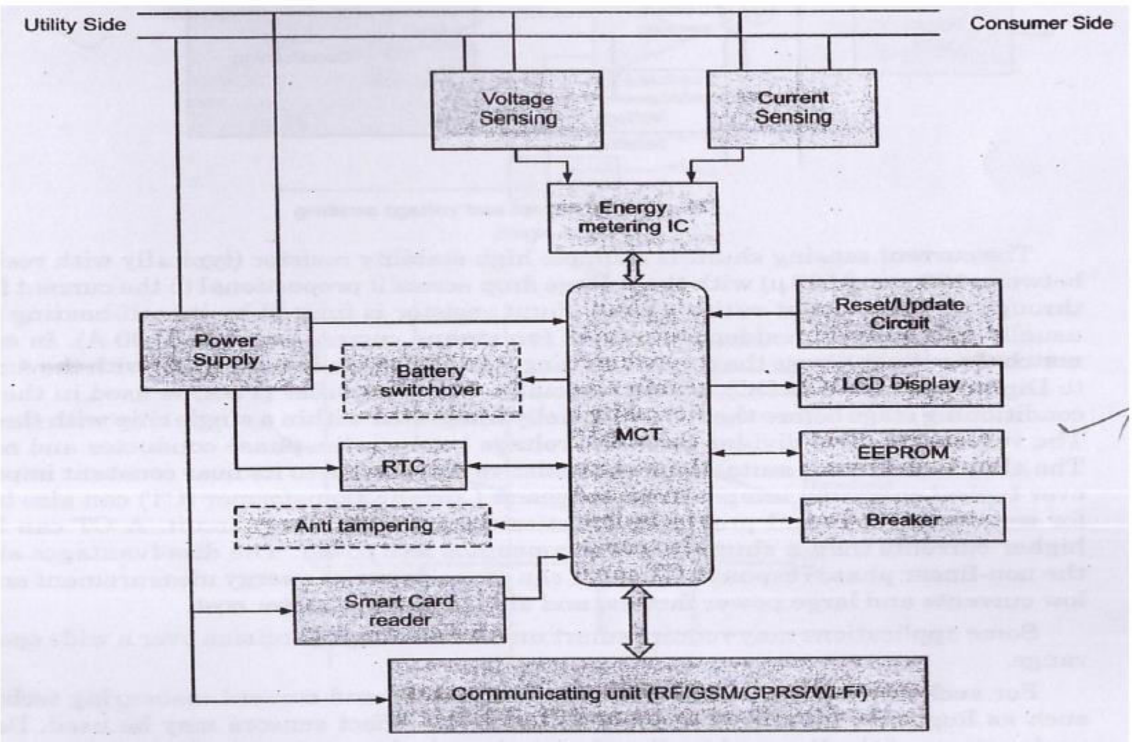
These enable a faster and deeper understanding of the disturbance causes and inform development of ways to avert such events in the future.

-2 Marks

UNIT - III

15. Explain the functional block diagram of a smart meter in detail and discuss in detail about the various utilities involved (11) **<u>(IT-2)</u>**

The replacement of electro-mechanical meters with electronic meters



offers several benefits Electronic meters not only can measure instantaneous power and the amount of energy consumed over time but also other parameters such as power factor, reactive power, voltage and frequency, with high accuracy. Data can be measured and stored at specific intervals.

Moreover, electronic meters are not sensitive to external magnets or orientation of the meter itself, so they are more tamper proof and more reliable. Early electronic meters had a display to show energy consumption but were read manually for billing purposes. More recently electronic meters with two-way communications have been introduced. Fig. provides a general functional block diagram of a smart meter. In the smart meter architecture has been split into five sections: signal acquisition, signal conditioning, Analogue to Digital Conversion (ADC), computation and communication

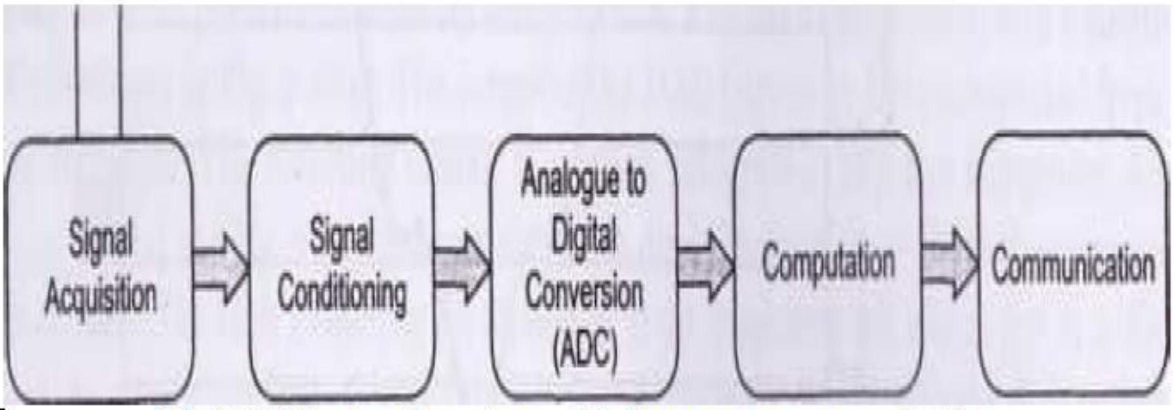


Fig 3.22 Electronic meters with Two-way communications

4 Marks

1.Signal Acquisition

A core function of the smart meter is to acquire system parameters accurately and Continuously for subsequent computation and communication. The fundamental electrical parameters required are the magnitude and frequency of the voltage and the magnitude and phase displacement (relative to the voltage) of current. Other parameters such as the power factor, the active/reactive power, and Total Harmonic Distortion (THD) are computed using these fundamental quantities. Current and voltage sensors measure the current into the premises (load) and the voltage at the point of supply.

2 Marks

2.Signal Conditioning

The signal conditioning stage involves the preparation of the input signals for the next step in the process, ADC. The signal conditioning stage may include addition/subtraction, attenuation/amplification and filtering. When it comes to physical implementation, the signal conditioning stages can be realized as discrete elements or combined with the ADC as part of an Integrated Circuit. Alternatively the stages can be built into 'System on a Chip' architecture with a number of other functions. In many circumstances the input signal will require attenuation, amplification or the addition/subtraction of an offset such that its maximum magnitude lies within the limits of the inputs for the ADC stage. To avoid inaccuracy due to aliasing, it is necessary to remove components of the input signal above the Nyquist frequency. **1 Mark**

3.Analogue to Digital Conversion

Current and voltage signals obtained from the sensors are first sampled and then digitized to be processed by the metering software. Since there are two signals (current and voltage) in a single phase meter, if a single ADC is used, a multiplexer is required to send the signals in turn to the ADC. The ADC converts analogue signals coming from the sensors into a digital form. As the number of levels available for analogue to digital conversion is limited, the ADC conversion always appears in discrete form.

4. Computation

The computation requirements are split into arithmetic operations on input signals, time stamping of data, preparation of data for communication or output peripherals, handling of routines associated with irregular input (such as payment, tamper detection), storage of data, system updates and coordinating different functions. The block diagram shown in Fig. 3.29 shows different functional blocks associated with the computation functions of a smart meter. **– 2 Marks**

5. Input/Output

A smart meter has a display that presents information in the form of text and graphs for -the human user. Liquid Crystal Displays (LCD) and the Light Emitting Diodes (LED) are preferred for their low cost and low power consumption requirements. Both display types are available in seven-segment, alphanumeric and matrix format. LEDs are relatively efficient light sources, as they produce a significant amount of light when directly polarized (at relatively low voltages: 1.2—1.6 V), and a current of a few milliamps is applied. Smart meters provide a small key pad or touch screen for human-machine interaction, for instance, to change the settings of a smart meter so as to select the smart appliance to be controlled or to select payment options.

6.Communication

Smart meters employ a wide range of network adapters for communication purposes. The wired options include the Public Switched Telephone Network (PSTN), power line carrier, cable modems and Ethernet. The wireless options include ZigBee, infrared, and GSM/GPRS/CDMA Cellular. **2 Marks**

(OR)

16. Discuss in detail about drivers and benefits of Advanced Metering Infrastructure over Automated Meter Reading (11) <u>(IT-1 & Model)</u>

ADVANCED METERING INFRASTRUCTURE BENEFITS & DRIVERS

The power grid has become a necessity in the modem society. Without a stable and reliable power grid, tens of millions of people's daily life will be degraded dramatically. With the development of information system and communication technology, many countries have been modernizing the aging power system into smart grid, which is featured with two way transmission, high reliability, real-time demand response, self-healing, and security. Within smart grid, Advanced Metering Infrastructure (AMI) plays a vital role and is associated with people's daily life most closely. AMI encompasses a whole electricity information network including Smart Meters on customer houses, communications to and from a utility, and eventually, communication to devices within a customer's home..

Advanced Metering Infrastructure comprises three key elements: Smart Meters, Meter Communication Infrastructure and Data Management. The combination of all three is vital to the development of a smart grid.

• Smart Meter Provides two-way communication between customer and utility, enabling functions such as outage detection, real time pricing and power quality monitoring.

• Meter Communication Infrastructure Describes the various methods of communication between meter and utility. These include power line communication (PLC), cellular (broadband or GPRS) and radio frequency (RF).

• Data Management Broadly covers managing all the data created by the meter - this includes transfer, storage and protecting privacy. – **5 Marks**

BENEFITS

The benefits of AMI are multifold and can be generally categorized as:

• **Operational Benefits:**

AMI benefits the entire grid by improving the accuracy of meter reads, energy theft detection and response to power outages, while eliminating the need for on-site meter reading. • Financial Benefits: AMI brings financial gains to utility, water and gas companies by reducing equipment and maintenance costs, enabling faster restoration of electric service during outages and streamlining the billing process.

• **Customer Benefits:**

AMI benefits electric customers by detecting meter failures early, accommodating faster service restoration, and improving the accuracy and flexibility of billing. Further, AMI allows for time-based rate options that can help customers save money and manage their energy consumption.

• **Security Benefits** - AMI technology enables enhanced monitoring of system resources, which mitigates potential threats on the grid by cyber-terrorist networks.

- **3 Marks**

DRIVERS

Despite its widespread benefits, deploying AMI presents three majors challenges that include high upfront investments costs, integration with other grid systems, and standardization.

1. High Capital Costs: A full scale deployment of AMI requires expenditures on all hardware and software components, including meters, network infrastructure and network management software, along with cost associated with the installation and maintenance of meters and information technology systems.

2. Integration: AMI is a complex system of technologies that must be integrated with utilities' information technology systems, including Customer Information Systems (CIS), Geographical Information Systems (GIS), Outage Management Systems (OMS), Work Management (WMS), Mobile Workforce Management (MWM), SCADA/DMS, Distribution Automation System (DAS), etc.

3. Standardization: Interoperability standards need to be defined, which set uniform requirements for AMI technology, deployment and general operations and are the keys to successfully connecting and maintaining an AMI-based grid system

- 3 Marks.

UNIT-IV

17. Discuss in detail with neat diagrams about the modulation and demodulation techniques adopted in a Smart Grid (11) <u>(QB)</u>

Certain applications require the transmission of data from one point to another and other uses may require the transmission of data from one point to multiple points. When a secure communication channel is required from one point to another, a dedicated link is used exclusively by the Source and Destination only for their communication. In contrast, when a shared communication channel is used, a message sent by the Source is received by all the devices connected to the shared channel. An address field within the message specifies for whom it is intended. Others simply ignore the message.

Figure shows a typical communication network used inside a substation. Each bay has a controller which takes the local measurements (e.g. from current and voltage transformers) and contains the software required for protection and control of the bay primary equipment (e.g.

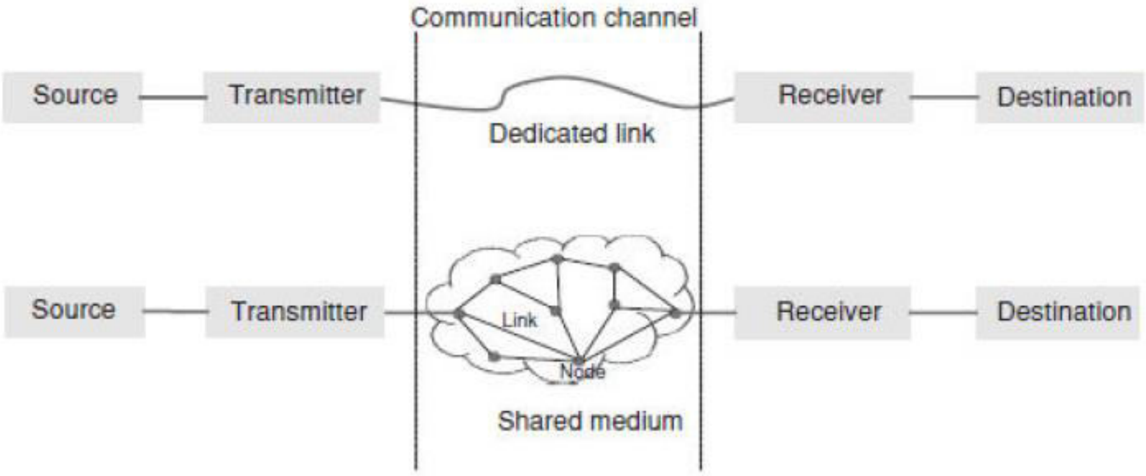


Figure 2.1 Model of simple point-to-point communication system

transformers and circuit breakers). These bay controllers are connected to substation control and monitoring equipment (station computer, RTUs) through a star or ring connection as shown in Figures a and b. In the star connection (Figure a), each bay controller has a dedicated link to the station computer. In the ring connection (Figure b), the bay controllers and the station computer are connected through a shared medium to form a Local Area Network (LAN).

-5 Marks

Dedicated communication channels are used for differential protection of transmission lines. The communication channel is used to transmit a signal corresponding to the summation of the three line currents (they are added using a

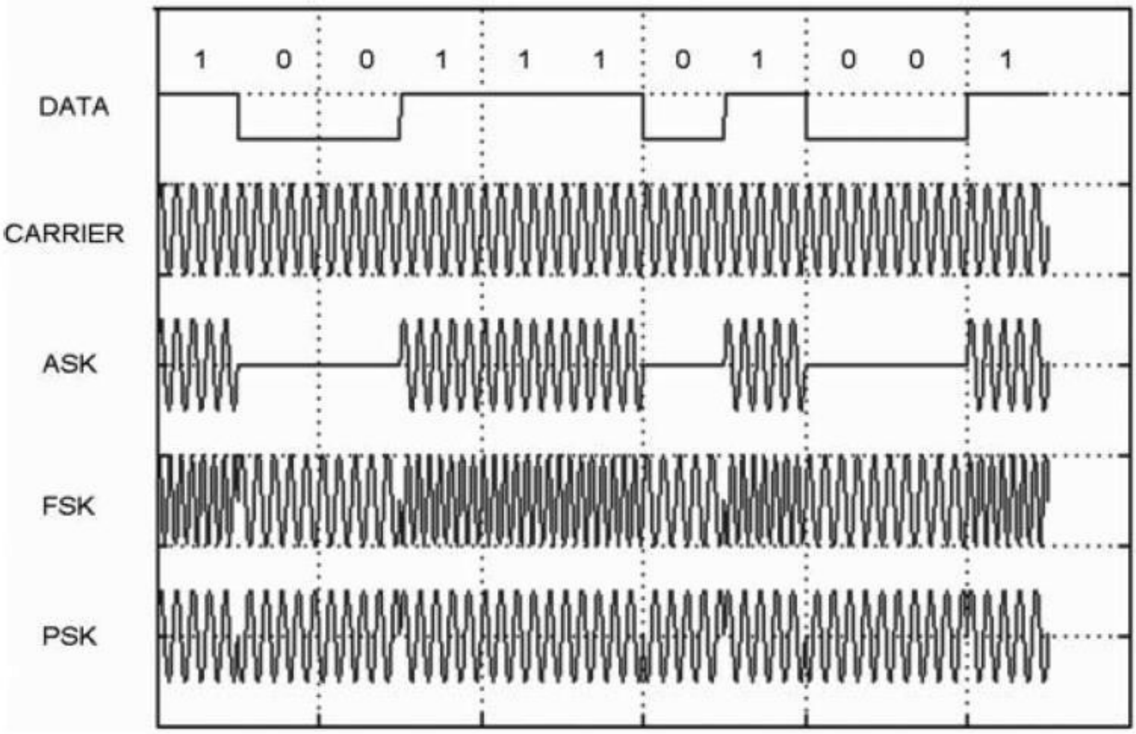


Figure 2.4 Modulation of carrier signals by digital bit streams

summation transformer) at one relaying point to another for comparison with similar signal at that point.

The modulation techniques usually employed are: Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK) . In ASK, the carrier frequency remains constant and the digital information is encoded in changes to carrier amplitude, as shown in Figure 2.4. In both FSK and PSK, the carrier amplitude remains constant with changes in the carrier frequency, or the phase of the carrier signal being used to modulate the digital information. Figure 2.5 shows a shared communication channel inside a substation that uses a multidrop connection arrangement.

The substation computer sends messages addressed to one or more IEDs; each IED takes its turn to communicate with the substation computer to avoid conflicts that could arise due to simultaneous access to the shared medium. In Figure 2.5, analogue measurements from the CT are first digitized using an encoder (situated inside the IED). The simplest and most widely used method of digitizing is Pulse Code Modulation (PCM) where the analogue signal is sampled at regular intervals to produce a series of pulses. These pulses are then quantized by assigning a discrete value as shown in Figure 2.6. This discrete value is then converted to a binary number that results in a bit stream which is subjected to further encoding depending upon the transmission medium used.

-6 Marks

(OR)

18. Explain in detail about the Radio and Power line Communication technologies involved in Smart Grid.(11) (Model)

RADIO COMMUNICATION

The substations of power networks are often widely distributed and far from the control centre. For such long distances, the use of copper wire or fibre optics is costly. Radio links provide an alternative for communication between the Control Centre and substations. Even though radio communication cannot provide the bandwidth offered by wired technology, the reliability, performance and running costs of radio networks have improved considerably over the past few years, making it an attractive option.

Radio communication may be multipoint or point-to-point, operating typically either at UHF frequencies (between 300 MHz and 3 GHz) or microwave frequencies (between 3 and 30 GHz).

1. Ultra high frequency

UHF radio represents an attractive choice for applications where the required bandwidth is relatively low and where the communication end-points are widespread over harsh terrain. It uses frequencies between 300

MHz and 3 GHz. Unlike microwave radio, UHF does not require a line of sight between the Source and Destination. The maximum distance between the Source and Destination depends on the size of the antennae and is likely to be about 10–30 km with a bandwidth up to 192 kbps.

2. **Microwave radio**

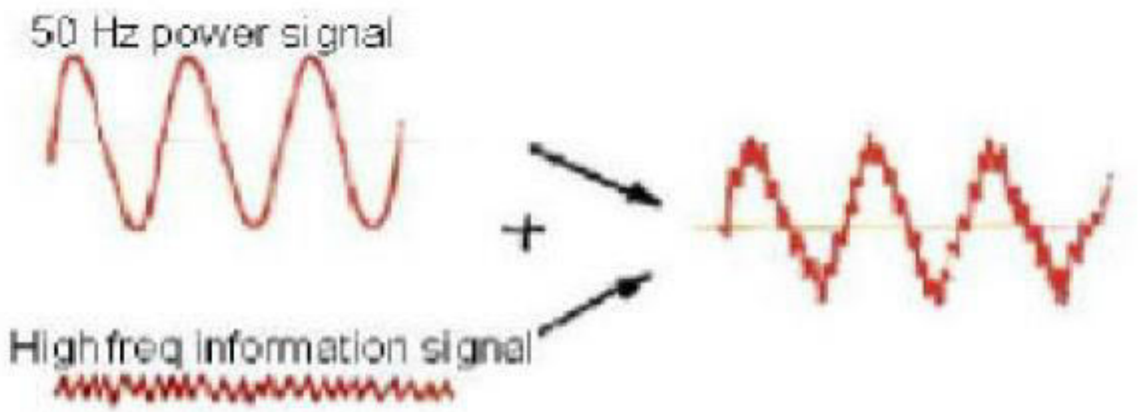
   Microwave radio operates at frequencies above 3 GHz, offering high channel capacities and transmission data rates. Microwave radio is commonly used in long-distance communication systems. Parabolic antennas are mounted on masts and towers at the Source to send a beam to another antenna situated at the Destination, tens of kilometres away. Microwave radio offers capacity ranging from a few Mbps to hundreds of Mbps. However, the capacity of transmission over a microwave radio is proportional to the frequency used, thus, the higher the frequency, the bigger the transmission capacity but the shorter the transmission distance. Microwave radio requires a line of sight between the Source and Destination, hence, high masts are required. In case of long-distance communications, the installation of tall radio masts will be the major cost of microwave radio. **-5 Marks**

POWER LINE COMMUNICATION

Power Line Communication is a communication technology that enables transferring data over AC power wiring. So there is no need to any additional wiring for communication network. Communication is achieved by adding a high frequency signal at low energy levels over the electric signal and the second signal is propagated through the power network to the receiving end. Electrical devices can be easily interconnected and managed through power lines.

Power line communication (PLC) carries data on a conductor that is also used simultaneously for AC electric power transmission or electric power distribution to consumers. Power line communication (PLC) leverages the existing power line infrastructure and provides costeffective approach for introducing intelligent monitoring and control to many industrial applications. It makes PLC one of the leading enabling technologies for Smart Grid applications ranging from smart metering, lighting control, solar, plug-in electrical vehicle home and building automation of heat and air conditioning, and security.

The principle of PLC is that a high frequency information signal is added ('modulated') to the 50Hz power flow signal ('carrier signal') at the sending end and is removed at the receiving end('de-modulated'), as shown in the following diagram:



3 Marks

PLC is appealing because there is no need to run additional wires to powered devices. PLC can also work where radio frequency (RF) cannot. For example smart meters in the basement of a building basement are unlikely to be able to use RF to communicate with the neighborhood data concentrator. PLC communication on the other hand can traverse the power wires to reach the data concentrator.

There are three primary challenges to reliable communications: high attenuation on the power line, the presence of noise sources on the power line, and channel distortion. There are two main modulation technologies for PLC- Spread Frequency Shift Keying (SFSK) and Orthogonal Frequency Division Multiplexing (OFDM), of which OFDM based ones are the latest. The most widespread PLC techniques on the market is spread frequency shift keying (S- FSK). S-FSK also known as IEC 61334 is a standard for low-speed reliable power line

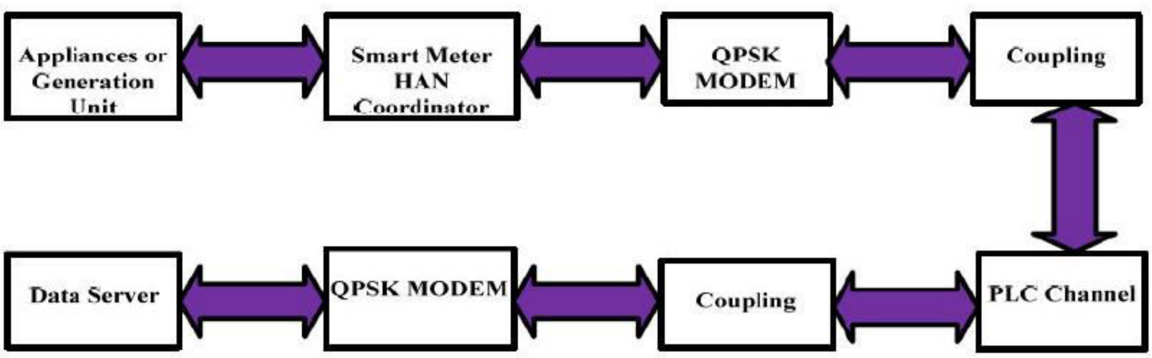


Fig.3. Block Diagram of QPSK Based on PLC Network For Smart Micro-Grid

communications.

Even though by using PLC we are taking advantage of the existing power line infrastructure one should keep in mind that communication quality can be affected by varying power line impedances, load, and electromagnetic interferences. Typically data signals cannot propagate through transformers and hence the power line communication is limited within each line segment between transformers. Data rates on power lines vary from a few hundred of bits per second to millions of bits per second, in a reverse proportional relation to the power line distance. Power line communication is appealing because it uses the existing power line infrastructure.

The basic block diagram of QPSK based on network for proposed Smart MicroGrid is shown in Fig.3. Data server was developed to allow multiple PLC connections to smart grid and flexible control over the message exchange between users and smart micro-grid. **3 Marks**

UNIT-V

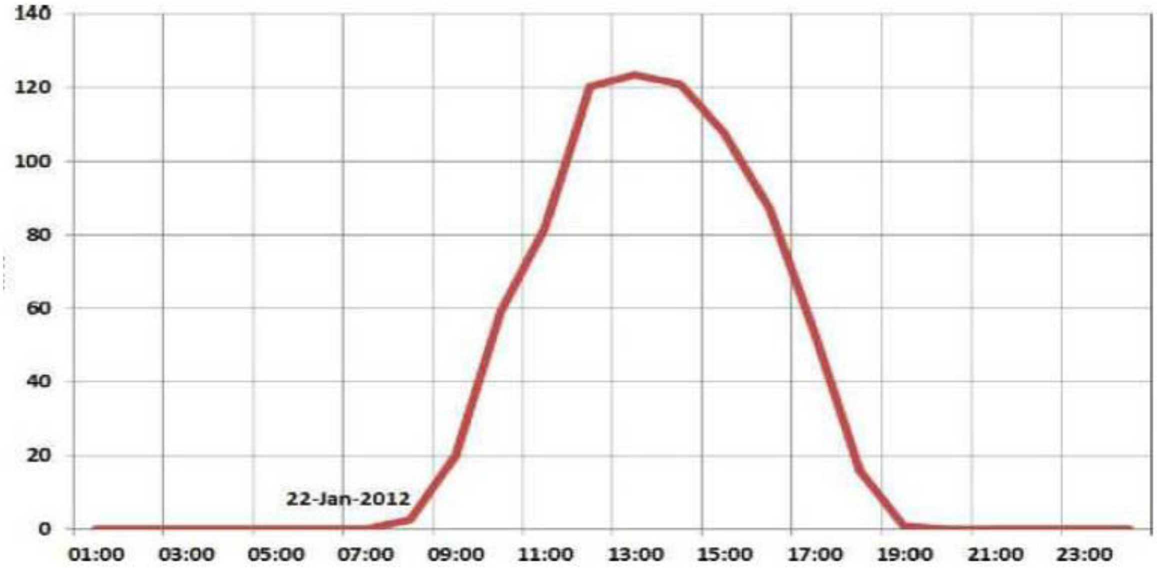
19. Discuss in detail about the various issues of renewable energy source integration when coordinated with the Smart Grid.(11) (QB)

Renewable Energy Integration focuses on incorporating renewable energy, distributed generation, energy storage, thermally activated technologies, and demand response into the electric distribution and transmission system. A systems approach is being used to conduct integration development and demonstrations to address technical, economic, regulatory, and institutional barriers for using renewable and distributed systems. In addition to fully addressing operational issues, the integration also establishes viable business models for incorporating these technologies into capacity planning, grid operations, and demand-side management.

The goal of Renewable energy integration is to advance system design, planning, and operation of the electric grid to:

- Reduce carbon emissions and emissions of other air pollutants through increased use of renewable energy and other clean distributed generation.
- Increase asset use through integration of distributed systems and customer loads to reduce peak load and thus lower the costs of electricity.

• Support achievement of renewable portfolio standards for renewable energy and energy efficiency.



• Enhance reliability, security, and resiliency from Micro-grid applications in critical infrastructure protection and highly constrained areas of the electric grid.

• Support reductions in oil use by enabling Plug-In Electric Vehicle (PHEV) operations with the grid, **- 5 Marks**

Consequently, renewable energy resources and DG's are receiving support and their shares in electricity generation are rapidly rising. The growing renewable generation in an inflexible system is the key challenge for developers and practitioners of smart grid system.

The addition of DG to the electrical distribution system has been the key driver in the evolution of distributed system; however DG hardly gets any market signals nor participates in system management for two reasons. Firstly, DG is often from renewable energy sources and therefore organized on the basis of priority under fixed feed-in tariffs and not obligated from market prices. Secondly, generators in distribution networks are often too small and not equipped with technology. Furthermore, one of the problems experienced is that the increasing renewable shares may cause congestion in distribution networks

In recent years, the utilization of renewable energy sources in smart grid system has been increasing. The quest for cleaner, green and more reliable energy sources has considerable implications to the existing power transmission and distribution system. Traditionally the power is generated in bulk and distributed to the large load centers via the transmission lines. The transfer of power was always one way, which is from the utilities to the consumers. Now in the immediate future, renewable energy sources cannot support the entire grid by themselves.

Renewable energy system is an innovative option for electricity generation, especially the PV system as it is a clean energy resource. However, to achieve a goal, a lots of issues need to be solved or addressed. These issues are basically related to the design and size of the system, the suitable and effective model which can cover the technical and financial aspects of PV smart grid to supply electricity, and the equalized electricity price for integrating PV in a smart grid system. Further nanotechnology based solutions and applications in the devices/components could help us in near future for improving the efficiency using smart grid. – **6 Marks**

(OR)

20. Explain the benefits, challenges involved in adopting Flow Batteries, Fuel Cell in Smart Grid. (11) **(Model)**

FLOW BATTERY

A flow battery uses two electrolytes, often different kinds of the same chemical compound. Both the positive and negative electrolytes are stored separately and are pumped through a cell. Inside the cell, the two electrolytes are kept separate. The electrochemical reaction takes place by transferring ions across a membrane as shown in Figure. The electrodes do not take part in the chemical reaction and thus do not deteriorate from repeated cycling.

-3 Marks

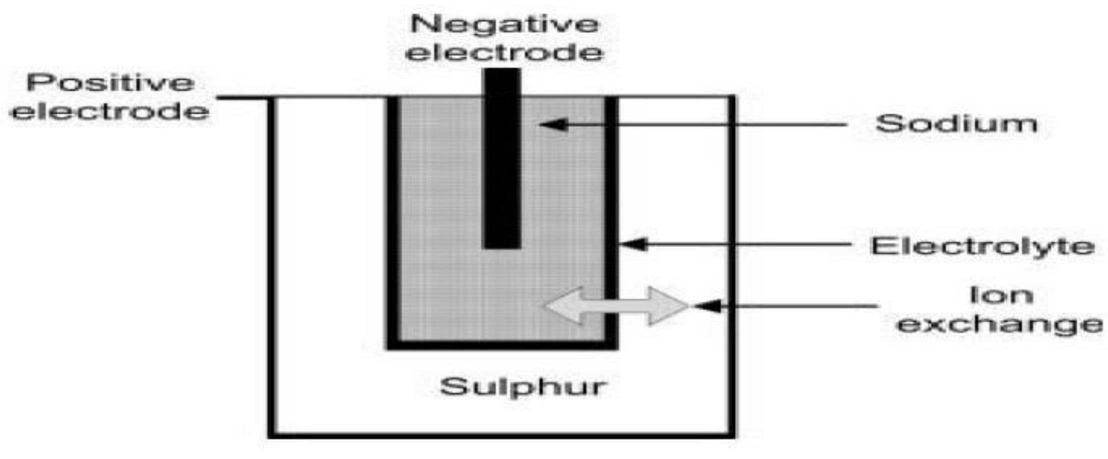
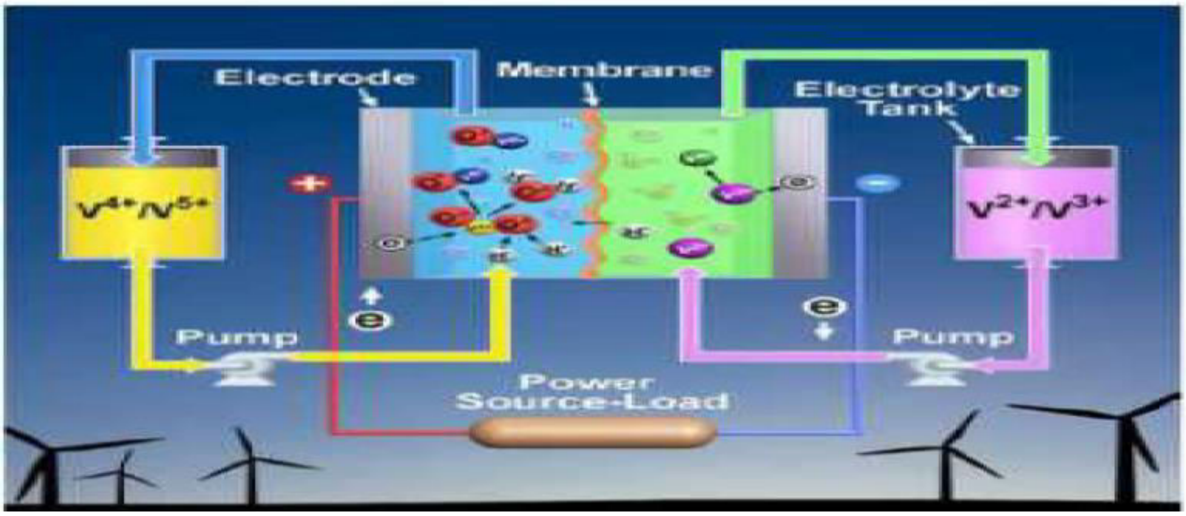


Fig : A NaS Battery

The amount of energy stored in a flow battery depends on the volume of the electrolyte in the tanks whereas the power output depends on the speed of ion transfer across the membrane. Flow batteries using Zinc Bromide (ZBB) and Vanadium Redox (VRB) are available. A ZBB consists of a zinc negative electrode and a bromine positive electrode separated by a micro porous membrane. An aqueous solution of zinc bromide (ZnBr) is circulated through the two compartments of the cell from two separate reservoirs as shown in Figure. On discharge, the zinc is oxidised, giving zinc ions, and the bromine is reduced to bromide ions. During charging, zinc is electroplated on the negative electrode and bromine is evolved at the positive electrode; this is stored as a chemically complex organic phase at the bottom of the positive electrolyte tank. A third pump is used for recirculation of the organic phase during the discharge cycle.



Applications

- Load balancing
- Storing energy from renewable sources
- Peak shaving, where spikes of demand are met by the battery.
- UPS, where the battery is used if the main power fails to provide an uninterrupted supply.
- Power conversion – because all cells share the same electrolyte/s.
- Electric vehicles – Because flow batteries can be rapidly "recharged"
- Stand-alone power system **- 3 Marks**

FUEL CELL

Similar to a battery, a fuel cell is a device that converts chemical energy directly into electrical energy. However, unlike batteries, with non-stop supply of fuels, fuel cell can run forever and produce steady supply of electrical energy. The two basic components used to run a fuel cell are hydrogen and oxygen. They react inside the fuel cell to generate electricity heat and water. This new energy source will never be used up as we have unlimited supply of oxygen on Earth. Hydrogen can be produced from water, gasoline, natural gas, landfill gas, coal based gas, methane, methanol and ethanol.

Most of the fuel cells use hydrogen and oxygen as their main fuel. At the negative electrode hydrogen is oxidized to form proton and electron. The electrons flow through the external electrical circuit whereas the hydrogen ions move towards the positive electrode through the electrolyte. The positive electrode is made from a porous material coated with a catalyst. At that electrode, the hydrogen ions combine with oxygen to produce water

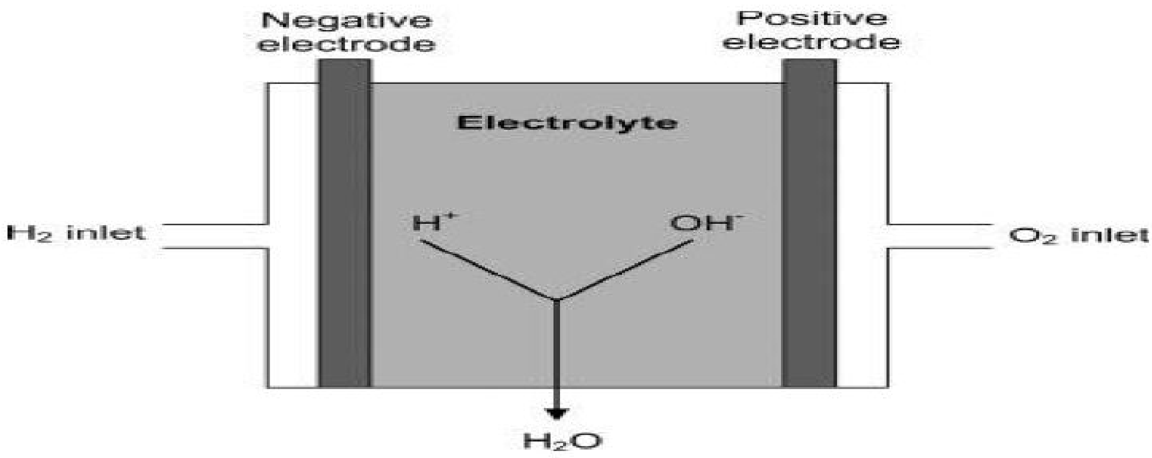


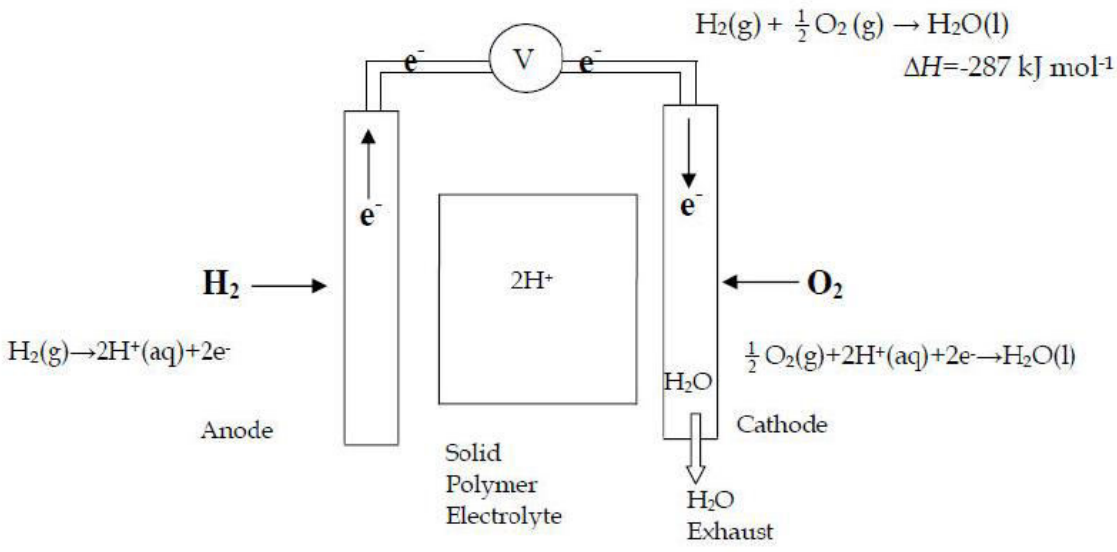
Fig : Fuel Cell

Working

A fuel cell consists of two electrodes, the anode and the cathode, separated by an electrolyte. Thin layer of platinum or other metals, depending on the type of the fuel cell, is coated on each electrode to activate the reaction between oxygen and hydrogen when they pass through the electrodes.

The overall reaction is shown by the equation below:

H2(g) + 1/2 O2 (g) → H2O(l) Δ H=-287 kJ mol-1



-3 Marks

TYPES

There are five major types of fuel cells being known or used in the market.

. ♦ Alkaline Fuel Cell (AFC)

♦ Phosphoric Acid Fuel Cell (PAFC)

♦ Molten Carbonate Fuel Cell (MCFC)

♦ Solid Oxide Fuel Cell (SOFC)

♦ Proton Exchange Membrane Fuel Cell (PEMFC)

APPLICATIONS

a. Space Exploration
b. Transportation
c. Stationary and Residential Applications
d. Portable Power for Electronics
e. Distributed generation
f. Emergency power systems
g. Hybrid vehicles,
h. Smartphones, laptops and tablets **-2 Marks**