A Learning Manual for

Emerging Trends in Electrical Engineering

(22628)

Semester– VI

(EE/EP/EU)

Maharashtra State

Board of Technical Education, Mumbai

(Autonomous) (ISO:9001:2015) (ISO/IEC 27001:2013)

Maharashtra State
Board of Technical Education, Mumbai

(Autonomous) (ISO:9001:2015) (ISO/IEC 27001:2013)

4th Floor, Government Polytechnic Building, 49, Kherwadi,
Bandra (East), Mumbai -400051.

Maharashtra State
Board of Technical Education

Certificate

This is to certify that Mr. / Ms. ……………………………………. Roll No……………………….of ……….. Semester of Diploma in……..……………………..…………………………….of Institute ……………………………………….………(Code………………..) has attained pre-defined practical outcomes(PROs) satisfactorily in course **Emerging Trends in Electrical Engineering Group (22628)** for the academic year 20…….to 20…..... as prescribed in the curriculum.

Place ………………. Enrollment No……………………
Date:…..................... Exam Seat No. …………………......

Course Teacher **Head of the Department** **Principal**

Seal of the Institute

Preface

The primary focus of any engineering work in the technical education system is to develop the much needed industry relevant competency & skills. With this in view, MSBTE embarked on innovative "I" scheme curricula for engineering diploma programmes with outcome based education through continuous inputs from socio economic sectors. The industry experts during the consultation while preparing the Perspective Plan for diploma level technical education categorically mentioned that the curriculum, which is revised and implemented normally further revised after 4-5 years. The technological advancements being envisaged and faced by the industry in the present era are rapid and curriculum needs to be revised by taking care of such advancements and therefore should have a provision of accommodating continual changes. These views of industry experts were well taken & further discussed in the academic committee of MSBTE, wherein it was decided to have a dynamism in curriculum for imparting the latest technological advancements in the respective field of engineering. In order to provide an opportunity to students to learn the technological advancements, a course with a nomenclature of "Emerging Trends in Electrical Engineering" is introduced in the 6th semester of Electrical Engineering Group.

The technological advancements to be depicted in the course called emerging trends was a challenging task and therefore it was decided to prepare a learning material with the involvement of industrial and academic experts for its uniformity in the aspect of delivery, implementation and evaluation.

Over the coming year's technological developments through the use of the internet and other forms of communication along with the smart controls of the various day to day activities will have a significant impact in the world of work and employment triggering far reaching changes. This dynamic course will give insight to the recent practices adopted by the Industries and awareness of these techniques will enhance career opportunities of Diploma in Electrical Engineering pass outs. The manual consists of five units viz. Digitization beyond automation, Smart Grid, Smart City (Electrical Features), Intelligent Motor Control Centers and Tariff, Metering and Billing. Each chapter essays to give an insight to the learner about the latest developments in the relevant fields.

This learning manual is designed to help all stakeholders, especially the students and teachers and to develop in the student the pre-determined outcomes. It is expected to explore further by both students and teachers, on the various topics mentioned in learning manual to keep updated themselves about the advancements in related technology.

MSBTE wishes to thank the Learning Manual development team, specifically Mr. S.A. Gaikwad, Chairman of the Course Committee, Industry Experts, Dr. S.S. Bharatkar Co-ordinator, Mr. V.K.Harlapur, Co-coordinator of the Programme and academic experts for their intensive efforts to formulate the learning material on "Emerging Trends in Electrical Engineering". Being emerging trend and with the provision of dynamism in the curricula, any suggestions towards enrichment of the topic and thereby course will be highly appreciated.

(Dr. Vinod M.Mohitkar)
Director
MSBTE, Mumbai

List of Content

Unit I

Digitization beyond automation

This unit focuses on following aspects:

1.1 Industrial Revolutions:

Versions 1.0, 2.0, 3.0 and 4.0; the driving energies/powers for these revolutions.

1.2 Components of Industrial Revolution 4.0: CPS (Cyber Physical Systems), IoT (Internet of Things), Cloud Computing and Cloud Manufacturing.

1.3 IoT principle and features.

1.4 IoT application areas in electrical systems: building automation SCADA, Smart metering, Illumination systems (public lighting).

1.5 IoT initiatives in power distribution systems.

1.1 Industrial Revolutions:

1.1.1 Introduction

Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum and author of The Fourth Industrial Evolution describe an industrial evolution as the appearance of "new technologies and novel ways of perceiving the world which triggered a profound change in economic and social structures."

The first industrial revolution began with the mechanization and mechanical power generation in 1800s. It brought the transition from manual work to the first manufacturing processes; mostly in textile industry. It is characterized by use of water and steam to mechanize production, an improved quality of life was a main driver of the change.

The second industrial revolution was triggered by electrification that enabled industrialization and mass production.

The third industrial evolution is characterized by the digitalization with introduction of electronics, IT and automation. In manufacturing this facilitates flexible production, where a variety of products is manufactured on flexible production lines with programmable machines.

The fourth industrial evolution is the IoT, robotics, Augmented Reality (AR) Virtual Reality (VR) and Artificial Intelligence (AI) are changing the way we live and work. Fig. 1.1 shows the industrial revolutions from 1 to 4.

It began at the turn of this century and builds on the digital revolution. It is characterized by a much more global and mobile Internet, by smaller and more powerful sensors that have become cheaper, and by artificial intelligence and machine learning. The world is at the cusp of the fourth industrial evolution. It is current and developing environment in which disruptive technologies and trends such as the Internet, AI, IoT, Autonomous Vehicles, 5G Telephony, Nanotechnology, Biotechnology, Robotics, Quantum 3D printing, Cloud Computing and the like marked the era of 4^{th} industrial evolution..

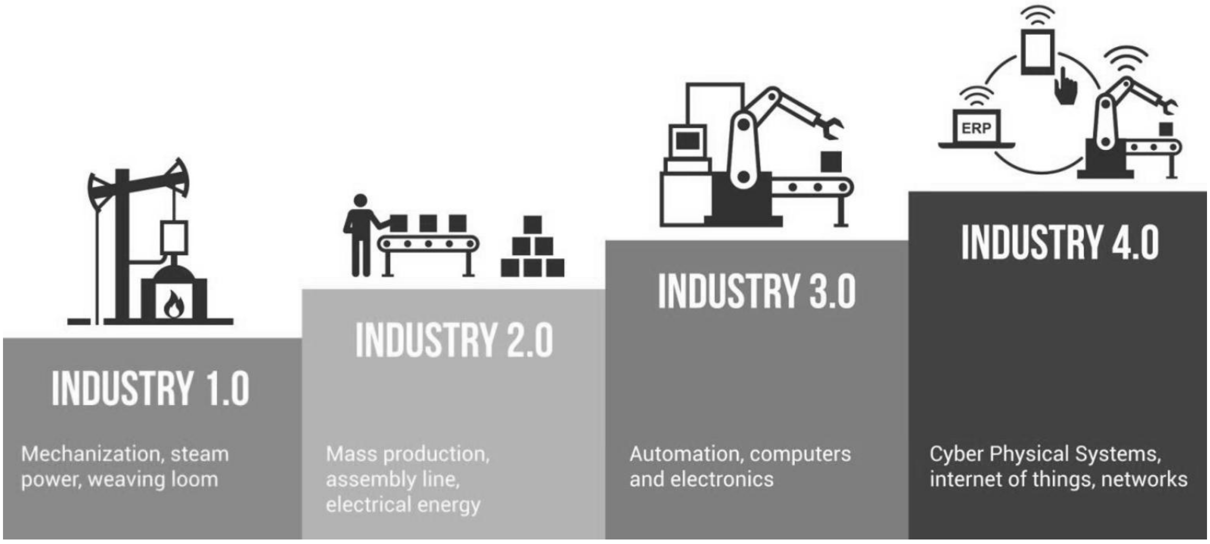


Fig. 1.1: The industrial revolutions from 1 to 4.

1^{st} Industrial Evolution: Agrarian societies to Mechanized production. The first industrial revolution began in the 18th century involved a change from mostly agrarian societies to greater industrialization as a consequence of the steam engine and other technological developments. It is marked by a transition from hand production methods to machines through the use of steam power and water power. It is started with use of steam power and mechanization of production. It is also called as the Age of Mechanical Production. Its effects had consequences on textile manufacturing, which was first to adopt such changes, as well as iron industry, agriculture, and mining. What before produced threads on simple spinning wheels, the mechanized version achieved eight times the volume in the same time using Steam power.

The use of it for **industrial purposes** was the greatest breakthrough for **increasing human productivity**. Instead of weaving looms powered by muscle, **steam-engines** were used for **power**. Through the advent of the steam engine, the focus has shifted from agriculture to textile manufacturing. But with steam power, those agrarian societies gave way to urbanization.

Developments such as the **steamship** or the **steam-powered locomotive** brought about further massive changes because humans and goods could move great distances in fewer hours. The world began to rely on steam power and machine tools, while steamships and railroads revolutionized how people got from A to B and what emerged as the new center of community life? Ultimately, advancing industrialization created a middle class of skilled workers. Cities and industries grew more quickly than ever before, and economies grew along with them.

2nd Industrial Revolution: The Age of Science and Mass Production

The **Second Industrial Evolution** better known as the technological evolution is the period between 1870 and 1914. It began with the discovery of **electricity** and **assembly line production. Henry Ford** took the idea of **mass production** from a slaughterhouse in Chicago: The pigs hung from conveyor belts and each butcher performed only a part of the task of butchering the animal. Henry Ford carried over these principles into **automobile production** and drastically altered it in the process. By the early part of the 20th century, Henry Ford's company was mass producing the groundbreaking Ford Model T, a car with a gasoline engine built on an assembly line in his factories.

While before one station assembled an entire automobile, now the vehicles were produced in partial steps on the conveyor belt **- significantly faster** and at **lower cost.** It was made possible with the extensive railroad networks and the telegraph which allowed for faster transfer of people and ideas. It is also a period of great economic growth, with an increase in productivity. It, however, caused a surge in unemployment since many workers were replaced by machines in factories.

Things started to speed up with a number of key inventions. Think gasoline engines, airplanes, chemical fertilizer. All inventions that helped us go faster and do more. But advancements in science weren't limited to the laboratory. Scientific principles were brought right into the factories. Most notably, the assembly line, which effectively powered mass production.

People follow the jobs, and the early 1900s saw workers leaving their rural homes behind to move to urban areas and factory jobs. By 1900, 40% of the population lived in cities, compared to just 6% in 1800. Along with increasing urbanization, inventions such as electric lighting, radio, and telephones transformed the way people lived and communicated.

3rd Industrial Evolution: Digital Revolution

The **Third Industrial Evolution** called the digital revolution involved the development of computers and Information Technology (IT) since the middle of the 20th century. This began in the 70's of the 20th century through **partial automation** using **memory-programmable controls** and **computers**. Since the introduction of these technologies, user can now able to **automate** an entire **production process -** without human assistance. Known examples of this are **robots** that perform programmed sequences without human intervention.

The third industrial evolution or Industry 3.0 occurred, after the end of the two big wars, as a result of a slowdown with the industrialization and technological advancement compared to previous periods. It is also called digital evolution. The global crisis in 1929 was one of the negative economic developments which had an appearance in many industrialized countries from the first two evolutions.

The production of Z1 (electrically driven mechanical calculator) was the beginning of more advanced digital developments. This continued with the next significant progress in the development of communication technologies with the supercomputer. In this process, where there was extensive use of computer and communication technologies in the production process. Machines started to abolish the need for human power in life.

Beginning in the 1950s, the third industrial evolution brought semiconductors, mainframe computing, personal computing, and the Internet—the digital evolution. Things that used to be analog moved to digital technologies, like an old television you used to tune in with an antenna (analog) being replaced by an Internet-connected tablet that lets you stream movies (digital).

The move from analog electronic and mechanical devices to pervasive digital technology dramatically disrupted industries, especially global communications and energy. Electronics and information technology began to automate production and take supply chains global.

Fourth Industrial Evolution: Cyber Physical Systems, IoT and Networks:

The **Fourth Industrial Evolution is** characterized by the application of **information** and **communication technologies** to **industry** and is also known as **"Industry 4.0".** It builds on the developments of the **Third Industrial Evolution** but considered as new era because of the explosiveness of its development and the disruptiveness of its technologies.

Origin of Industry 4.0 concept comes from Germany, since Germany has one of the most competitive manufacturing industries in the world and is even a global leader in the sector of manufacturing equipment. Industry 4.0 is a strategic initiative of the German government that traditionally supports development of the industrial sector. In this sense, Industry 4.0 can be seen also as an action towards sustaining Germany's position as one of the most influential countries in machinery and automotive manufacturing.

The basic concept was first presented at the Hannover fair in the year 2011. Since its introduction, Industry 4.0 is in Germany a common discussion topic in research, academic and industry communities at many different occasions. The main idea is to exploit the potentials of new technologies and concepts such as:

1. Availability and use of the internet and IoT,
2. Integration of technical processes and business processes in the companies,
3. Digital mapping and virtualization of the real world,
4. ‘Smart’ factory including ‘smart’ means of industrial production and ‘smart’ products.

Besides being the natural consequence of digitalization and new technologies, the introduction of Industry 4.0 is also connected with the fact that, many up to now exploited possibilities for increasing the profit in the industrial manufacturing are almost exhausted and new possibilities have to be found. Namely the production costs were lowered with introduction of just-in-time production, by adopting the concepts of lean production and especially by outsourcing production to countries with lower work costs. When it comes to the decreasing costs of industrial production, Industry 4.0 is a promising solution.

Advantages and reasons for the adoption of this concept including:

1. A shorter time-to-market for the new products,
2. An improved customer responsiveness,
3. Enabling a custom mass production without significantly increasing overall production costs,
4. More flexible and friendlier working environment, and
5. More efficient use of natural resources and energy.

Production systems that already have **computer technology** are expanded by a **network connection** and have a **digital twin** on the Internet so to speak. These allow communication with other facilities and the output of information about themselves. This is the next step in **production automation**. The **networking** of all systems leads to **"cyber-physical production systems"** and therefore **smart factories,** in which **production systems, components** and **people** communicate via a **network** and **production is nearly autonomous.**

The advent of 5G telecommunication technologies will make real-time downloads possible. This will enable a whole host of things, such as a majority of driverless cars plying on the roads, and talking to each other using the IoT. The autonomous vehicle, enabled by 5G technology, will result in a lower demand for automobiles and release parking space for parks.

When combined with an increasing population of non-polluting electrical vehicles, it will benefit the environment.

The electrical vehicles will be powered by renewable energy, and the use of fossil fuel would reduce. The cost of solar panels is likely to drop. Real-time speeds using 5G would allow devices to be connected and to communicate with each other through the IoT. Thus cars on the road will talk to each other, avoiding accidents. Machines in factories will talk to each other, leading to productivity gains.

1.1.2 Benefits of Industry 4.0

The main benefits of industry 4.0 are:

1. **Improved Efficiency and thus Productivity: Industry** enables you to do more with less. That is, user can produce more and faster while allocating your resources more cost-effectively and efficiently. User production lines will also experience less downtime because of enhanced machine monitoring and automated/semi-automated decision-making. Overall Equipment Effectiveness will improve as your facility moves closer to becoming an Industry 4.0 Smart Factory.

Multiple areas of user production line will become more efficient as a result of Industry 4.0-related technologies. These efficiencies are less machine downtime, the ability to make more products and make them faster. Other examples of improved efficiency include faster batch changeovers, automatic track and trace processes, and automated reporting. New Product Introductions also become more efficient as does business decision making and more.

2. **Increased Knowledge Sharing and Collaborative Working:** Traditional manufacturing plants operate individually and in isolation. This results in minimal collaboration or knowledge sharing. Industry 4.0 technologies allow your production lines, business processes, and departments to communicate regardless of location, time zone, platform, or any other factor. This enables, for example, knowledge learned by a sensor on a machine in one plant to be disseminated throughout your organization.

Best of all, it is possible to do this automatically, i.e. machine-to-machine and system-to-system, without any human intervention. In other words, data from one sensor can instantly make an improvement across multiple production lines located anywhere in the world.

3. **Flexibility and Agility:** The benefits of Industry 4.0 also include enhanced flexibility and agility. For example, it is easier to scale production up or down in a Smart Factory. It is also easier to introduce new products to the production line as well as creating opportunities for one-off manufacturing runs, high-mix manufacturing, and more.

4. Better Customer Experience: Industry 4.0 also presents opportunities to improve the service you offer to customers and enhance the customer experience. For example, with automated track and trace capabilities, you can quickly resolve problems. In addition, you will have fewer issues with product availability, product quality will improve, and you can offer customers more choice.

5. Cost Reduction: Becoming a Smart Factory does not happen overnight, and it won't happen on its own. To achieve it, you need to invest, so there are upfront costs. However, the cost of manufacturing at your facilities will dramatically fall as a result of Industry 4.0 technologies, i.e. automation, systems integration, data management, and more.

Primary drivers for these reduced costs include:

a. Better use of resources
b. Faster manufacturing
c. Less machine and production line downtime
d. Fewer quality issues with products
e. Less resource, material, and product waste
f. Lower overall operating costs

6. Better return on Investment: Industry 4.0 technologies are transforming manufacturing across the world. The benefits of Industry 4.0 and potential return on investment are what is truly important, though. To stay competitive and equip your production lines for the future, the time to think about the next stage of your Industry 4.0.

7. Machine downtime reductions: Predictive maintenance in Industry 4.0 means that equipment failure will be identified before it occurs. Systems can spot repetitive patterns that precede failures, notify your teams and have them schedule an inspection. Such systems also learn over time, becoming capable to spot even more granular changes and help you continuously optimize your production process.

8. Improved supply/demand matching: Cloud-based inventory management solutions enable better interactions with suppliers. Instead of operating in "individual silo", user can create seamless exchanges and ensure those users have:

a. High service-parts fill rates;
b. High levels of product uptime with minimal risk;

c. Higher customer service levels.

By pairing user inventory management system with a big data analytics solution, user can improve his demand forecasts by at least 85%. User can also perform real-time supply chain optimization and gain more visibility into the possible bottlenecks, protruding your growth.

1.1.3 Challenges in implementation of Industry 4.0

1. Economic

a. High economic costs
b. Business model adaptation
c. Unclear economic benefits/ excessive investment.

2. Social

a. Privacy concerns
b. Surveillance and distrust
c. General reluctance to change by stakeholders
d. Threat of redundancy of the corporate IT department
e. Loss of many jobs to automatic processes and IT-controlled processes, especially for blue collar workers

3. Administrative/policy:

a. Lack of regulation, standards and forms of certifications
b. Unclear legal issues and data security

4. Organizational/ Internal

a. IT security issues, which are greatly aggravated by the inherent need to open up those previously closed production shops
b. Reliability and stability needed for critical machine-to-machine communication (M2M), including very short and stable latency times
c. Need to maintain the integrity of production processes
d. Need to avoid any IT snags, as those would cause expensive production outages
e. Need to protect industrial know-how (contained also in the control files for the industrial automation gear)
f. Lack of adequate skill-sets to expedite the transition towards the fourth industrial evolution
g. Low top management commitment
h. Insufficient qualification of employees

Table 1.1 Comparisons I3.0 with I4.0

Sr. No	Feature	I4.0	I3.0
1	Characterized by	A fusion of technologies across physical, digital and biological spheres. Physical– Autonomous Vehicles, 3D Printing, Advanced Robotics, New Materials etc. Digital–IoT, Block chain, AI etc. Biological – Molecular biology and genetics, application of engineering principles to biology, 3DBio printing etc.	Digital evolution. rise of telecommunications technologies and computers and IT
2	Technologies used	For smart automation technology used is Cyber physical systems, IOT, IIoT, smart factory, **Cloud,** Big Data Analytics, and AI.	For automation technology used is mainly PLC's and Robots.
3	Automation level	in Industry 4.0 machines work autonomously without the intervention of a human	Industry 3.0 the machines are only automotive
4	Impact	The impact of the fourth industrial evolution is global and is on all the aspects of human life i.e. Economy, Business, Governments, Society, and Individuals.	Impact is limited to geographical and manufacturing industry only
5	Efficiency, Productivity and performance	By combining machine-to-machine communication with industrial big data analytics, IR4.0 is driving unprecedented levels of efficiency, productivity, and performance.	Due to limitation of technological advancements lower Efficiency, Productivity and performance
6	Implemented by	Cyber physical systems, IoT, Smart factory, Big data, Cloud, Cyber security.	Production, planning and control, IT support, ERP, MES and data management.

Sr. No	Feature	I4.0	I3.0
7	Scope	Real time, Interconnected global system.	Not real and global in nature
8	Example	if the CNC Milling machine is in the Industry 4.0 the tool changes are automatic at the same time the spindle speeds and all other parameters essential to carry out the process are recorded by the hundreds of sensors present in the machine and the optimum settings are done on its own based on the large amount of data there is to compare and optimize the process. i.e. No human intervention	If a CNC Milling machine is in the era of Industry 3.0, the tool changes can be done automatically but the speed at which the spindle should run is to be observed by the operator and the corrections should be made by him. I.e. Human intervention/ assistance.

1.2 Components of Industry Revolutions 4.0

"Industry 4.0" is an abstract and complex term consisting of many components when looking closely into our society and current digital trends. To understand how extensive these components are, here are some contributing digital technologies as examples

- Mobile devices
- Internet of Things (IoT) platforms
- Location detection technologies
- Advanced human-machine interfaces
- Authentication and fraud detection
- 3D printing
- Smart sensors
- Big data analytics and advanced algorithms
- Multilevel customer interaction and customer profiling
- Augmented reality/ wearable's
- Fog, Edge and Cloud computing

- Data visualization and triggered "real-time" training

Mainly these technologies can be summarized into four major components, defining the term “Industry 4.0” or “smart factory”:

- Cyber-physical systems
- IoT
- Cloud computing and cloud manufacturing.

1.2.1 Cyber-Physical Systems (CPSs): Cyber-Physical Systems represent systems, where computations are tightly coupled with the physical world, meaning that physical data is the core component that drives computation. Industrial automation systems, wireless sensor networks, mobile robots and vehicular networks are just a sample of cyber-physical systems. CPS’s have limited computation and storage capabilities due to their tiny size and being embedded into larger systems. CPSs extend their capabilities by taking advantage of the emergence of cloud computing and the IoT

1.2.2 The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Data speed in 4G is 60Mbps and data speed in 5G is 700Mbps.

Things: A thing, in the context of the Internet of things (IoT), is an entity or physical object that has a unique identifier, an embedded system and the ability to transfer data over a network. Things can be a part of domestic, process or manufacturing areas like smart TV, PLC, CNC machine etc.

IoT evolved from machine-to-machine (M2M) communication, i.e., machines connecting to each other via a network without human interaction. M2M refers to connecting a device to the cloud, managing it and collecting data. Taking M2M to the next level, IoT is a sensor network of billions of smart devices that connect people, systems and other applications to collect and share data. As its foundation, M2M offers the connectivity that enables IoT.

The IoT is also a natural extension of SCADA (supervisory control and data acquisition), a category of software application program for process control, the gathering of data in real time from remote locations to control equipment and conditions. SCADA systems include hardware and software components. The hardware gathers and feeds data into a computer that has SCADA software installed, where it is then processed and presented it in a timely manner. The evolution of SCADA is such that late-generation SCADA systems developed into first-generation IoT systems.

1.2.3 Cloud Computing and Cloud Manufacturing.

1.2.3.1 Cloud Computing

Cloud is a parallel and distributed computing system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements (SLA) established through negotiation between the service provider and consumers. Roots of cloud computing is as shown in Fig. 1.2.

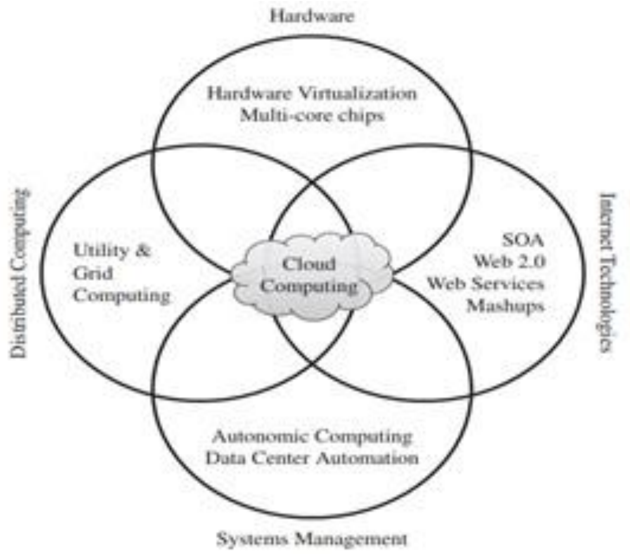


Fig. 1.2 Roots of cloud computing.

Cloud has the responsibility of accepting large amount of information from the IoT gateway, store and process them into actionable resources and send them to the user interface (web app/mobile app/dashboard).

There is an inextricable link between IoT and Cloud. The data collected by the sensors is quite huge in the case of an industrial application of IoT and a gateway is not capable of processing and storing it. This data is stored in cloud (a secure database) and processed in an affordable and scalable way. Cloud basics are as shown in Fig. 1.3.

The cloud is connected to the IoT gateway through the internet and receives all the data fed to the gateway by the sensors. There are a few protocols that connect gateways to the IoT cloud applications and the most common among them is MQTT.

Sensors collect and feed data at all times and this huge chunk of data after the aggregation and some pre-processing is transferred to the cloud for storage and processing

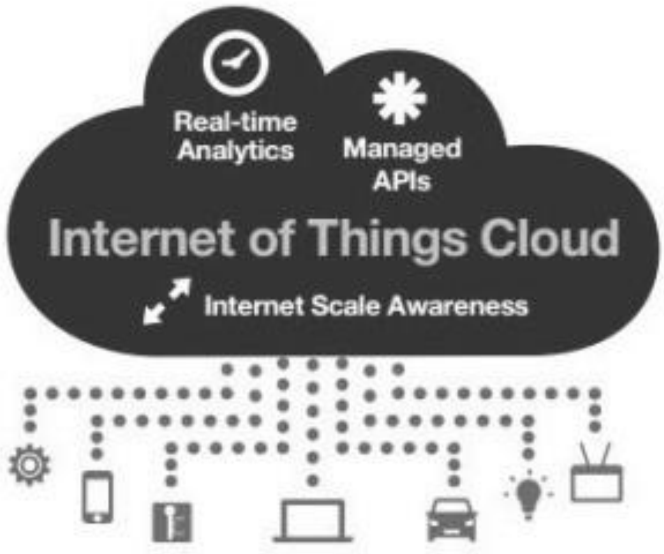


Fig. 1.3: Cloud basics

Depending on the nature of the IoT implementation the cloud may have varying degrees of complexity. In simple applications, the cloud may consist of a database that stores the data collected by the IoT as well as the information of the users who possess the right to access/modify the data.

In bigger and more complex implementations the IOT cloud applications may also have the capability of machine learning, performing analytics, generating reports and more.

IoT Cloud Applications:

Cloud is where the real action takes place. IoT cloud application along with the APIs and other interfaces manage the data and commands to and from the sensors or the gateways is as shown in Fig. 1.4. Different APIs need to be integrated so that the data is read and stored accurately.

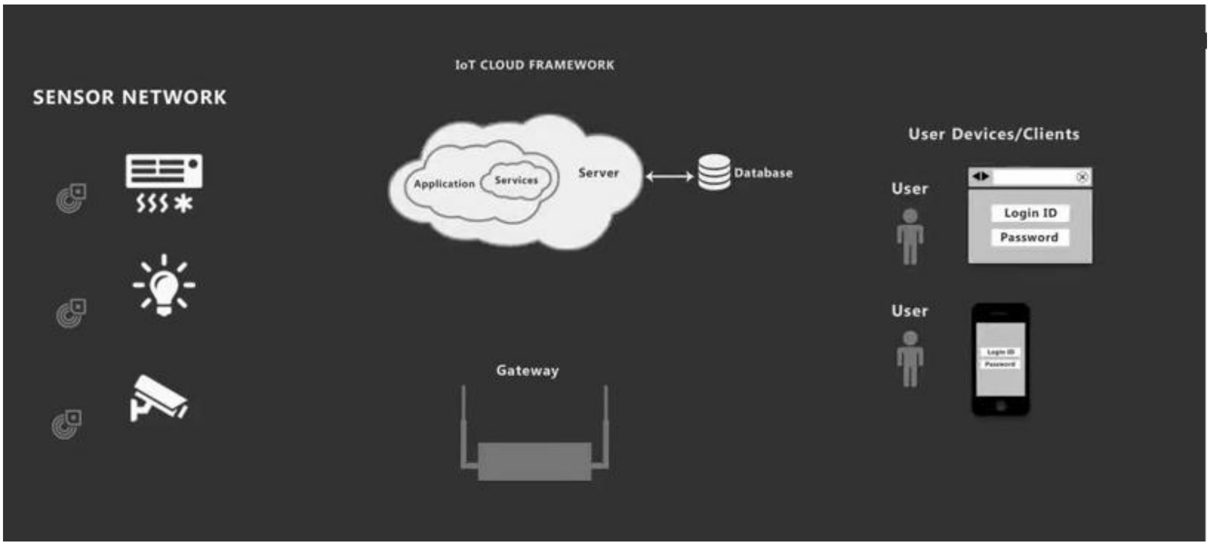


Fig. 1.4: Cloud Application

Some of the protocols such as MQTT, Web socket, CoAP, and AMQP are used to develop a powerful and secure interface that facilitates seamless communication between the sensors and the cloud. In order to ensure that there is no data loss during heavy inflow of data, a robust database is designed as well.

Benefits of Cloud in an IoT ecosystem:

1. Caters the data storage and processing demands of IoT:
   IoT has huge potential and in near future, all kinds of physical entities connected to each other. This would require raw computing power and only cloud can provide that.
2. Advanced analytics and monitoring:
   With ‘things’ now being connected, there would be a need for constant analysis and monitoring in order to ensure seamless IoT experience to the users. Advanced cloud application development will ensure that the cloud is equipped with such capabilities.
3. Smoother inter-device connectivity:
   In an IoT, the sensors not only talk to the users, they also interact with each other. IoT Cloud applications along with the IoT gateway ensure that different sensors and actuators are able to talk to each other without any incompatibility.

1.2.3.2 Cloud Manufacturing.

Cloud manufacturing (CMfg): Cloud manufacturing is a new manufacturing paradigm developed from existing advanced manufacturing models (e.g., ASP, AM, NM, MGrid) and enterprise information technologies under the support of cloud computing, Internet of Things (IoT), virtualization and service-oriented technologies, and advanced computing technologies. It transforms manufacturing resources and manufacturing capabilities into manufacturing services, which can be managed and operated in an intelligent and unified way to enable the full sharing and circulating of manufacturing resources and manufacturing capabilities. CMfg can provide safe and reliable, high quality, cheap and on-demand manufacturing services for the whole lifecycle of manufacturing. The concept of manufacturing here refers to big manufacturing that includes the whole lifecycle of a product (e.g. design, simulation, production, test, maintenance).The concept of Cloud manufacturing was initially proposed by the research group led by Prof. Bo Hu Li and Prof. Lin Zhang in China in 2009. Related discussions and research were conducted hereafter, and some similar definitions (e.g. Cloud-Based Design and Manufacturing (CBDM)) to cloud manufacturing were introduced. Cloud manufacturing is a type of parallel, networked, and distributed system consisting of an integrated and inter-connected virtualized service pool (manufacturing cloud) of manufacturing resources and capabilities as well as capabilities of intelligent management and on-demand use of services to provide solutions for all kinds of users involved in the whole lifecycle of manufacturing.

1.3 IoT Principle and features:

1.3.1 Principles of IoT

In the near future, our everyday lives will be more and more filled with intelligent, connected objects. They will appear in our homes, in our working environments and in the cities we live in as well as travel with us everywhere we go in the form of wearable's, smart clothing and things we cannot even imagine right now. This development is called the internet of things, IoT.

For designers focused on designing SW services and screen based interfaces or physical products, designing IoT solutions creates totally new design challenges. IoT solutions consist of multiple elements: physical devices like sensors, actuators and interactive devices, the network connecting these devices, the data gathered from these devices and analyzed to create a meaningful experience and last but definitely not least, the physical context in which user interacts with the solution. You need to do various types of design, from industrial product design to service and business design. All of these factors have their impact to the total UX of the IoT system and the task of designing in this context may feel quite overwhelming. To make it a little easier, I have gathered my list of the 7 most important design principles for IoT.

1. Focus on value: In the world of IoT, user research and service design are more crucial than ever. While early adopters are eager to try out new technology, many others are reluctant to take new technology into use and cautious about using it, due to not feeling confident with it. For your IoT solution to become widely adopted, you need to dig deep into users' needs in order to find out where lies a problem truly worth solving and what is the real end user value of the solution. You also need to understand what might be the barriers of adopting the new technology in general and your solution specifically. For deciding on your feature set, you need research too. The features that might be valuable and highly relevant for the tech early adopters may be uninteresting for the majority of the users and vice versa, so you need to plan carefully what features to include and in which order.

2. Take a holistic view: IoT solutions typically consist of multiple devices with different capabilities and both physical and digital touch points. The solution may also be provided in co-operation with multiple different service providers. It is not enough to design one of the touch points well, instead you need to take a holistic look across the whole system, the role of each device and service, and the conceptual model of how user understands and perceives the system. The whole system needs to work seamlessly together in order to create a meaningful experience.

3. Put safety first: As the IoT solutions are placed in the real world context, the consequences can be serious, when something goes wrong. At the same time the users of the IoT solutions may be vary of using new technology, so building trust should be one of your main design drivers. Trust is built slowly and lost easily, so you really need to make sure that every interaction with the product/service builds the trust rather than breaks it. What it means in practice? First of all, it means understanding possible error situations related to context of use, HW, SW and network as well as to user interactions and trying to prevent them. Secondly, if the error situations still occur, it means appropriately informing the user about them and helping them to recover. Secondly, it means considering data security & privacy as key elements of your design. It is really important for users to feel, that their private data is safe, their home, working environment and everyday objects cannot be hacked and their loved ones are not put at risk. Thirdly, quality assurance is critical and it should not only focus on testing the SW, but on testing the end to end system, in a real-world context.

4. Consider the context: IoT solutions exist at the crossroads of the physical and digital worlds. Commands given through digital interfaces may produce real world effects, but unlike digital commands, the actions happening in the real-world cannot necessarily be undone. In the real world context lots of unexpected things can happen and at the same time user should be able to feel safe and in control. The context places also other kind of requirements to the design. Depending on the physical context, the goal might be to minimize distraction of the user or e.g. to design devices that hold up against changing weather conditions. IoT solutions in homes, workplaces and public areas are typically multi-user systems and thus less personal than e.g. screen based solutions used in smart phones, which also brings into picture the social context where the solution is used and its' requirements for the design.

5. Build a strong brand: Due to the real world context of the IoT solutions, regardless of how carefully you design things and aim to build trust, something unexpected will happen at some point and your solution is somehow going to fail. In this kind of situations, it is of utmost importance, that you have built a strong brand that truly resonates with the end users. When they feel connected to your brand, they will be more forgiving about the system failures and will still keep on using your solution. While designing your brand, you must keep in mind, that trust should be a key element of the brand, one of the core brand values. This core value should also be reflected in the rest of the brand elements, like the choice of color, tone of voice, imagery etc.

6. Prototype early and often: Typically HW and SW have quite different lifespans, but as successful IoT solution needs both the HW and SW elements, the lifespans should be aligned. At the same time, IoT solutions are hard to upgrade, because once the connected object is placed somewhere, it is not so easy to replace it with a newer version, especially if the user would need to pay for the upgrade and even the software within the connected object may be hard to update due to security and privacy reasons. Due to these factors and to avoid costly hardware iterations, it's crucial to get the solution right, from the beginning of implementation. What this means from the design perspective is that prototyping and rapid iteration of both the HW and the whole solution are essential in the early stages of the project. New, more creative ways of prototyping and faking the solution are needed.

7. Use data responsibly: IoT solutions can easily generate tons of data. However, the idea is not to hoard as much data as possible, but instead to identify the data points that are needed to make the solution functional and useful. Still, the amount of data may be vast, so it's necessary for the designer to understand the possibilities of data science and how to make sense of the data. Data science provides a lot of opportunities to reduce user friction, i.e. reducing use of time, energy and attention or diminishing stress. It can be used to automate repeated context dependent decisions, to interpret intent from incomplete/inadequate input or to filter meaningful signals from noise. Understanding what data is available and how it can be used to help the user is a key element in designing successful IoT services.

1.3.2 Features of IoT

The most important features of IoT on which it works are connectivity, analyzing, integrating, active engagement, and many more. Some of them are listed below:

i) Connectivity: Connectivity refers to establish a proper connection between all the things of IoT to IoT platform it may be server or cloud. After connecting the IoT devices, it needs a high speed messaging between the devices and cloud to enable reliable, secure and bi-directional communication.

ii) Analyzing: After connecting all the relevant things, it comes to real-time analyzing the data collected and use them to build effective business intelligence. If we have a good insight into data gathered from all these things, then we call our system has a smart system.

iii) Integrating: IoT integrating the various models to improve the user experience as well.

iv) Artificial Intelligence: IoT makes things smart and enhances life through the use of data. For example, if we have a coffee machine whose beans have going to end, then the coffee machine itself order the coffee beans of your choice from the retailer.

v) Sensing: The sensor devices used in IoT technologies detect and measure any change in the environment and report on their status. IoT technology brings passive networks to active networks. Without sensors, there could not hold an effective or true IoT environment.

vi) Active Engagement: IoT makes the connected technology, product, or services to active engagement between each other.

vii) Endpoint Management: It is important to be the endpoint management of all the IoT system otherwise; it makes the complete failure of the system. For example, if a coffee machine itself orders the coffee beans when it goes to end but what happens when it orders the beans from a retailer and we are not present at home for a few days, it leads to the failure of the IoT system. So, there must be a need for endpoint management.

1.4 IoT application areas in electrical systems

1.4.1 Building Automation

IOT based solutions enable the efficient way of monitor and control of buildings to property owners as they connect lighting systems, elevators, environmental systems and other electrical appliances with internet and communication technologies. It saves the power consumption by automatically turning off the lights when rooms are not occupied and also by making sure of not drawing too much power by appliances. IOT based appliances provide remote monitoring and control through mobile and web applications to the end users or owners. Building automation system is as shown in Fig. 1.5.

Fig. 1.5: Building automation system.

1.4.2 SCADA (Supervisory Control And Data Acquisition):

SCADA is one of the major application areas of IOT. SCADA allows the centralized monitoring and control of remote located generation and transmission systems. It consists of sensors, actuators, controllers and communication devices at the remote field place, and central master unit with communication systems at the controlling side. It collects the data from sensors in the field and provides a user interface in HMI at central station. Also, it stores the time-stamped data for later analysis.

Fig. 1.6: SCADA system.

IOT SCADA is a step beyond SCADA that has been in use from earlier days. It provides real-time signal acquisition and data logging through IOT servers and internet technologies. It integrates the individual devices, machines, sensors and other electrical equipment with internet by realizing the functionality of supervision and control. One of the examples of SCADA system is as shown in Fig. 1.6.

1.4.3 Smart Metering

A smart meter is an electronic device that records consumption of electric energy and communicates the information to the electricity supplier for monitoring and billing. Smart meters typically record energy hourly or more frequently, and report at least daily. Smart meters enable two-way communication between the meter and the central system. Such an advanced metering infrastructure (AMI) differs from automatic meter reading (AMR) in that it enables two-way communication between the meter and the supplier. Communications from the meter to the network may be wireless, or via fixed wired connections such as power line carrier (PLC). Wireless communication options in common use include cellular communications (which can be expensive), Wi-Fi (readily available), wireless adhoc networks over Wi-Fi, wireless mesh networks, low power long range wireless (LoRa), ZigBee (low power, low data rate wireless), and Wi-SUN (Smart Utility Networks).

Smart metering offers potential benefits to householders. These include, a) an end to estimated bills, which are a major source of complaints for many customers. b) a tool to help consumers better manage their energy purchases-stating that smart meters with a display outside their homes could provide up-to-date information on gas and electricity consumption and in doing so help people to manage their energy use and reduce their energy bills. An academic study based on existing trials showed that homeowners' electricity consumption on average is reduced by approximately 3-5%. Fig. 1.7 shows the block diagram of smart metering system.

Advance metering system: -Advanced Metering Infrastructure (AMI) refers to systems that measure, collect, and analyze energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters, and water meters, either on request or on a schedule.

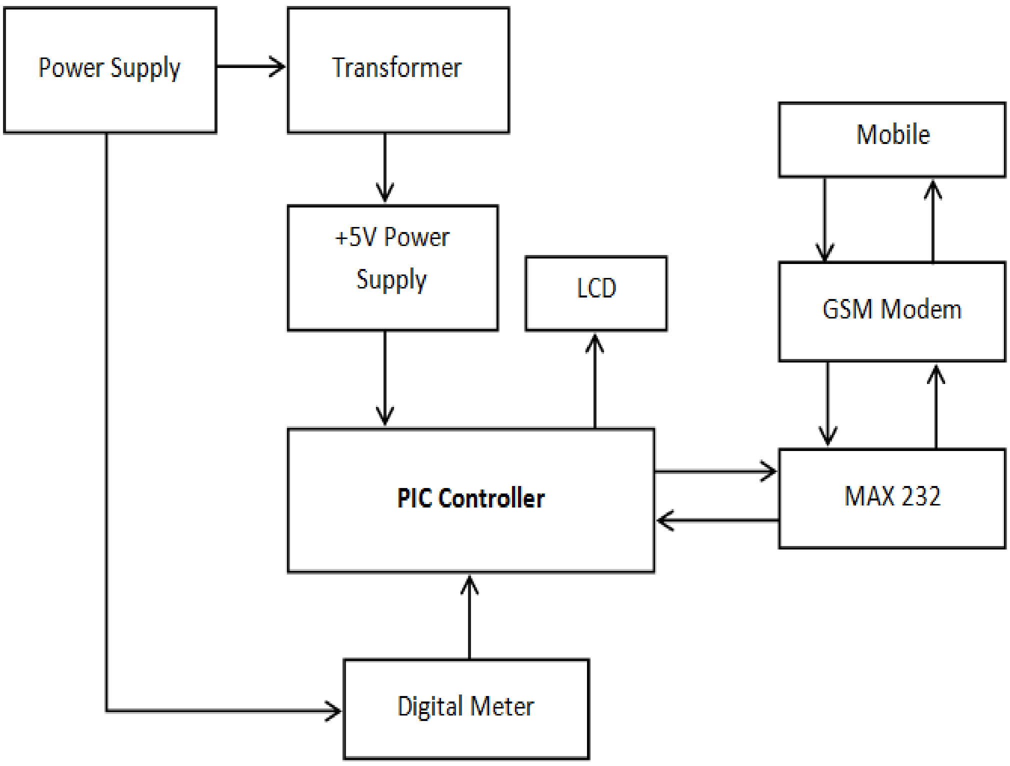


Fig. 1.7: Smart metering system.

These systems include hardware, software, communications, consumer energy displays and controllers, customer associated systems, meter data management software, and supplier business systems. The network between the measurement devices and business systems allows collection and distribution of information to customers, suppliers, utility companies, and service providers. This enables these businesses to participate in demand response services. Consumers can use information provided by the system to change their normal consumption patterns to take advantage of lower prices. Pricing can be used to curb growth of peak demand consumption. AMI differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter. Systems only capable of meter readings do not qualify as AMI systems. Fig 1.8 shows block diagram of smart meter.

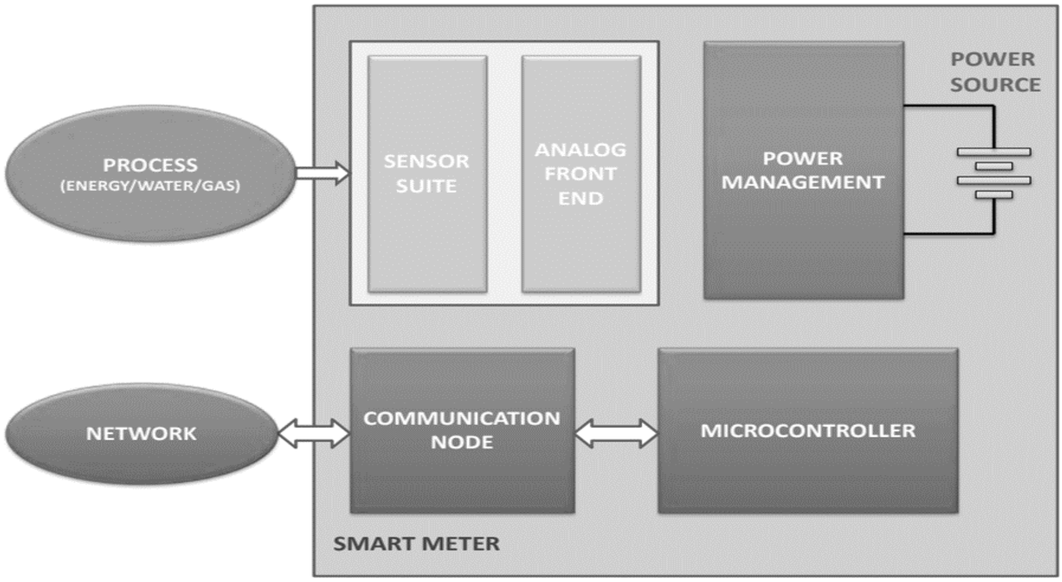


Fig. 1.8: Block diagram Smart Meter.

Smart metering is an essential element in smart grid implementations as they are using Internet of Things technologies to transform traditional energy infrastructure. Smart metering through IOT helps to reduce operating costs by managing metering operations remotely. It also improves the forecasting and reduces energy theft and loss. These meters simply capture the data and send it back to the utility companies over highly reliable communication infrastructure. Fig. 1.9 shows one of such smart meter.

Fig. 1.9: Smart Meter.

1.4.4 Illumination systems (Public lighting)

Smart switches are the most cost-effective way to make the lights in home work with a mobile app or smart home system, because it doesn’t need to replace every light bulb in the home with a smart one, which is more expensive than replacing a few switches. Controlling lights with voice have smart lighting systems to make a feel all-powerful. Smart lighting generally uses mesh networking, where each smart bulb wirelessly connects to its nearest neighbor. That network is controlled by a hub that plugs into router, enabling other networked devices - such as phone or tablet - to communicate with bulbs. Some systems also have an away from home mode that enables to control the lights when far away, which is handy if just remembered that the lights were left on. Smart light systems can also be accessorized with additional items such as dimmer switches or motion detectors, and in some cases they can be linked to the IFTTT (If This Then That) service to create complex rules that trigger particular recipes for particular things.

Smart Lighting includes-

i) Smart Light Bulbs

ii) Smart Dimmers

iii) Smart Ceiling fans

iv) Smart flash mount lighting

v) Smart lighting kits

vi) Smart light switches

vii) Smart outdoor lighting

viii) Smart outlets

ix) Smart plugs

1.5. IoT initiatives in power distribution systems:

Industrial manufacturing plants are becoming increasingly networked, are automated in the way they work together, and collect data and monitor systems. This is all made possible by products and systems for electrical power distribution that integrate seamlessly into digital environments. In this way, operational energy efficiency and plant availability can be significantly increased, operating procedures and maintenance optimized and the entire value-added process in control cabinet and plant engineering simplified.

This chapter describes the specific demands on electrical power distribution in automated production plants. These include, in particular, automated engineering, fail-safe power supply, the integration of power distribution into comprehensive energy efficiency concepts, and connection to industrial automation and cloud-based IoT operating systems like Mind Sphere.

Efficient engineering with digital twins:

Like the entire energy system, electrical power distribution is also changing, influenced by factors like changing load conditions, a growing number of electrical consumers and, in particular, the increasing networking and automation in industrial environments, buildings and infrastructure. In addition, there are stricter standards and increased demands on operational energy management. As a consequence, planning and operation of electrical power distribution systems are becoming more complex and the technical demands on the underlying products and systems are increasing – especially with regard to their flexibility, and communication and integration capability. Smooth interaction between hardware and software, with systematic data management, is necessary to ensure the appropriate support for dynamic, networked production environments.

Fail-safe power supply:

In situations where everything is interlinked, system and component availability is more important than ever. In a worst-case situation, if a single element in the manufacturing process fails, the entire system may be damaged, bringing the whole production process to a standstill. The electrical power distribution in automated environments must therefore combine maximum safety with maximum flexibility. An integrated protection concept for industrial applications includes components for the continuous protection of all plants, machines and systems. That means devices to protect semiconductors and machines, and also to provide protection against short circuits, overloads, voltage spikes, fire and contact. Selectivity also plays an important part in circuit protection: if a fault occurs in a circuit with several overcurrent protection devices connected in series, like circuit breakers or fuses, only one device will be tripped: the one directly upstream of the fault location. Despite the fault at that one point, the power supply for the rest of the system will continue to run. The error will also be easier to locate and faster to fix.

Incorporation into industrial automation:

The technical basis for integrating electrical power distribution in automated environments is provided by communication-capable components like the 3VA molded case circuit breakers and 7KM PAC measuring devices from the Siemens Sentron portfolio. The molded case circuit breakers and measuring devices are directly integrated into the TIA Portal and the TIA Portal Energy Suite. Electrification is thus an integral part of the automation solution.

Integration in end-to-end energy efficiency concepts:

The data gathered on current, voltage and energy can be used for detailed evaluations and systematic management of processes in production automation. Faults in the plant are identified at an early stage, failures are prevented, and operation is made more energy-efficient overall. The energy data can be used to assess the state of the system and the quality of the network, as well as to optimize energy consumption and capacity utilization.

Data management in the cloud:

Finally, Mind Connect components enable all captured energy data to be made available in Mind Sphere, the cloud based IoT operating system from Siemens, making it available for specific evaluations. With Mind Sphere, Siemens offers an open operating system for the Internet of Things. This platform as a service (PaaS) makes it possible to develop, operate and provide applications (apps) and digital services. Huge volumes of data from countless intelligent devices can be captured and analyzed quickly and efficiently in this way.

Automated, networked production plants are making new demands on the electric power supply, particularly with regard to security and flexibility.

Sr. No.	Reference Books/ Website used
1.	https://en.m.wikipedia.org/wiki/Technological_revolution#Potential_future_technological_revolutions
2.	https://www.plm.automation.siemens.com/global/en/our-story/glossary/industry-4-0/29278

3.	https://www.industry.siemens.com/topics/global/en/digital-enterprise-suite/Documents/PDF/PLMportal_Industrie-40-Internet-revolutionizes-the-economy.pdf
4.	https://iot-analytics.com/the-leading-industry-4-0-companies-2019/
5.	https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT
6.	https://www.sequiturlabs.com/secure-edge-gateway/
7.	https://electronicsforu.com/technology-trends/tech-focus/IoT-sensors
8.	https://whatis.techtarget.com/definition/IoT-gateway
9.	https://www.embitel.com/blog/embedded-blog/role-of-cloud-backend-in-IoT-and-basics-of-IoT-cloud-applications
10.	https://www.automation.com/automation-news/article/the-next-generation-of-hmi-and-scada
11.	https://solace.com/blog/understanding-IoT-protocols-matching-requirements-right-option/
12.	https://www.mouser.com/blog/gateways-the-intermediary-between-sensors-and-the-cloud

MCQs and Answer key Chapter 1

Sr. No.	Choose the correct option for each of the following:	**Marks**
1.	Identify which is not an element of IoT? a. People. b. Process. c. Security. d. Things.	1
2.	Internet of things is natural extension of ---------------- a. Smart Factory b. Computer c. SCADA d. I3.0	1
3.	Which of the following is first and most commonly used smart, interactive IoT device? a. Smart Watch b. ATM c. Health Tracker d. Video Game.	1

Sr. No.	Choose the correct option for each of the following:	**Marks**
4.	IOT is evolved from --------------- communication a. B2B b. M2B c. M2H d. M2M	1
5.	------------------ are smart devices that uses embedded processors, sensor and communication hardware to collect and send data which is acquired from environment a. Computers b. Network c. Things d. Protocols	1
6.	-------------- is the physical device or software program that serves as the connection point between the cloud and controllers a. SCADA b. PLC c. Actuator d. IOT Gateway	1
7.	Sequence of devices in IoT architecture from bottom layer to top layer is a. Sensosrs->things->IoTgateway->Edge IT-> Data Center/ Cloud b. Things ->Sensosrs ->IoTgatway->Edge IT-> Data Center/ Cloud c. Things ->Sensosrs -> Edge IT->IoTgatway-> Data Center/ Cloud d. Data Center/ Cloud-> Edge IT ->IoTgatway->Sensosrs->Things	2
8.	The role of internet technologies and IoT in the context of Industry 4.0 is___________. a. They from the base to connect everyday items. b. They from the base for an environmental friendly products c. They form among others base for corporate communication d. IoT and internet have no role to play	2
9.	----------------- is the direct contact between two smart objects when they share information instantaneously without intermediaries a. Device to device b. Device to gateway c. Gateway to data systems d. Between data systems	1

Sr. No.	Choose the correct option for each of the following:	Marks
10.	Top layer in IOT architecture is a. Sensors, connectivity and network layer b. Application layer c. Management Service d. Gateway and network	2
11.	Agriculture IoT stick is smart gadget work on principle of a. Plug & sense b. Plug and play c. Plug and work d. Plug and socket	2
12.	Data speed in 4G is________. a. 10Mbps b. 64Kbps c. 2 Mbps d. 2.4 Kbps	2
13.	Electrical power and locomotives are the inventions of a. First revolution b. Second revolution c. Third Revolution d. Fourth revolution	2
14.	Industrial revolution is a. Significant change that affects a single industry only b. New technologies and novel ways of perceiving the world that trigger a profound change in economic and social structures c. An event that happened in a previous century and doesn't affect modern society d. A series of technological advances that may or may not have a profound effect on societies	1
15.	Which series of events best describes the transformations of the first three industrial revolutions? a. Mechanization of production; introduction of mass production; the digital revolution b. Mechanization of production; invention of steamships and railroads; the digital revolution c. Discovery of electricity; the growth of mass production; the digital revolution d. Mechanization of production; the agrarian revolution; the digital revolution	2
16.	IOT cloud application may have capability of	2

Sr. No.	Choose the correct option for each of the following:	Marks
	a. Only Machine learning b. Only Performing analytics c. Only Generating reports d. All of the above	
17.	IoT, Cyber Physical Systems, AI and Machine learning is characterized by a. First revolution b. Second revolution c. Third Revolution d. Fourth revolution	1
18.	Key impact of the Third Industrial Revolution is a. Agrarian societies become more urban. b. The world became less reliant on animals and humans for energy creation. c. Mass production created more jobs for skilled workers. d. Electronics and information technology began to automate production.	1
19.	The following applications are included under smart lighting: i. Smart bulbs ii. Smart dimmers. iii. Smart flash mount lighting. a. Only i b. Only ii c. Only iii d. i, ii and iii.	1
20.	E-learning helps in: i. Increases Effectiveness. ii. Improves productivity iii. Hands on advanced technological tools. a. Only i b. Only ii c. Only iii d. i, ii and iii.	1
21.	The objective of industry 4.0 is a. Increase efficiency b. Reduce complexity c. Enabled self-controlling d. All above	1
22.	SCADA is abbreviation of a. Supervisory Control And Data Acquisition b. Smart Control And Data Acquisition c. Sensors Control And Data Acquired d. Smart Control And Data Acquired	1

Sr. No.	Choose the correct option for each of the following:	**Marks**
23.	Data speed in 5G is__________. a. 1Gbps b. 64Kbps c. 2 Mbps d. 2.4 Kbps	1
24.	________________devices are able to intervene the physical reality like switching of the light or adjust the temperature of room. a. IoT Gateway b. Cloud c. Sensors d. Actuators	2
25.	Data is aggregated , summarized, filtered and forwarded by _______________ for further processing a. IOT gateway b. Cloud c. Sensor d. Actuator	2
26.	_________ is the other way of referring to IoT devices. a. Connected. b. Smart c. Both A and B d. None of the above	2
27.	IIoT means a. Information Internet of things. b. Industrial Internet of things. c. Innovative Internet of things. d. Itemized Internet of things.	1
28.	Advance analytics and monitoring in IoT ecosystem is provided by a. IoT Gateway b. Cloud c. Sensors d. Actuators	2
29.	__________is best described about industry 4.0. a. Analytics b. Speed c. Smart factory d. Prediction	1
30.	CPS means a. Central Power System b. Central Physical System c. Cyber Power System d. Cyber Physical system	2

Sr. No.	Choose the correct option for each of the following:	Marks
31.	CMfg means a. Cloud Manufacturing b. Cloud Making Fix Gadgeting c. Cloud Making Fix gateway d. Cone Manufacturing	2
32.	Following is the feature of IoT a. Connectivity b. Analyzing c. Sensing d. All of the above	1
33.	AMR means a. Automatic Meter Recycling b. Automatic Monitoring Record c. Automatic Monitoring Reading d. Automatic Meter Reading	1
34.	Following is the application of Industry 4.0 a. 3D Printing b. Mobile Devices c. Smart Sensors d. All of the above	1
35.	Electrical Energy is related to which industry revolution a. Industry Revolution 1.0 b. Industry Revolution 2.0 c. Industry Revolution 3.0 d. Industry Revolution 4.0	1
36.	Top First layer in IOT architecture is a. Sensors Connectivity b. Application Layer c. Management Service d. Network Layer	1
37.	Who is the founder of Industry Revolution 4.0 a. Prof. Paul Dirac b. Prof. Klaus Schwab c. Prof. Richard Feynman d. Prof. William Gilbert	1
38.	The first revolution is about a. Water and steam to mechanize production b. Mass production Electronics & IT c. Electric Power d. Mass production	1

Unit II

Smart Grid

This Unit focuses on following aspects:

2.1 Smart grid

- Introduction
- What is Smart grid?
- Need of Smart grid in present scenario
- Stages in evolution of smart grid
- Layout and components of smart grid
- Comparison of smart grid and Conventional Power grid
- Advantages of Smart Grid
- Barriers and challenges of smart grid
- Smart Grid Projects in India.

2.2 Micro-Grid & Distributed Generation

- Introduction of Micro grid
- Difference conventional grid and micro-grid
- Difference between smart grid and micro-grid
- Need and Significance of Micro-grid
- Major Components of Micro-grids
- Operation of micro grid
- Types of Micro Grid
- AC & DC Grid
- Distributed generation system
- Technologies for Distributed Generation
- Role of Distributed Generation in Smart Grid
- Distributed Generation in India

2.3 Smart Substation:

- Introduction of Smart substation
- **Need and Significance of Distributed Generation**
- Layout and Components
- Specifications of existing Smart substations in India.

2.1 Smart Grid:-

2.1.1 Introduction

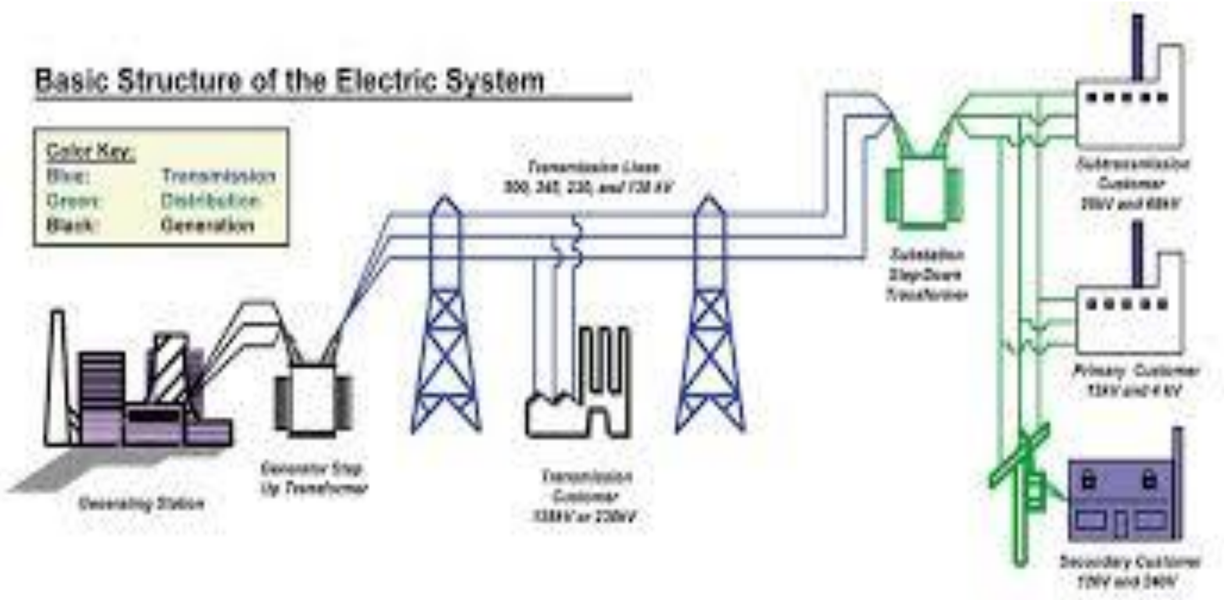


Fig 2.1

In the present era, due to increased power demand to meet up the industrial requirements, the shortfalls in power generation have been attempted to mitigate between supply and demand through developments of National Grid connected systems where all the national power generation sources are connected to National grid and on the basis of the zonal requirement, the energy management is implemented. An “electricity grid” is not a single entity but an aggregate of multiple networks and multiple power generation companies with multiple operators employing varying levels of communication and coordination, most of which is manually controlled With this concept, the earlier power shortage has been to some extent equated and is able to control the transmission losses and improve the transmission efficiency to some extent. This contrasts with 60 percent efficiency for grids based on the latest technology which may be the solution for the above problem. A smart grid is an umbrella term that covers modernization of both the transmission and distribution grids. The concept of a smart grid is that of a “digital upgrade” of distribution and long distance transmission grids to both optimize current operations by reducing the losses, as well as open up new markets for alternative energy production

An electric grid is a network of synchronized power providers and consumers that are connected by transmission and distribution lines and operated by one or more control centers. When most people talk about the power "grid," they're referring to the transmission system for electricity.

Many countries and electricity markets are looking at Smart Grid as advanced solutions in delivering mix of enhanced values ranging from higher security, reliability and power quality, lower cost of delivery, demand optimization and energy efficiency. Its advanced capabilities - demand optimization, delivery efficiency and renewable energy optimization will lead to lower carbon footprint and overall lower energy cost and investment in energy related infrastructure. It is to ensure sustainable development in the electricity sector and many benefits of the all stakeholders.

2.1.2 What is smart grid?

The word smart grid has many definitions. It may be looked upon as a reform process by which the balance is accomplished between available energy and demand by putting in place appropriate policies and operational framework. Simply put, it is the integration of information and communication technology in to electric transmission and distribution networks.

The smart grid is *"an automated, widely distributed energy delivery network characterized by a two-way flow of electricity and information, capable of monitoring and responding to changes in everything from power plants to customer preferences to individual appliances."*

Definition by National Institute of Standards and Technology (NIST), USA: A modernized grid that enables bidirectional flows of energy and uses two-way communication and control capabilities that will lead to an array of new functionalities and applications. Refer fig 2.2

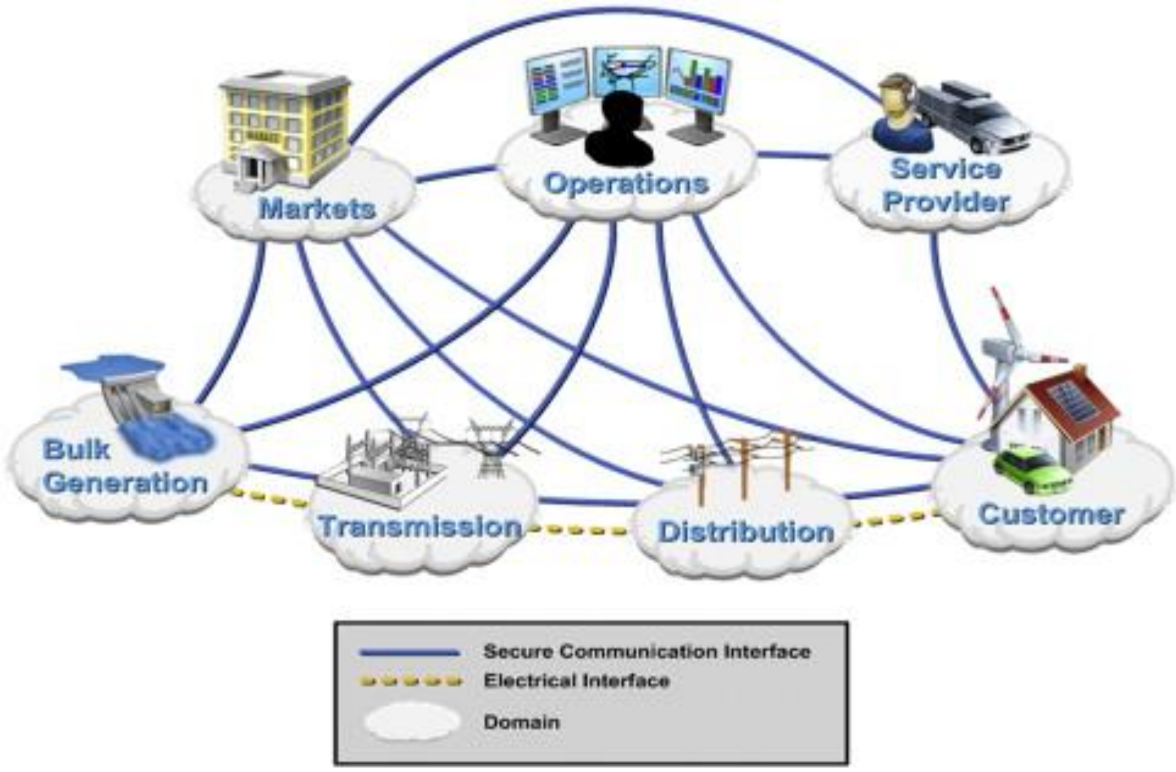


Fig. 2-2

Definition: Smart grid an electric grid that uses information and communication technology to gather data and act on information about the behavior of suppliers and consumers in an automated fashion. Hence Smart Grid is a generic label for the application of computer, intelligence and networking abilities to the existing dumb electricity distribution systems.

Definition as per IEEE: Smart grid is a large ‘System of Systems’, where each functional domain consists of three layers: (i) the power and energy layer, (ii) the communication layer, and (iii) the IT/computer layer. The last two layers enable the infrastructure that makes the existing power and energy infrastructure ‘smarter’.

The basic concept of Smart Grid is to add monitoring, analysis, control, and communication capabilities to the national electrical grid system. This in turn maximizes the output of equipment, helps utilities lower costs power generation and transmission, improves the reliability, decreases interruptions in supply and reduce fuel consumption.

In simple way Smarter Generation, Smarter transmission, Smarter Distribution, Smarter Operations and participation of Customer Markets Service Providers .Overall objective of smart grid is Smart/best/optimal utilization of all the available resources.

2.1.3 Need of Smart grid in present scenario:

- The economic activity of any country supported by industrial growth, citizen‘s life style, agriculture, trade and research is a drive for sustained energy demand more in the form of electrical energy. The growth is phenomenal but inadequate to meet the demand. This is typical situation in many countries.
- As per research reports the current energy path is unsustainable and the world will need at least 50% more energy in 2030 than it uses today. Since most of this energy is emanating from fossil fuels the carbon emissions is also a concerned issue.
- The inter dependence of economic activity, energy demand and Green-House Gas (GHG) emissions has forced to an innovative approach towards energy generation, distribution and utilization.
- The smart grid is a fall out of the growing concern on energy security, climate change and the urgency to embrace in a big way the renewable form of energy sources.
- A need of power grid more efficient and reliable, improving safety and quality of supply in accordance with the requirements of the digital age.
- Higher Penetration of renewable resources or distributed generation adopted in power sector forced the major transformation in power grid.

- Higher operating efficiency and greater resiliency against attacks and natural disasters is required for raising the reliability of supply.
- Presently the Indian Electricity System faces a number of challenges such as shortage of power, power theft, and poor access to electricity in rural areas, huge losses in the grid, inefficient power consumption, and poor reliability. To overcome these problems smart grid is needed.

2.1.4 Stages in evolution of smart grid:

	Elementary stage	**Evolutionary stage**	**Fully Integrated Smart Grid**
Metering	To large extent Manual metering and some automated meters are used for large industrial users.	Use of Smart meters with automated meter reading and real time display	Use of Advance meters with real time rate changes and remote on/off facility
Transmission Grid	Manual operation of Transmission lines ,switches and substations	Enduring automation of HV system and substations	Full automation of HV system and substations with remote controlled switches and power flow
Distribution network	Manual operation of distribution lines, circuit breakers and substation. Also finding faults manually.	Partial automation in control circuits (switches, circuit breakers) for fault identification. Manual operation with LV network	Fully automated remotely operated distribution network with remote sensing and voltage control capacity.
Integration	Basic communication exists between grid components. Limited ability to control the load dispatch.	Online monitoring of load flows in transmission grid and ability to maintain balance in the system.	Total integration of supply and use of electricity. Ability to control load dispatch and usage remotely.

2.1.5 Layout and Components of Smart grid:

As shown typical smart grid network consists of following components.

i. **Grid domain**: It includes bulk energy generation, transmission and distribution.

In generation system has transformed into a mix generation system where various types of renewable and non-renewable generating technologies are used. Power System operator has to coordinate the operation of the generation plants and ensure the stable and secure operation of the grid system. Wide-area measurement system (WAMS) enabled by communication technologies need to be used to control the operation of the generating stations. Communication infrastructure needs to be in place between the generating facilities and the system operator, electricity market, and the transmission system.

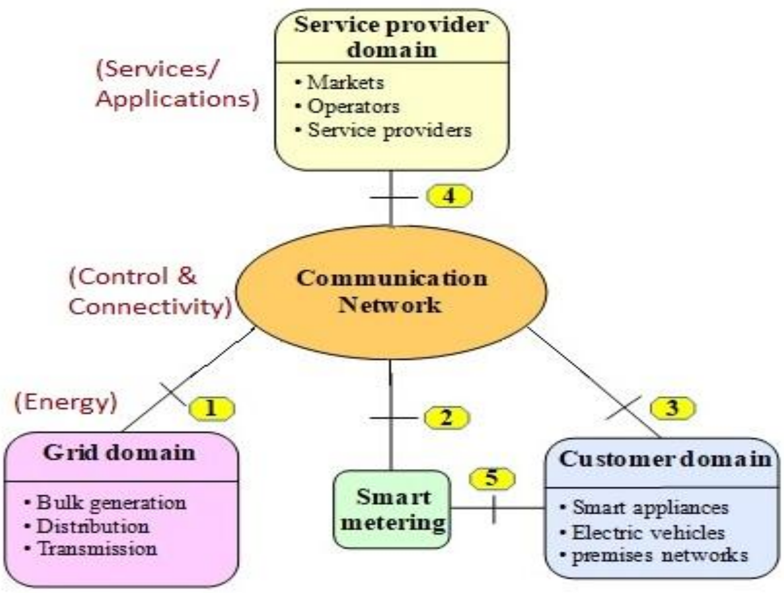


Fig 2-3

The transmission system that interconnects all major substation and load centers is the backbone of an integrated power system. Transmission lines must tolerate dynamic changes in load and contingency without service disruptions. Efficiency and reliability at an affordable cost continues to be the ultimate aims of transmission planners and operators. Energy-efficient transmission network will carry the power from the bulk generation facilities to the power distribution systems. Communication interface exists between the transmission network and the bulk-generating stations, system operator, power market, and the distribution system. Now the transmission network needs to be monitored in real-time, and protected against any potential disturbance. The power flow and voltage on the lines need to be controlled in order to maintain stable and secure operation of the system. An important task of the system operator is to ensure optimal utilization of the transmission network, by minimizing the losses and voltage deviations, and maximizing the reliability of the supply.

The distribution system is the final stage in the transmission of power to end users. Primary feeders at this voltage level supply small industrial customers and secondary distribution feeders supply residential and commercial customers. At the distribution level, intelligent support schemes will have monitoring capabilities for automation using smart meters, communication links between consumers and utility control, energy management components, and AMI .Smart Distribution system will have Substation automation and distribution automation. Increasing use of distributed energy resources (DERs) will be an important feature of future distribution systems. Distribution system operator typically controls the distribution system remotely. Communication infrastructure to exchange information between the substations and a central distribution management system (DMS) therefore should be in place. An important job of the distribution system operator is to control the DERs in a coordinated way to ensure stability and power quality of the distribution system. Information exchange between the distribution system operator and the customers for better operation of the distribution system is a new feature of the smart distribution systems.

ii. **Customer's domain**: Customers can be classified into three main categories: residential, commercial, and industrial. In smart grids, customers are going to play a very important role through demand response. By peak-load shaving, valley-filling, and emergency response, customers are going to play an active role in better operation of the distribution system. Building or home automation system will monitor and control the power consumption at the consumer premises in an intelligent way. Proper communication infrastructure will be required for the consumers to interact with the operators, distribution systems, and the market.

iii. **Service provider domain:** Third party Service providers are used where system vendors, operators, web companies etc. work as third party. Real-time information exchange with the power market needs to be established in order to implement power trading and scheduling. The operators need to interact with various service providers for ensuring proper functioning of the smart grid.

iv. **Communication network domain**: Smart Grid is based on Digital Technology that is used to supply electricity to consumers via Two-Way Digital Communication. Smart grid operations require communication interface with the bulk generating facilities, transmission system, substation automation, distribution automation, DMS, consumers, and the market.

Communication network (Connects smart meters with consumers and electricity company for energy monitoring and control operations, include various wireless technologies such as zig-bee, wifi, Home Plug, cellular (GSM, GPRS, 3G, 4G-LTE) etc. Smart Devices work as Interface Component for monitoring and control form part of the generation components real-time information processes. These resources need to be seamlessly integrated in the operation of both centrally distributed and district energy systems.

v. **Smart metering**: The intelligence of smart grid is built over by deployment of SCADA, AMI and Smart Meters and by leveraging the potential of ICT. Metering, recording, and controlling operations come under the purview of the smart grid operations. Smart meters Consumer domain (HAN -Home Area Network) consists of smart appliances and more).

2.1.6 Comparison of smart grid and Conventional Power grid

Sr. No.	Smart Grid	Conventional grid
1.	Digital grid	Electromechanical grid
2.	Two-way communication	One-way communication
3.	Distributed generation	Centralized generation
4.	Self-monitoring	Manual monitoring/ BLIND
5.	Self-healing	Manual restoration
6.	Pervasive control	Limited control
7.	Network	Hierarchical
8.	Increased customer participation	Total control by utility
9.	Transaction between supplier to customer through Third party	Direct Transaction between supplier to customer
10.	Smart metering	Mostly analog metering
11.	Adaptive and Islanding	Failures and Blackouts
12.	Excessive real time monitoring	Lack of real time monitoring
13.	Energy storage	No energy storage
14.	Many customers choices	Few customers choices

2.1.7 Advantages of Smart Grid:

1. Accommodates all generation plants as well as distributed generation with storage options.

2. Integration of the resources – including renewable, small-scale combined heat and power, will increase the value chain, from suppliers to marketers to customers.
3. Enhances the Reliability and power quality of supply.
4. Advanced control methods monitor essential components, enabling rapid diagnosis and solutions to events that impact power quality, such as lightning, switching surges, line faults and harmonic sources.
5. Enables participation of customers in the stability of the system by modifying the way they use and purchase electricity, Real Time Monitoring of consumption, Control of smart appliances, Building Automation
6. Enables new products, services and market.
7. Enhancing Power System Efficiency by asset Management and optimal utilizations, Distribution Automation and Protection
8. Provides resiliency to disturbances, attacks and natural disasters
9. Power Quality by Self-Healing, Frequency Monitoring and Control, Load Forecasting, Anticipation of Disturbances
10. Reduced operating costs for utilities along with increased efficiency and conservation.
11. Lower the greenhouse gas (GHG) and other emissions.
12. Intelligent devices can automatically adjust to changing conditions to prevent blackouts and increase capacity.
13. Provision for adoption of development/ new technologies and markets.
14. Self-Healing A smart grid automatically detects and responds to routine problems and quickly recovers if they occur, minimizing downtime and financial loss.
15. A smart grid gives all consumers industrial, commercial, and residential-visibility in to real-time pricing, and affords them the opportunity to choose the volume of consumption and price that best suits their needs.
16. Improves National Security , Improved Environmental Conditions , Improved Economic Growth

2.1.8 Barriers and challenges of smart grid:

Among the issues as the followings:

- Lack of recognition or rewards on operational efficiency
- Customer concerns over privacy and transfer of data without their knowledge,
- Fair distribution of electricity demand
- Social concerns over information abuses

- People are concerns on extra control of electricity that government have
- Customers are concerns on computer security
- Malware and hacker threat
- Utilities hard to justify for investment on smart grid
- Problem over intermittent RE source – e.g. weather
- Outdate and old existing electrical facilities

Some of the challenges faced presently by the Indian Electricity System are Shortage of power, Power Theft, Poor access to electricity in rural areas, huge losses in the Grid, Inefficient Power Consumption, and Poor reliability.

Technology	**Challenges**	**Examples**
Self –healing feature	Security	Open to the internet attacks (spasm, computer worms, virus etc.), Issues related to National security
	Reliability	System outages, total blackouts and failure due to natural calamities
Integration of Renewable energy systems	Power generation by Renewable(solar and wind)	Solar and wind energies are long-lasting but un-predictable alternating sources of energy. Provide unscheduled power flow and load dispatch.
	Optimization of power flow	Requires huge investment, transmission line congestions
	Stability of Power System	Decoupling causes system stability issues.
Energy storage systems	Complexity	Complex design and network
	Expenditure	Expensive systems like Ultra capacitors, Small And Medium-Sized Enterprises (SMES), Compressed Air Energy Storage(CAES) etc.
	Non-flexibility	Require unique designed storage system for all individual networks and also not ease for adaptation.
Consumers participation	Privacy	Sharing of data cause privacy invasion
	Security	Interception of data, data corruption, illegal power handling and smuggling of data, malware attack.
	Consumer awareness	Corruption and system threats like security and privacy issues.
Reliability of supply	Grid automation	Require strong data routing system with secure and private communication network for reliable protection, monitoring, control and communication.

	Reconfiguration of grid	Balance between generation and demand, power system stability along with grid complexity.
Power quality	Large and small Disturbances	Local faults, Line faults, Failure of apparatus, sudden rise or fall in the demand.
	Harmonics suppressions	System instability due to voltage sag, over voltage, under voltage, voltage flickering etc.

2.1.9 Smart Grid activities in India

Every global driver for smart grids applies to India, but India also has additional drivers in the short term. The Indian power system is now the fourth largest in the world, but per-capita consumption of electricity in India is only about one-fourth of the world average. This underscores the need to grow the power system at a rapid pace for the next several decades. This low consumption is amplified by the lack of access to electricity to a significant proportion of the population. The potential demand by 2032 is estimated to be as high as 900 GW. India is also pursuing an aggressive renewable generation program.

India is venturing very fast into renewable energy (RE) resources like wind and solar. ... Hence, the opportunities for building smart grids in India are immense, as a good electric supply is one of the key infrastructure requirements to support overall development. A power system of this size growing at such a pace (8-10% per year) with an increased share of renewable energy requires smarter systems to manage it efficiently and ensure its stability and reliability

The **'National Smart Grid Mission'** was approved by the Indian Ministry of Power on 27 March 2015. Currently, it has allocated 14 **smart grid** pilot projects across **India** that will be implemented by state-owned distribution utilities.

Smart Grid Vision for India is: *"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."*

It is aligned to the Government's overreaching policy of **"Access, Availability and Affordability of Quality Power for all".** Indian Smart Grid Task Force (ISGTF) under MoP, GoI has shortlisted fourteen (14) Smart Grid Pilot Projects spread across the country for demonstration of technology. Govt. of India will finance 50% of the cost of the project as grant and balance cost has to be borne by respective state utilities.

Fourteen smart grid pilot projects in different distribution companies have been shortlisted for funding by India's Ministry of Power, on the recommendations of the India Smart Grid Task Force (ISGTF).

The smart grid projects are:

1. CESC (Karnataka) – AMI, outage management, peak load management, micro-grid and distributed generation with an initial 21,800 consumers in the Mysore Additional City area
2. Andhra Pradesh CPDCL – AMI, outage management, peak load management and power quality management with 11,900 consumers in the Jeedimetla suburb of Hyderabad
3. Assam PDCL – AMI, outage management, peak load management, power quality management and distributed generation with 15,000 consumers in the Guwahati area
4. Gujarat VCL – AMI, outage management, peak load management and power quality management with 39,400 consumers in Naroda and Deesa
5. Maharashtra SEDCL – AMI and outage management with 25,600 consumers in Baramati in the Pune district
6. Haryana BVN – AMI and peak load management with 30,500 consumers in Panipat City
7. Tripura SECL – AMI and peak load management with 46,000 consumers in Agartala
8. Himachal Pradesh SEB – AMI, outage management, peak load management and power quality management with 650 industrial consumers in Nahan
9. Puducherry electricity department – AMI with 87,000 consumers
10. JVVNL (Rajasthan) – AMI and peak load management with 2,600 consumers in Jaipur
11. Chattisgarh SPDCL – AMI with 500 industrial consumers in Siltara
12. Punjab SPCL – outage management with 9,000 consumers in Amritsar
13. Kerala SEB –AMI with 25,000 industrial consumers
14. West Bengal SEDCL – AMI and peak load management with 4,400 consumers in Siliguri town in the Darjeeling district.

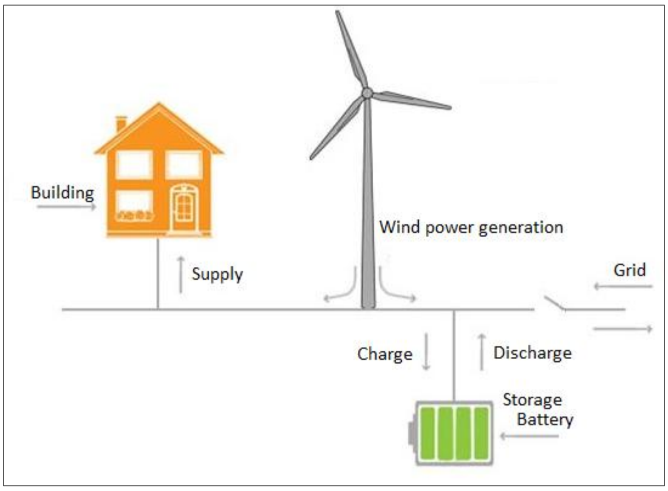


Fig 2.4

2.2 Micro-Grid & Distributed Generation

2.2.1 Introduction of Micro-grid:

A micro grid is a small-scale power grid that can operate independently or collaboratively with other small power grids. The practice of using micro grids is known as distributed, dispersed, decentralized, district or embedded energy production (refer fig 2.4).

Any small-scale, localized power station that has its own generation and storage resources and definable boundaries can be considered a micro grid. If the micro grid can be integrated with the area's main power grid, it is often referred to as a hybrid micro grid.

Micro grids are typically supported by generators or renewable wind and solar energy resources and are often used to provide backup power or supplement the main power grid during periods of heavy demand. A micro grid strategy that integrates local wind or solar resources can provide redundancy for essential services and make the main grid less susceptible to localized disaster.

Examples of micro grid:

Buildings equipped with electric generation capabilities through solar panels and contingency generators can also generate energy and revenue during downtime. By joining together with smart grid deployments, excess energy can be sold back to local micro grids to create revenue in addition to providing resilience and capacity to local electrical grids. (refer fig 2.5)

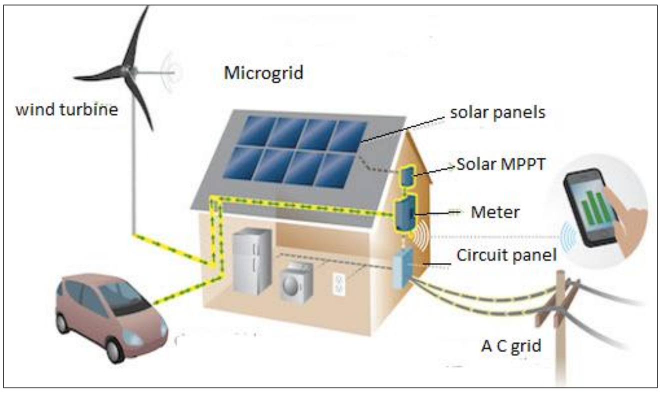


Fig 2-5

Definition as per IEEE:

A micro-grid is a group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.

2.2.2 Difference between conventional grid and micro-grid:

The key differences between a Micro-grid and a conventional power plant are as follows:

~ Micro-sources are of much smaller capacity with respect to the large generators in conventional power plants.

~ Power generated at distribution voltage can be directly fed to the utility distribution network.

~ Micro-sources are normally installed close to the customers' premises so that the electrical/heat loads can be efficiently supplied with satisfactory voltage and frequency profile and negligible line losses.

2.2.3 Difference between smart grid and micro-grid

Smart grids are those electrical systems that includes multiple smart generating systems, smart transmission and distribution systems which are controlled through advanced technology like telecommunication system. .A micro-grid is an electrical system that includes multiple loads and distributed energy resources that can be operated in parallel with the broader utility grid or small, independent power system. A micro-grid is designed for a small scale usually for a certain community whiles the smart grid is designed for the whole electrical system. Refer fig 2.6.

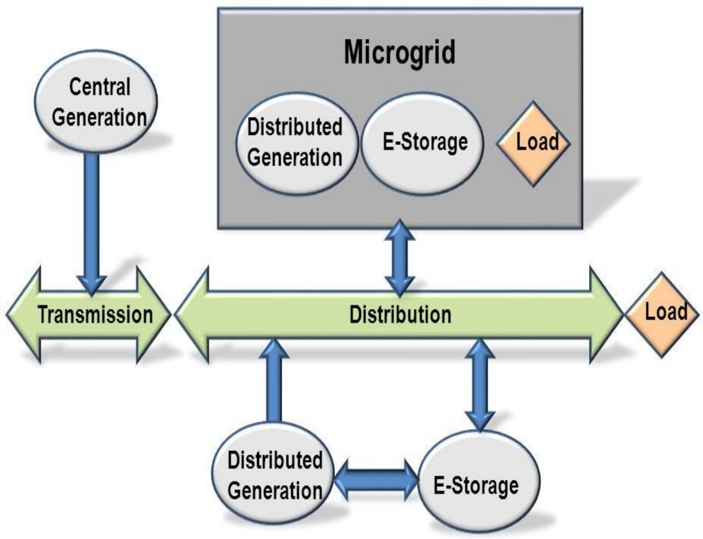


Fig 2-6

They do not have any difference on the energy sources utilized. Micro-grid increases reliability with distributed generation,

increases efficiency with reduced transmission length and easier integration of alternative energy sources while A smart grid is a modernized electrical grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production, transmission and distribution of electricity and operations wide- area monitoring, control and protection.

2.2.4 Need and Significance of Micro-grid

1. Enables the use of micro level power generating plants by using Renewable and alternative fuels and thereby conserves the fossil fuels.
2. Optimum and efficient use of distribution energy systems.
3. Enables to enhance the use of energy storage systems which raises the reliability factor of the grid.
4. Improves the power quality through the easy frequency and voltage regulation, smoothing the output of renewable energy sources, providing backup power for the system.
5. Playing crucial role in optimization of cost of energy.
6. Minimizes the green gas production by adoption of renewable.
7. Enables to increase the efficiency of energy management system through demand side management, energy conservation measures.
8. Enhances the power balance in the grid and improves the stability of the grid.
9. Micro-grids provide revenue by selling energy and services back to the grid.

2.2.5 Major Components of Micro-grids (fig 2.7)

a. Energy Supply System**:** For a micro-grid to provide energy supply to its connected loads without help from the utility there must be a source of generation within the micro-grid. This could be solar PV, wind, combustion turbines, reciprocating engines, cogeneration, or any other form of generation. Distributed Generation (like renewable sources, small combustion turbines)

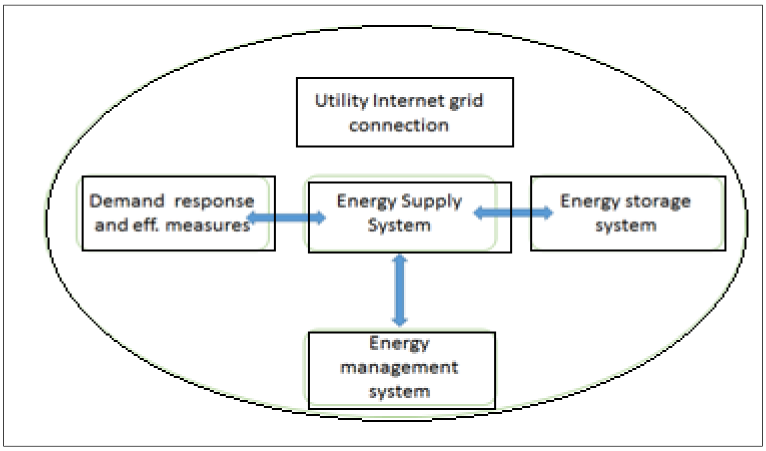


Fig 2.7

b. Energy Storage Capacity: Energy storage that allows the micro-grid to absorb and store energy that is produced when supply exceeds demand, and to return that energy when the demand exceeds supply. (E.g. during evening hours when solar production is not available). Like Batteries, thermal storage are used.

c. Demand Response and Efficiency Measures: More sophisticated micro-grids will incorporate the ability to control end-uses in a manner that allows the generation and storage resources to be optimized. For example, non-critical loads like lighting, hot water heaters, etc. can be automatically shut off or turned down to help maintain energy flow to critical loads (e.g. computer servers, life-support equipment, etc.), especially during times when variable renewable generators are not available. As with storage, load control can also provide arbitrage opportunities in power markets and/or where time-based rates are available.

d. Energy Management Systems: This system ties all of the components together and maintains the real-time balance of generation and load. In a very simple micro-grid, a control system is typically a governor control on a diesel generator. In more complex micro-grids, control systems are made up of sophisticated software platforms, sensors, metering, and communication paths designed for real-time optimization and control of the generators, energy storage, loads, and utility interchange. During interconnected operation, the control system must be able to manage the utility interface and communicate with the utility's (or independent system operator's) system operations center (including demand-response management systems) in near real-time. (Maintain Balance and Stable Systems and Real-time response, Predictive and forecasting analysis).

e. Utility Grid Interconnection: A key design feature of a micro-grid includes the interface with the utility's power grid. During interconnected operation the micro-grid-utility interconnection must be designed for safe and reliable parallel operation of the micro grid and the power system. For reliability-based micro-grids where operation in an islanded mode is anticipated, the interconnection must also include equipment that will allow for the seamless disconnection and reconnection of the micro-grid and the power grid. This "re-synchronization" of the two systems is not a trivial undertaking and failure to properly plan and design for this function can result in the instability of both grids. Accordingly, islanding of micro-grids must be addressed at both technical and policy levels.

2.2.6 Operation of micro grid:

Micro-grid can operate in two modes:

1. Grid connected mode: In this mode micro-grid operate synchronously with the main grid. During the grid-connected mode the micro-grid sources will be controlled to provide constant real and reactive power injection. A simple example is a small power system network with

distributed generators such as wind, solar and combined heat power (CHP) plants that can operate in conjunction with the grid to supply a fraction of the total load. Refer fig 2-8

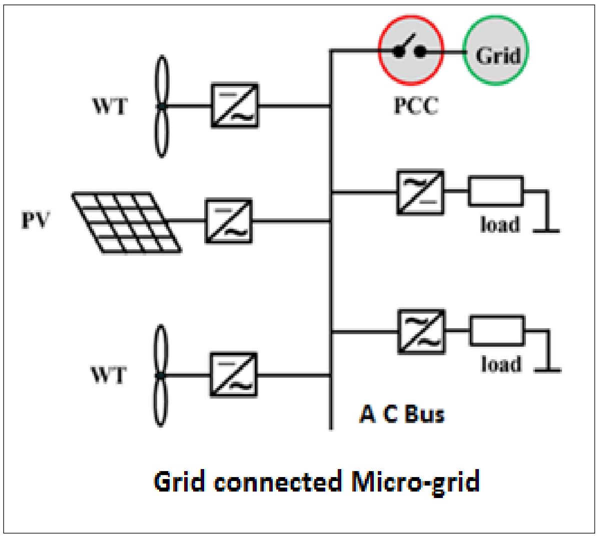


Fig 2-8

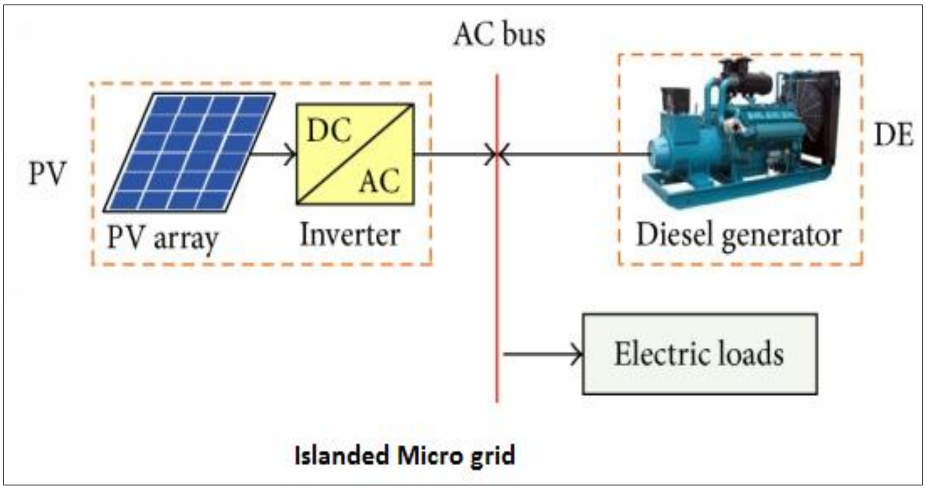


Fig 2.9

2. Islanded mode: Islanding is the condition in which a distributed generator (DG) continues to power a location even though electrical grid power is no longer present. Refer 2.9. During the islanded mode the sources will be controlled to provide constant voltage and frequency operation. A simple example of islanding is a distribution feeder that has solar panels attached to it.

A traditional wide area synchronous grid (macro-grid), but can also disconnect to "island mode" — and function autonomously as physical or economic conditions dictate. A micro-grid connects to the grid at a point of common coupling that maintains voltage at the same level as the main grid unless there is some sort of problem on the grid or other reason to disconnect. A switch can separate the micro-grid from the main grid automatically or manually, and it then functions as an island.

2.2.7 Types of Micro Grid:

Micro grids are classified based on

i) Types of supply—AC , DC and Hybrid

ii) Source ----- Renewable (solar, wind, biomass, small hydro) , Diesel, Hybrid

iii) Scenario----Residential, Industrial and Commercial

iv) Size---- < 10 kW, between10kW to 1 MW, >1 MW

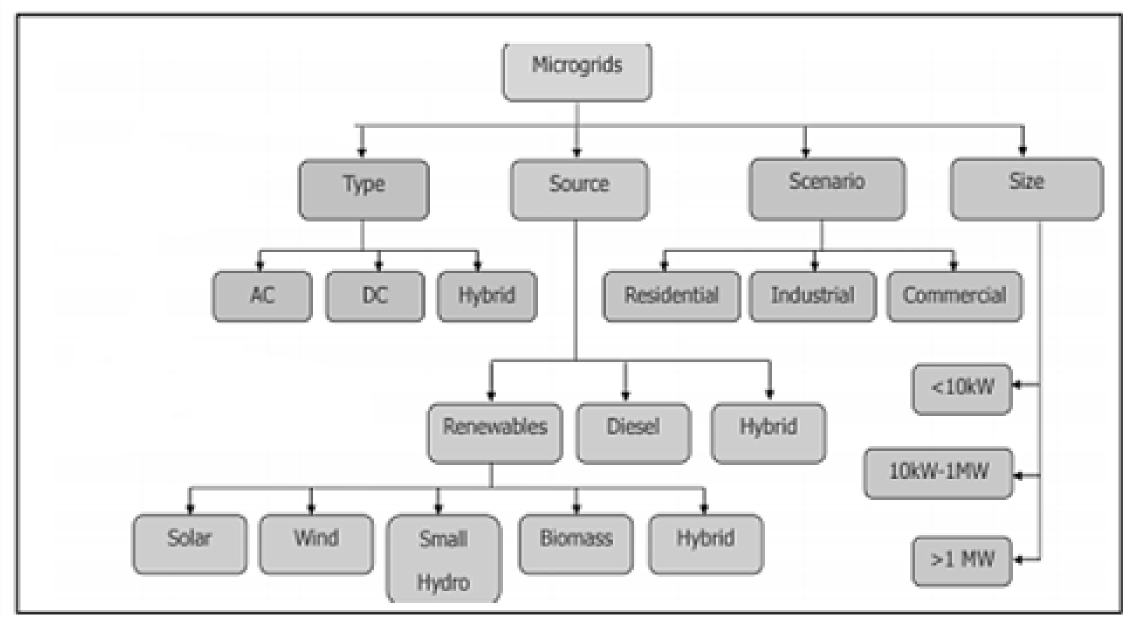


Fig 2.10

2.2.8 AC & DC Grid

In AC micro-grid, all Distributed Energy Resources and loads are connected to a common AC bus. Block diagram of AC and DC micro-grid. Refer fig 2.10. DC generating units as well as energy storage will be connected to the AC bus via DC-to-AC inverters, and further, AC-to-DC rectifiers are used for supplying DC loads.

Many new distributed energy resources are direct DC, e.g. photovoltaic (PV) generation, stationary batteries, mobile batteries, and fuel cells. Also, many high efficiency loads are also direct DC. Lay out of DC micro-grid system is shown in figure Utilizing a DC bus in micro-grid may avoid many of the power conversion steps required when using an AC bus, potentially leading to higher energy efficiency and improved economic operation. Refer fig 2.11

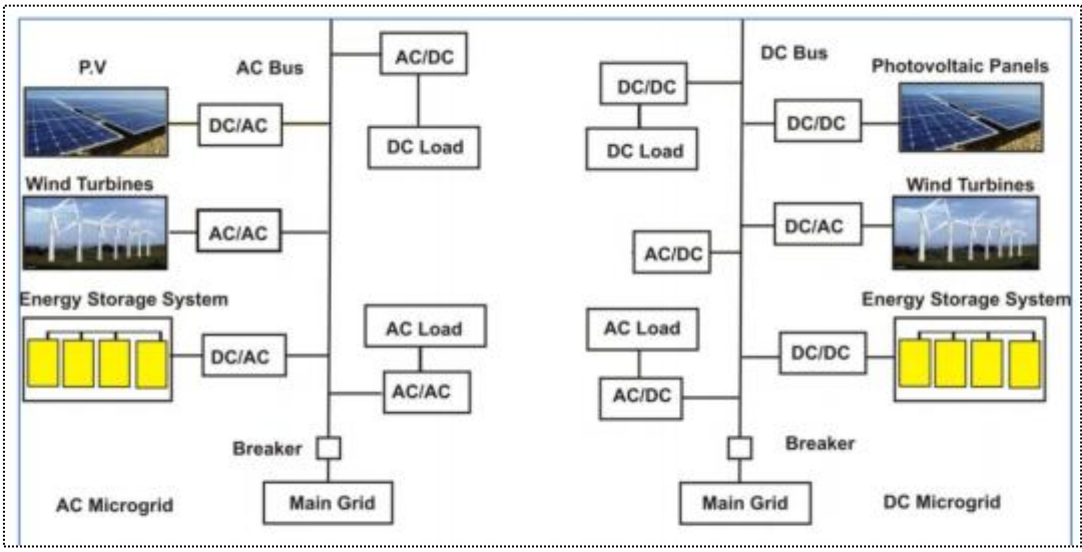
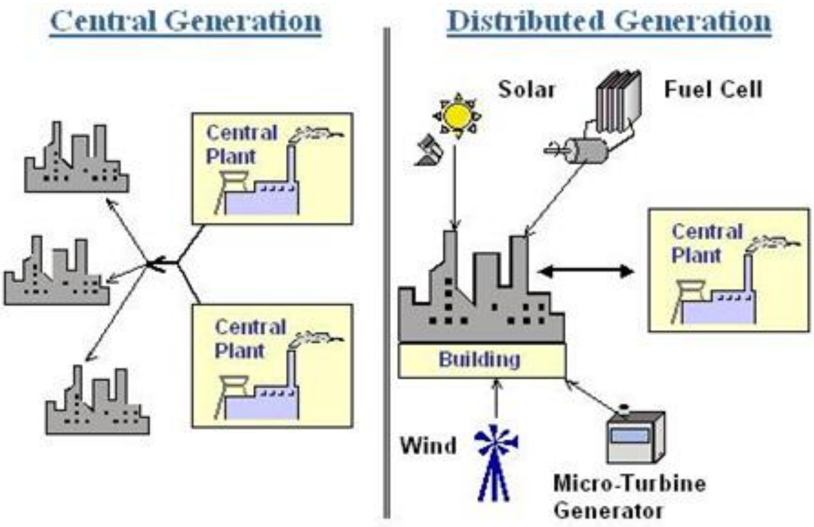


Fig 2.11

2.2.9 Distributed Generation System:

Distributed generation is an approach that employs small-scale technologies to produce electricity close to the end users of power. DG technologies often consist of modular and sometimes renewable-energy generators and they offer a number of potential benefits.

When energy is generated and distributed using small scale technologies closer to its end users, it is termed as Decentralized Generation. These generations are based on the technologies, mainly renewable, including but not limited to, wind turbines, photovoltaic cells, geothermal energy and micro hydro power plants. Onsite power generation has many benefits over the centralized power generation systems, as it eliminates the costs associated with the transmission and distribution of power over long distances. These small scale technologies can yield power from 1KW to as much as 100MW. Refer fig 2.12.



Centralized vs. Decentralized Generation (Source: www.jcwinnie.biz)

Fig 2.12

Decentralized generation can take place at two scales. At a local level, site specific energy sources are used to generate electricity, constituting a Micro-Grid which is a cluster of generations serving a limited number of consumers. It can be either connected to the grid at a single point or can be totally independent of it. At the second level, the same technologies are used at much smaller scale and are installed by an individual energy consumer. Such a system is called Distributed Generation. These sources can be individually connected to grid, so that they can supply power to the grid when required – creating a prosumer, i.e., a producer and a consumer of electricity.

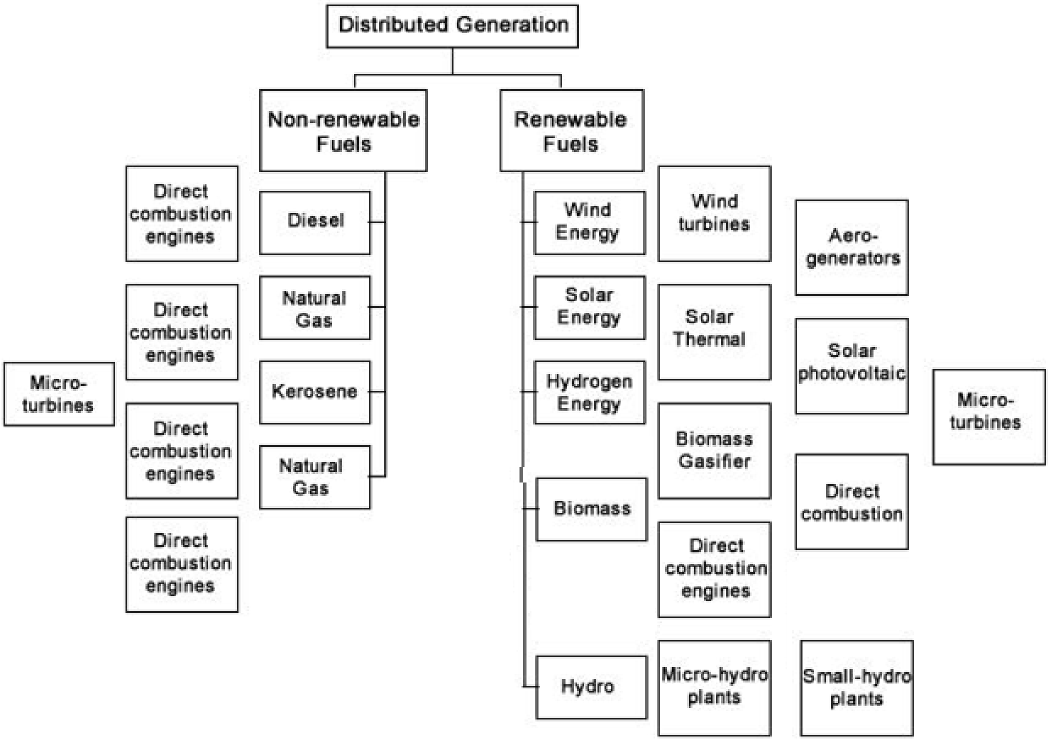
Need and Significance of Distributed Generation in present Power Scenario

Decentralized generations are small and offer numerous benefits in comparison to the conventional centralized systems. Few of its benefits are discussed as follows:

- ***Increase in power demand and depletion of fossil fuels***: Rise in population and adoption of advanced technologies has raised the power demand which cannot be fulfilled by depleting fissile fuels.
- ***No high peak load shortages*** -Distributed generation systems can reduce the peak demand and offer an effective solution to the problem of high peak load shortages and peak operating cost.
- ***Reduced high transmission and distribution losses*** **–** Proximity of load and sources can greatly reduce the losses during transmission and distribution of power. In India, the current losses amount to about 10 to 25% of the total available energy.
- ***Linking remote and inaccessible areas*** **-** Distributed generation can play a major role in providing power to remote and inaccessible areas. For a country like India, it offers a solution towards rural electrification.
- ***Faster response to new power demands*** **–** The micro-grid systems are small scaled and often require lower gestation periods; it enables faster and easy capacity additions when required.
- ***Improved supply reliability and power management*** **-** With independence from utility grid systems, distributed generation systems offer easy maintenance of power, voltage and frequency. It also offers the possibility of combining energy storage and management systems with reduced congestion.
- ***Enhances electric market:*** Provide***s*** more choices for consumer to select the power generated by different resources.

2.2.10 Technologies for Distributed Generation

- A distributed generation system is very flexible, as it can be based on renewable or non-renewable energy sources. The decentralized generation technologies include but are not limited to the following. Refer fig 2.13



Technology option in Distributed generation

Fig 2.13

- **Reciprocating Engines:** Reciprocating engines can be fueled either by diesel or natural gas, with varying emission outputs. Almost all engines used for power generation are four-stroke and operate in four cycles of intake, compression, combustion, and exhaustion. Reciprocating engines are manufactured in various size ranges. Their typical usage is in providing continuous power supply or backup emergency power.
- **Micro-turbines:** Micro turbines are an emerging class of small-scale distributed power generation system in the size range of 30-400 kW. Micro-turbines consist of a compressor, combustor, turbine, and a generator. The compressors and turbines have radial-flow designs, and resemble automotive engine turbochargers. Most designs are single-shaft and use a high-speed permanent magnet generator producing variable voltage, variable frequency alternating current (AC) power. Most micro-turbine units are designed for continuous operation with higher electric efficiencies.

- **Combustion Gas Turbines:** Simple cycle combustion turbine units start at about 1MW. These turbines can also be configured as combined cycle power systems to achieve up to 15MW, also called as industrial turbines or mini turbines. Combustion turbines have relatively low installation costs, low emissions, and require infrequent maintenance. However, their low electric efficiency has limited turbines to primarily peaking unit and combined heat and power (CHP) applications. Cogeneration DG installations are particularly advantageous when a continuous supply of steam or hot water is desired.
- **Fuel Cells:** There are many types of fuel cells currently under development in the 5-1000+ kW size range, including phosphoric acid, proton exchange membrane, molten carbonate, solid oxide, alkaline, and direct methanol. Fuel cells have very low levels of NO_x and CO emissions because the power conversion is an electrochemical process.
- **Photovoltaic (PV):** Photovoltaic systems are most commonly known as solar panels. Photovoltaic solar panels are made up of smaller cells connected together that convert light radiation into electricity. The PV cells produce direct-current (DC) electricity, which must then be inverted for use in an AC system. Photovoltaic systems produce no emissions, are reliable, and require minimal maintenance to operate.
- **Wind Turbines:** Wind turbines utilizes wind to produce electricity and require no additional investments in setting up large infrastructure such as new transmission lines, and are thus commonly employed for remote power applications.

2.2.11 Role of Distributed Generation in Smart Grid:

- Distributed Generations are natural extensions of smart grids. Their ability for on-site decentralized power generation helps in reducing peak loads and hence better system management of the central grid. In future, both smart micro grids and smart decentralized generations will be able to sell their generation back to the utilities from whom they buy the power thus providing additional revenue stream. This will help utilities to reduce the need for massive investments in building new high-voltage transmission lines to carry renewable power from far-off plants to towns and cities. Locally based solar, wind, biomass generators, fuel cells and other decentralized generation systems are much more convenient sources of power, thereby cutting down on the line losses associated with long-range transmission.
- A key feature of a micro-grid is its ability to separate and isolate itself from the utility seamlessly during a utility grid disturbance with little or no disruption to the loads within the micro-grid. The micro-grid can automatically resynchronize itself when the

utility grid returns to normal functioning, and reconnects itself to the grid, in an equally seamless fashion. Additionally, it reduces carbon emission and thus supports sustainable livelihood.

2.2.12 Distributed Generation in India

In India, many renewable energy technologies are being employed in a number of decentralized generation projects. The figure below illustrates the technology options for decentralized power generation.

In typical Indian rural areas, smart micro-grids can provide clean, reliable, affordable, and scalable electrical power. For Indian economy rising fuel costs, under investment in old infrastructure and climate change are some of the biggest challenges being faced by the energy industry today. A Micro-Smart Grid can deliver benefit by use of renewable energy sources, while improving the reliability, security, and useful life of electrical infrastructure. The development of basic smart grid technologies can be accelerated by bringing together all stakeholders namely, state and local governments, utility companies, public electricity regulators, and IT companies towards a common goal.

2.3 Smart Substation:

2.3.1 Introduction of Smart substation

Substation is integral part of a power system and form important links between the generating station, transmission systems, distribution systems and the load points. Voltage level transformation and regulation is the one of the main objective of substation. Electric power flow between the generating plant and the consumer passes through several substations at different voltage levels.

Substation automation is the integration of existing substation devices and a new network infrastructure. By integrating primary devices with networked secondary devices, the substation can perform automatic industrial tasks such as data acquisition, device control, and event recording.

Substation automation has the following features:

1. Upgrades and optimizes the secondary equipment within the power system, such as measuring units, signals, relay controllers, automation units, and RTUs.
2. Combines electronic, telecommunication, and signal process technology to enable substation automation.
3. Integrates the automatic monitoring, measuring, controlling, and protection of the equipment used in power generation, distribution, and dispatch.

4. A complete intelligent system of function integration, structure computerization, display-based monitoring, and smart management.

SMART substation is a key component of a smart grid. At present, smart substations are mainly based on the IEC61850 standard which uses the “three layers and two networks” architectural framework.

A smart substation has the following features:

1. All primary devices have been upgraded as intelligent devices.
2. All secondary devices have been networked.
3. Substation operation and management have all been automated

2.3.2 Layout smart substation:

The secondary system of the smart substation adopts the “three-tier, two-network” structure. The "three layers" refers to the station control layer, the bay layer, and the process layer. The "two networks" refers to the station control layer network and the process layer network.

i. **Station Control Layer**: The station control layer is composed of a host and operator station, a tele-control communication device, a network communication record analysis system and other various secondary functional stations, and provides a man-machine contact interface for the operating personnel in the substation. The station control layer realizes the monitoring, control, alarming, and information exchange of the entire station, including the bay level equipment and the process level equipment, and collects and manages the related electrical quantity parameters, protection signals, and operation information. It is the monitoring and control center of the entire smart substation. , And is responsible for communication with the remote control center, upload all the information required by the control center. Refer fig 2.14.

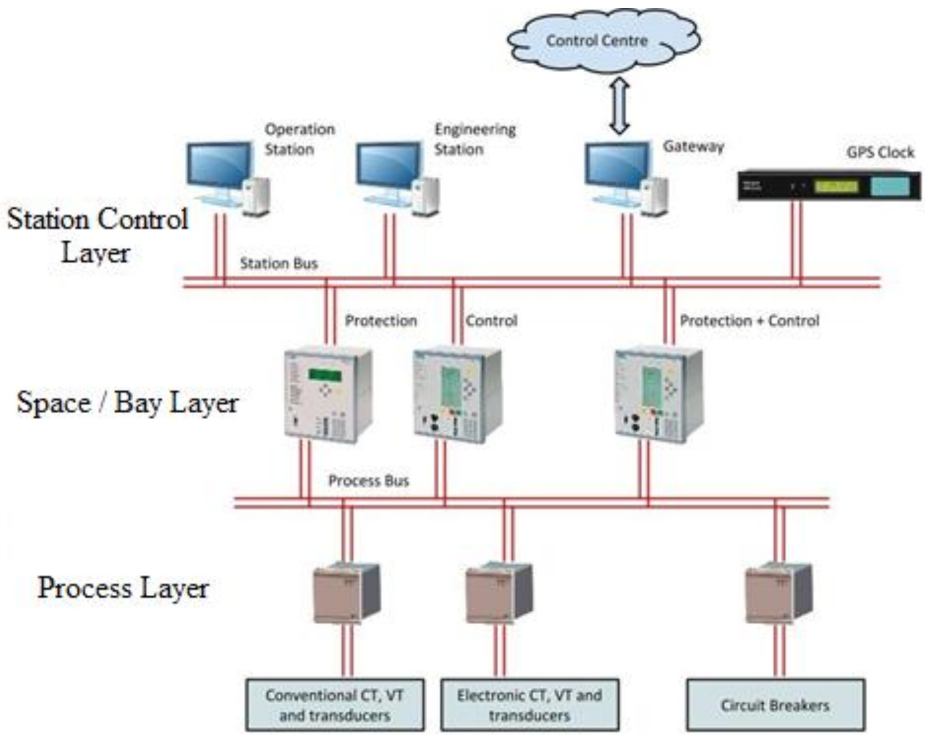


Fig 2.14

ii. **Bay / Spacer Layer:** The spacer layer is generally composed of secondary devices such as a system measurement and control device, an energy metering device, a relay protection device, and a centralized processing device. The spacer device can collect data of one interval and can affect the operation of the primary device of the interval, and realize the transmission of data signals and control signals with the remote ports. The separation layer composed of several secondary subsystems has a certain degree of independence, and even in the case of losing connection with the network of the station control layer, the normal operation of the on-site monitoring function of the bay level equipment can still be guaranteed.

iii. **Process Layer**: The process level includes primary devices such as main transformers, switches, switches current transformers and voltage transformers, as well as smart units and smart terminals associated with these devices. Compared with conventional substations, the most obvious change in the structure of smart substations is the emergence of the process layer. The process layer connects the primary device and the secondary device through intelligent components, intelligent terminals and merging units. Its main role is to assist and support primary devices, electronic transformers, merging units, intelligent terminals, on-line monitoring devices and related Auxiliary equipment acts on functions related to primary equipment, such as collecting and sending real-time operating data, monitoring and managing equipment operating status, and receiving and executing remote control commands.

Challenges in smart substations:

- Although the smart substation solves such issues as digital information sharing and collecting equipment reconfigurations, but 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 substation devices related to substation protection, measurement, control, and data collection needs improvement.
- Other functions, including discrete configuration and equipment integration invite high construction costs.
- Also, there are different types of intelligent devices in large quantities, which lead to many challenges in the commissioning, operation, and maintenance of those devices.
- For the above reasons, the popularization and application of the smart substation system is hampered to some extent.

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

Sr. No.	References
1.	Smart Grid and Renewable Energy, 2011, 2, 305-311 doi:10.4236/sgre.2011.24035 Published Online November 2011 (http://www.SciRP.org/journal/sgre)
2.	https://www.bharathuniv.ac.in/colleges1/downloads/courseware_eee/Notes/CE3/BEE01 smartgrid.pdf
3.	http://www.indiasmartgrid.org/reports/Context of%20Smart%20Grids%20in%20India-KnowledgePaperofIndiaSmartGridDay2013.pdf
4.	Research paper - ‘Smart Grid: An Overview’ by Tamilmaran Vijayapriya1, DwarkadasPralhadasKothari*Smart Grid and Renewable Energy*, 2011, 2, 305-311
5.	“THE SMART GRID Introduction’ e-book by _Department Of Energy, USA_
6.	http://www.indiasmartgrid.org/pilot.php
7.	Scholarly articles for Smart Grid: Concepts and Deployment Dr. S. Chakrabarti Department of Electrical Engineering,IIT Kanpur

Sr. No.	References
8.	https://www.researchgate.net/publication/224325606_Microgrid_standards_and_technologies/link/54b28c9b0cf2318f0f952568/download
9.	https://shodhganga.inflibnet.ac.in/bitstream/10603/142737/3/12.%20chapter%203.pdf
10.	http://uni-site.ir/khuelec/wp-content/uploads/Microgrids-and-Active-Distribution-Networks.pdf
11.	https://whatis.techtarget.com/definition/microgrid
12.	https://www.hdbaker.com/article/what-are-the-components-of-a-microgrid-
13.	https://myelectrical.com/notes/entryid/245/how-a-digital-substation-works
14.	https://www.researchgate.net/publication/224408154_Communication_Protocols_and_Networks_for_Power_Systems_-_Current_Status_and_Future_Trends
15.	https://www.sciencedirect.com/topics/engineering/substation-automation

MCQ s

		Choose the correct option for each of the following:	Marks
1.		Electric grid is a single entity with …. a. Multiple generation plants and transmission network b. Conventional generation plants and transmission network c. Multiple generation plants and distribution network d. Multiple generation plants, transmission and distribution network	1
2		Smart grid an electric grid that uses information and communication technology a. To gather data and act on information b. To gather data only c. To gather the information only d. To gather data and not to act on information	1
3		Objective of Smart grid is… a. Smart utilization of all the available resources. b. Best utilization of all the available resources c. optimum utilization of all the available resources d. all of the above	1
4		Function of the communication network in Smart grid is….. a. Energy Generation b. Control and connectivity c. Applications d. Optimum use of energy	1
5		Following are sub-domains of Grid domain of Smart Grid. a. Generation domain only b. Generation and transmission domain only c. Generation , transmission and distribution domain only d. Distribution and transmission domain only	1

6		Third stage in evolution of Smart Grid is…. a. Preliminary stage b. Elementary stage c. Evolutionary stage d. Post evolutionary stage	2
7		Self-healing is the significant feature of …… a. Conventional grid b. Smart grid c. Micro grid d. Macrogrid	2
8		Which of the following plays crucial role in optimization of cost of energy? a. Macro grid b. Micro grid c. Smart grid d. Conventional grid	1
9		Challenge faced by Energy Storage System of smart grid is…. a. Complex design and network b. Security c. Consumer awareness d. Stability of Power flow	2
10		ISGTF abbreviation stands for …. a. India Smart Grid Task Force b. International Scout And Guide Fellowship c. International Smart Grid Task Force d. India Standard Grid Task Force	2
11		Classification of micro grids is based on … a. type of controlling apparatus b. type of supply (AC/DC) c. type of load d. number of generating units	1
12		Distributed generation plays significant role in macro grid to improve a. increasing the power demand on the grid b. increasing the transmission line losses c. increasing the reliability factor of supply d. increasing the cost of power generation	1
13		Technologies for Distributed Generation includes a. Micro- compressors b. Micro –hydro turbines c. Macro –hydro turbines d. Macro- turbines	2
14		A key feature of a micro-grid is its ability………from the utility seamlessly during grid disturbance a. not to separate and isolate itself b. to separate and isolate itself c. to separate but not to isolate itself d. not to separate and isolate itself	2

15		______________is a stakeholders of smart grid. a. Oil manufacturing companies b. Utility companies c. Motor manufacturing companies d. Political Parties	1
16		A localized grouping of electricity generations, energy storages, and loads is termed as? a. Macro grid b. Micro grid c. National grid d. State grid	2
17		What is the full form of DR in the perspective of Smart Grids? a. Divide and Rule b. Demand and Response c. Delivery Rate d. Data Reduction	1
18		A micro-grid is designed for a _____________usually for a certain community whiles the smart grid is designed for the ________electrical system. a. small scale, whole b. medium scale, whole c. large scale ,whole d. small scale, partial	2
19		India Smart Grid Task Force (ISGTF) recommended ___________number of pilot projects in different distribution companies. a. 20 b. 18 c. 14 d. 16	2
20		"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." a. Micro Grid Vision for India b. Smart Grid Vision for USA c. Smart Grid Mission for India d. Smart Grid Vision for India	2
21		Micro Grid can be operated said to be in islanded mode when…… a. it function synchronously b. it functions autonomously. c. it function asynchronously d. it stops functioning.	2

Answer ke: Unit-II
Unit-II –Smart Grid 1-d ; 2- a ; 3-d ; 4-b ; 5-c ; 6-c ; 7-b ; 8-b ; 9-a ; 10-a ; 11-b ; 12-c ; 13 –b ; 14- b ; 15-b ; 16- b ; 17 –b ; 18-a ; 19-c ; 20-d ; 21-b

Unit III

Smart City (Electrical Features)

This unit focuses on following aspects:

3.1 Smart City: Features, components, Objectives and challenges of smart Cities in India.

3.2 E-car: Role of Electric Vehicles in energy transition, basics of electric car, types of electric cars, working principle, charging stations. Fuel cell for e-cars, types, features, limitations.

3.3 Smart Home: Features and Components. Illumination and smart appliance control principles (block diagram/s).

Introduction:

The first question is what is meant by a 'smart city'. The answer is, there is no universally accepted definition of a smart city. It means different things to different people. The conceptualization of Smart City, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents. A smart city would have a different connotation in India than, say, Europe. Even in India, there is no one way of defining a smart city.

Some definitional boundaries are required to guide cities in the Mission. In the imagination of any city dweller in India, the picture of a smart city contains **a wish list of infrastructure and services that describes his or her level of aspiration.** To provide for the aspirations and needs of the citizens, urban planners ideally aim at developing the entire urban eco-system, which is represented by the four pillars of comprehensive development-institutional, physical, social and economic infrastructure. This can be a long-term goal and cities can work towards developing such comprehensive infrastructure incrementally, adding on layers of 'smartness'.

3.1.1 Features of comprehensive development in Smart Cities are described below: -

i. Promoting mixed land use in area-based developments: — planning for 'unplanned areas' containing a range of compatible activities and land uses close to one another in order to make land use more efficient. The States will enable some flexibility in land use and building bye-laws to adapt to change;

ii. Housing and inclusiveness: — expand housing opportunities for all;

iii. Creating walkable localities: — reduce congestion, air pollution and resource depletion, boost local economy, promote interactions and ensure security. The road network is created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, and necessary administrative services are offered within walking or cycling distance;

iv. Preserving and developing open spaces: — parks, playgrounds, and recreational spaces in order to enhance the quality of life of citizens, reduce the urban heat effects in Areas and generally promote eco-balance;

v. Promoting a variety of transport options: — Transit Oriented Development (TOD), public transport and last mile para-transport connectivity;

vi. Making governance citizen-friendly and cost effective: — increasingly rely on online services to bring about accountability and transparency, especially using mobiles to reduce cost of services and providing services without having to go to municipal offices; form e-groups to listen to people and obtain feedback and use online monitoring of programs and activities with the aid of cyber tour of worksites;

vii. Giving an identity to the city: - — based on its main economic activity, such as local cuisine, health, education, arts and craft, culture, sports goods, furniture, hosiery, textile, dairy, etc;

viii. Applying Smart Solutions: - These are for infrastructure and services in area-based development in order to make them better. For example, making Areas less vulnerable to disasters, using fewer resources and providing cheaper services.

As far as Smart Solutions are concerned, an illustrative list is given below. This is not, however, an exhaustive list, and cities are free to add more applications.

Fig 3.1 Smart Solutions for Smart City

3.1.2 The core infrastructure elements in a smart city would include:

i. Adequate water supply,

ii. Assured electricity supply,

iii. Sanitation, including solid waste management,

iv. Efficient urban mobility and public transport,

v. Affordable housing, especially for the poor robust IT connectivity and digitalization,

vii. Good governance, especially e-Governance and citizen participation,

viii. Sustainable environment,

ix. Safety and security of citizens, particularly women, children and the elderly, and

x. Health and education.

Accordingly, the purpose of the Smart Cities Mission is to drive economic growth and improve the quality of life of people by enabling local area development and harnessing technology, especially technology that leads to Smart outcomes. Area-based development will transform existing areas (retrofit and redevelop), including slums, into better planned ones, thereby improving livability of the whole City. New areas (greenfield) will be developed around cities in order to accommodate the expanding population in urban areas. Application of Smart Solutions will enable cities to use technology, information and data to improve infrastructure and services. Comprehensive development in this way will improve quality of life, create employment and enhance incomes for all, especially the poor and the disadvantaged, leading to inclusive Cities.

3.1.3 Components of Smart City: -The strategic components of area-based development in the Smart Cities Mission are city improvement (retrofitting), city renewal (redevelopment) and city extension (greenfield development) plus a Pan-city initiative in which Smart Solutions are applied covering larger parts of the city. Below are given the descriptions of the three models of Area-based smart city development:

i) Retrofitting: It will introduce planning in an existing built-up area to achieve smart city objectives, along with other objectives, to make the existing area more efficient and livable. In retrofitting, an area consisting of more than 500 acres will be identified by the city in consultation with citizens. Depending on the existing level of infrastructure services in the identified area and the vision of the residents, the cities will prepare a strategy to become smart. Since existing structures are largely to remain intact in this model, it is expected that more intensive infrastructure service levels and a large number of smart applications will be packed into the retrofitted smart city. This strategy may also be completed in a shorter time frame, leading to its replication in another part of the city.

ii) Redevelopment: It will effect a replacement of the existing built-up environment and enable co-creation of a new layout with enhanced infrastructure using mixed land use and increased density. Redevelopment envisages an area of more than 50 acres, identified by Urban Local Bodies (ULBs) in consultation with citizens. For instance, a new layout plan of the identified area will be prepared with mixed land-use, higher FSI and high ground coverage. Two examples of the redevelopment model are the Saifee Burhani Upliftment Project in Mumbai (also called the Bhendi Bazaar Project) and the redevelopment of East Kidwai Nagar in New Delhi being undertaken by the National Building Construction Corporation.

iii) Greenfield development: - It will introduce most of the Smart Solutions in a previously vacant area (more than 250 acres) using innovative planning, plan financing and plan implementation tools (e.g. land pooling/ land reconstitution) with provision for affordable housing, especially for the poor. Greenfield developments are required around cities in order to address the needs of the expanding population. One well known example is the GIFT City in Gujarat. Unlike retrofitting and redevelopment, greenfield developments could be located either within the limits of the ULB or within the limits of the local Urban Development Authority (UDA).

iv) Pan-city development: - It envisages application of selected Smart Solutions to the existing city-wide infrastructure. Application of Smart Solutions will involve the use of technology, information and data to make infrastructure and services better. For example, applying Smart Solutions in the transport sector (intelligent traffic management system) and reducing average commute time or cost of citizens will have positive effects on productivity and quality of life of citizens. Another example can be waste water recycling and smart metering which can make a huge contribution to better water management in the city.

The smart city proposal is expected to encapsulate either a retrofitting or redevelopment or greenfield development model, or a mix thereof and a Pan-city feature with Smart Solution(s). It is important to note that pan-city is an additional feature to be provided. Since smart city is taking a compact area approach, it is necessary that all the city residents feel there is something in it for them also. Therefore, the additional requirement of some (at least one) city-wide smart solution has been put in the scheme to make it inclusive.

3.1.4 Objectives of the Smart City: -

i) Promote cities that provide core infrastructure and give a decent quality of life to its citizens,

ii) A clean and sustainable environment and application of 'Smart' Solutions in which the focus is on sustainable and inclusive development and the idea is to look at compact areas,

iii) Create a replicable model which will act like a light house to other aspiring cities.

The Smart Cities Mission of the Government is a bold, new initiative. It is meant to set examples that can be replicated both within and outside the Smart City, catalyzing the creation of similar Smart Cities in various regions and parts of the country.

3.1.5 Challenges of Smart City: -

i) This is the first time, a MoUD programme is using the 'Challenge' or competition method to select cities for funding and using a strategy of area-based development.

ii) This captures the spirit of 'competitive and cooperative federalism'.

iii) States and ULBs will play a key supportive role in the development of Smart Cities. Smart leadership and vision at this level and ability to act decisively will be important factors determining the success of the Mission.

iv) Understanding the concepts of retrofitting, redevelopment and greenfield development by the policy makers, implementers and other stakeholders at different levels will require capacity assistance.

v) Major investments in time and resources will have to be made during the planning phase prior to participation in the Challenge. This is different from the conventional DPR-driven approach.

The Smart Cities Mission requires smart people who actively participate in governance and reforms. Citizen involvement is much more than a ceremonial participation in governance. Smart people involve themselves in the definition of the Smart City, decisions on deploying Smart Solutions, implementing reforms, doing more with less and oversight during implementing and designing post-project structures in order to make the Smart City developments sustainable. The participation of smart people will be enabled by the SPV through increasing use of ICT, especially mobile-based tools.

3.2 E-car: Role of Electric Vehicles in energy transition, basics of electric car, types of electric cars, working principle, charging stations. Fuel cell for e-cars, types, features, limitations.

3.2.1 Role of Electric Vehicles in energy transition:

Historically, mobility and fossil fuels have been inextricably linked with electric vehicles being successful only in a few niche markets. However, over the last decade, a collection of circumstances has conspired to create an opening for electric vehicles to enter the mass market. Those reasons include:

1. Climatic change: The prospect of rapid global temperature increase has created the need for a reduction in the use of fossil fuels and the associated emissions. India has committed to cutting its GHG emissions intensity by 33% to 35% percent below 2005 levels by 2030.

2. Advances in renewable energy: Over the last decade, advances in wind and solar electricity generation technologies have drastically reduced their cost and introduced the possibility of clean, low-carbon and inexpensive grids. India proposes to add 175 GW of renewable energy capacity by 2020 and to achieve 40 percent of its electricity generation from non-fossil sources by the same year.

3. Rapid urbanization: Economic development, especially in emerging economies, is creating a wave of urbanization as rural populations move to cities in search of employment. While urbanization is an important component of the process of economic development, it also stresses upon the energy and transport infrastructure leading to congestion and pollution. According to a recent study by WHO, India is home to 14 out of 20 most polluted cities in the world. Electric vehicles (EVs) can improve that scenario by reducing local concentrations of pollutants in cities.

4. Data capture and analysis: With the rise of GPS enabled smartphones and the associated universe of mobility applications, mobility has undergone a digital revolution. That digital revolution has created possibility of a greater utilization of existing transportation assets and infrastructure. For EVs, which rely on lower variable costs to offset relatively high fixed costs, this enhanced utilization is a critical element of achieving total costs of ownership compared to internal combustion vehicles.

5. Battery chemistry: Advances in battery technology have led to higher energy densities, faster charging and reduced battery degradation from charging. Combined with the development of motors with higher rating and reliability, these improvements in battery chemistry have reduced costs and improved the performance and efficiency of electric vehicles.

6. Energy security: The petrol, diesel and CNG needed to fuel an internal combustion engine (ICE) based mobility system requires an extensive costly supply chain that is prone to disruption from weather, geopolitical events and other factors. India needs to import oil to cover over 80 percent of its transport fuel. That ratio is set to grow as a rapidly urbanizing population demands greater intra-city and inter-city mobility. As a result, developed economies such as EU, the USA and Japan as well as developing economies such as China and India have all included Electric Vehicles (EV) in their policies to lower their carbon emissions while providing convenient and cost-effective mobility.

The key objectives of the EV policy are:

1. Reduce primary oil consumption in transportation.
2. Facilitate customer adoption of electric and clean energy vehicles.
3. Encourage cutting edge technology in India through adoption, adaptation, and research and development.
4. Improve transportation used by the common man for personal and goods transportation.
5. Reduce pollution in cities.
6. Create EV manufacturing capacity that is of global scale and competitiveness.
7. Facilitate employment growth in a sun-rise sector.

3.2.2 Basics of electric car: -

An electric car is an automobile that is propelled by one or more electric motors, using energy stored in rechargeable batteries. The first practical electric cars were produced in the 1880s. Electric cars were popular in the late 19th century and early 20th century, until advances in internal combustion engines, electric starters in particular, and mass production of cheaper gasoline vehicles led to a decline in the use of electric drive vehicles.

From 2008, a renaissance in electric vehicle manufacturing occurred due to advances in batteries, illnesses and deaths due to air pollution and the desire to reduce greenhouse gas emissions. Several national and local governments have established government incentives for plug-in electric vehicles, tax credits, subsidies, and other incentives to promote the introduction and adoption in the mass market of new electric vehicles, often depending on battery size, their electric range and purchase price. Compared with internal combustion engine cars, electric cars are quieter, have no tailpipe emissions, and lower emissions in general.

Charging an electric car can be done at a variety of charging stations, these charging stations can be installed in both houses and public areas.

As of December 2018, there were about 5.3 million light-duty all-electric and plug-in hybrid vehicles in use around the world. Despite the rapid growth experienced, the global stock of plug-in electric cars represented just about 1 out of every 250 vehicles (0.40%) on the world's roads by the end of 2018.The plug-in car market is shifting towards fully electric battery vehicles, as the global ratio between annual sales of battery BEVs and PHEVs went from 56:44 in 2012, to 60:40 in 2015, and rose to 69:31 in 2018.

There are a variety of technologies available in conventional vehicles, plug-in electric vehicles (also known as electric cars or EVs) have different capabilities that can accommodate different drivers' needs. A major feature of EVs is that drivers can plug them in to charge from an off-board electric power source. This distinguishes them from hybrid electric vehicles, which supplement an internal combustion engine with battery power but cannot be plugged in.

An Electric Car is an automobile by itself and consists of many components and a large cluster of wires connecting them all. But there are few basic bare minimum materials for an Electric Car which is shown in the block diagram below.

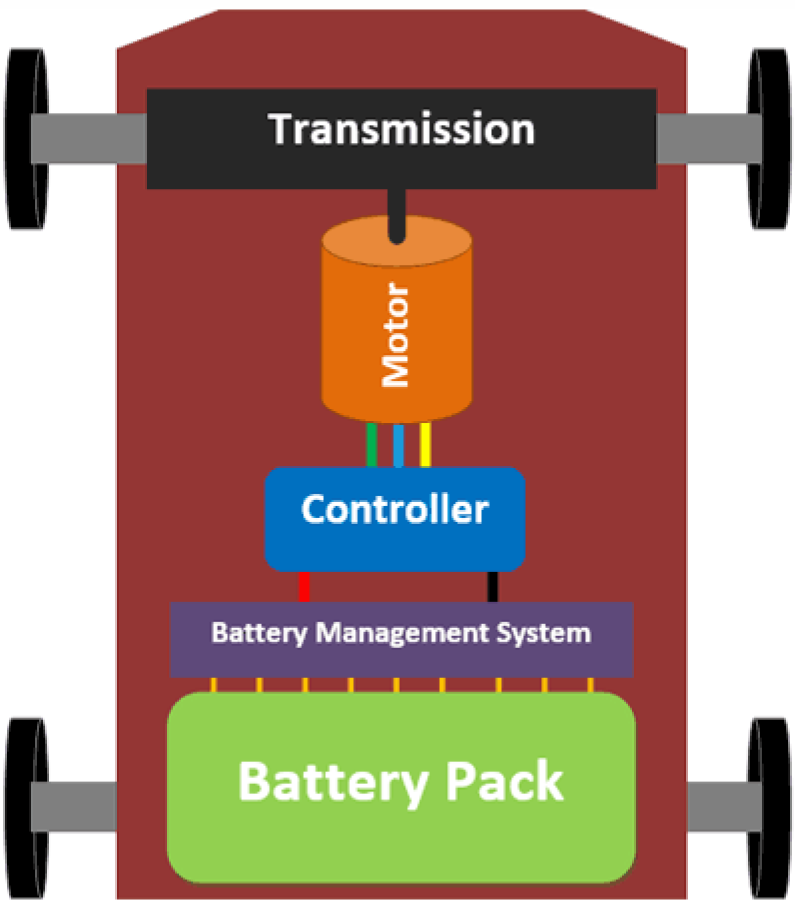


Fig 3.2 Block Diagram of Electric Vehicle

The Engine of a conventional IC Engine Car is replaced by an electrical Motor and the fuel tank is replaced by the Battery Pack. Of all the components only the Battery Pack and Motor alone contributes to about more than 50% of the total cars weight and the price. As you can see the major parts are: -

i) Battery Pack: Batteries are the fuel source for Electric Cars. The voltage rating of the cells (per cell) will be anywhere from 3.7V for a lithium battery and a maximum of 12V for Lead-Acid batteries. But as you might have guessed this voltage is not enough to run an electric car. The Tesla for example has a battery pack voltage of 356 Voltas and even for a normal electric bi-cycle we need a minimum of 36V so how do we get this higher voltage from lithium cells that are only 3.7V. So, to get the higher voltage from 3.7V lithium cells, battery packs are used which are formed by combining more than one battery together. When two batteries are connected in series their voltage ratings are added and when two batteries are connected in parallel their Ah rating is added. For example, assume we have 3.7V 2000mAh Lithium batteries. If you connect two of these in series the resulting system is called a module and this module will have 7.4V 2000mAh. Likewise, if we connect two of these in parallel the resulting module will be 3.7V 4000mAh.monitored for a safe operation.

ii) Battery Management System (BMS) Controller: Once the system Voltage and Ampere hour (Ah) rating is obtained by combining various modules in series and parallel configuration this set-up should be placed inside the EV. But it is not so easy; the reason is -its complexity. Lithium cells are unstable in nature and any mishap like short circuit or excess charging or discharging can make there batteries get very hot leading to fire or explosion. So, the voltage, current and temperature of each cell should be The duty of monitoring the cells during the charging and discharging procedure is given to the circuit called Battery Management system or BMS for short. Every BMS measures only three vital parameters of the battery which are the Voltage, current and Temperate of the cell. It constantly compares these values with safety limits and disconnects the load if they exceed the threshold values. Apart from safety purpose the BMS is also used for some computational purpose like measuring the parameters of a battery. So, once the battery modulus is ready it should be connected to the BMS and a cooling system for safe operation of battery. The complete set-up is kept in a steel casing to prevent mechanical damage. This complete arrangement along with the BMS, cooling system casing and the battery modules all together is called as a Battery Pack of a car.

iii) Motor: - There are many types of Motors used in EV and the one used for Scooters and bikes is totally different form the one that is used in cars. The commonly used ones that are BLDC motors, Brushed DC motors and AC Induction Motor.

a) BLDC Motors: BLDC Motors have been the choice for EV’s from its origin in 1900. Even today it is commonly used in Electric cycles and scooters. BLDC stands for Brush Less DC motor; these motors have a constant torque and fast response making it suitable for automotive applications. Apart from EV’s these motors are also used in wipers, power windows etc.

b) Brushed DC motors: The Brushed DC motor also known as DC series motor was the preferable choice for all old Electric cars. These motors provide a lot of torque which could easily give a sporty feel to the EV. The pull/pick-up of the EV would be almost at par with an average conventional car that these motors were used by drag racers during then. But now after 2008, these motors are not much in use any longer the reason is DC motors cannot provide a constant torque under a varying load. Meaning cursing or climbing a hill with the car will be difficult. Also, DC motors cannot start without a load that is it cannot self start due to its high initial current which might damage the motor itself.

c) AC Induction Motors: Most Modern-day Electric cars like the Tesla uses an AC Induction motor. The reason why these motors are selected is that they do not have permanent magnets within them and thus low cost. It also has good life since there are no magnets, magnets would lose their tendency in day course. The downside of the motor would be that it is hard to control the speed and torque of the motor and advanced circuitries are required.

iv) Transmission unit: All cars have gears, including electric cars. However most electric cars do not have nor need a multispeed transmission due to the high torque available over a very wide range of motor speeds. Generally, the electric motor is always connected to the drive wheels through a fixed ratio reduction gear.

3.2.3 Types of electric cars and working principle:

There are three types of electric vehicle: Battery Electric Vehicle (BEV), Plug in Hybrid Electric
Vehicle (PHEV) and Hybrid Electric Vehicle (HEV).

i) Battery electric vehicle (BEV): These runs entirely using an electric motor and battery, without the support of a traditional internal combustion engine, and must be plugged into an external
source of electricity to recharge its battery. Like all electric vehicles, BEVs can also recharge their batteries through a process known as regenerative braking, which uses the vehicle's electric motor to assist in slowing the vehicle, and to recover some of the energy normally converted to heat by the brakes. Most have ranges of 80 to 100 miles, while a few luxury models have ranges up to 250 miles. When the battery is depleted, it can take from 30 minutes (with fast charging) up to nearly a full day (with Level 1 charging) to recharge it, depending on the type of charger and battery.

Advantages:

1. No emissions
2. No gas or oil changes
3. Ability to conveniently charge at home
4. Fast and smooth acceleration
5. Low cost of operation - about $30 a month.

Disadvantages:

1. Shorter range than gasoline vehicles, although most people drive well within the range of today's BEV and could rent a hybrid for the rare long trips.
2. Slightly more expensive than their gasoline equivalent although the gasoline savings pay off the difference in typically 2-3 years.

ii) Plug-in Hybrid Electric Vehicle (PHEV)

Plug-in hybrids (PHEVs) use an electric motor and battery that can be plugged into the power grid to charge the battery, but also has the support of an internal combustion engine that may be used to recharge the vehicle's battery and/or to replace the electric motor when the battery is low. Because Plug-in Hybrids use electricity from the power grid, they often realize more savings in fuel costs than tradition hybrids electric vehicles (HEV).

Advantages:

1. Longer range than BEV
2. Less gas consumption than gas only vehicle
3. Fewer emissions
4. Very simple mechanics, less to go wrong.

Disadvantages:

1. Produces tailpipe emissions
2. Needs gas and oil changes
3. More expensive to operate than Battery Electric Vehicle (BEV) but less than traditional
   Hybrid vehicle (HEV).

PHEVs run on electricity for shorter ranges (6 to 40 miles), then switch over to an internal combustion engine running on gasoline when the battery is depleted. The flexibility of PHEVs allows drivers to use electricity as often as possible while also being able to fuel up with gasoline if needed. Powering the vehicle with electricity from the grid reduces fuel costs, cuts petroleum consumption, and reduces tailpipe emissions compared with conventional vehicles. When driving distances are longer than the BEV, PHEVs act like hybrid electric vehicles, consuming less fuel and distances are longer than the all-electric range, PHEVs act like hybrid electric vehicles, consuming less fuel and producing fewer emissions than similar conventional vehicles. Depending on the model, the internal combustion engine may also power the vehicle at other times, such as during rapid acceleration or when using heating or air conditioning. PHEVs could also use hydrogen in a fuel cell, biofuels, or other alternative fuels as a back-up instead of gasoline.

iii) Hybrid Electric Vehicle: Hybrid Electric Vehicles (HEVs) have two complementary drive systems: a gasoline engine with a fuel tank; and an electric motor with a battery. Both the engine and the electric motor can
turn the transmission at the same time, and the transmission then turns the wheels. HEVs cannot be recharged from the electricity grid – all their energy comes from gasoline and from regenerative braking.

Advantages:

1. Longer range than BEV
2. Less gas consumption than gas only vehicle
3. Fewer emissions than gas only vehicle

Disadvantages

1. Still produces emissions
2. Complex mechanics – Gasoline + Electric
3. Expensive to operate (8-10 times more expensive than BEV) but less than traditional gasoline vehicle.
4. No ability to conveniently charge at home

3.2.4 Charging Stations:

An electric vehicle charging station, is an element in an infrastructure that supplies electric energy for the recharging of plug-in electric vehicles—including electric cars, neighborhood electric vehicles and plug-in hybrids electric vehicles.

Charging stations fall into three basic categories:

i) Residential charging stations: An EV owner plugs into a standard when he or she returns home, and the car recharges overnight. A home charging station usually has no user authentication, no metering, and may require wiring a dedicated circuit. Some portable chargers can also be wall mounted as charging stations.

ii) Charging while parked: A commercial venture for a fee or free, offered in partnership with the owners of the parking lot. This charging may be slow or high speed and encourages EV owners to recharge their cars while they take advantage of nearby facilities. It can include parking stations, parking at malls, small centers, and train stations (or for a business's own employees).

iii) Fast charging at public charging stations: These have rating more than 40 kW, capable of delivering over 60-mile (97 km) of range in 10–30 minutes. These chargers may be at rest stops to allow for longer distance trips. They may also be used regularly by commuters in metropolitan areas, and for charging while parked for shorter or longer periods.

For charging at home or work, some electric vehicles have converters on board that can plug into a standard electrical outlet or a high-capacity appliance outlet. Others either require or can use a charging station that provides electrical conversion, monitoring, or safety functionality. These stations are also needed when traveling, and many supports faster charging at higher voltages and currents than are available from residential EVSEs. Public charging stations are typically on-street facilities provided by electric utility companies or located at retail shopping centers, restaurants and parking places, operated by a range of private companies.

The charging time depends on the battery capacity and the charging power. In simple terms, the time rate of charge depends on the charging level used, and the charging level depends on the voltage handling of the batteries and charger electronics in the car. The U.S.-based SAE International defines Level 1 (household 120V AC) as the slowest, Level 2 (upgraded household 240 VAC) in the middle and Level 3 (super charging, 480V DC or higher) as the fastest. Level 3 charge time can be as fast as 30 minutes for an 80% charge, although there has been serious industry competition about whose standard should be widely adopted.

Charge time can be calculated using the formula:

Charging Time [h] = Battery Capacity [kWh] / Charging Power [kW]

For normal charging (up to 7.4 kW), car manufacturers have built a battery charger into the car. A charging cable is used to connect it to the electrical network to supply 230-volt AC current. For quicker charging (22 kW, even 43 kW and more), manufacturers have chosen two solutions:

i) Use the vehicle's built-in charger, designed to charge from 3 to 43 kW at 230 V single-phase or 400 V three-phase.

ii) Use an external charger, which converts AC current into DC current and charges the vehicle at 50 kW.

The typical charging time for 100Km of BEV is as shown in following table:

Charging time for 100 km of BEV range	**Power supply**	**Power**	**Voltage**	**Max. current**
6–8 hours	Single phase	3.3 kW	230 V AC	16 A
3–4 hours	Single phase	7.4 kW	230 V AC	32 A
2–3 hours	Three phase	11 kW	400 V AC	16 A
1–2 hours	Three phase	22 kW	400 V AC	32 A
20–30 minutes	Three phase	43 kW	400 V AC	63 A

Charging time for 100 km of BEV range	Power supply	Power	Voltage	Max. current
20–30 minutes	Direct current	50 kW	400–500 V DC	100–125 A
10 minutes	Direct current	120 kW	300–500 V DC	300–350 A

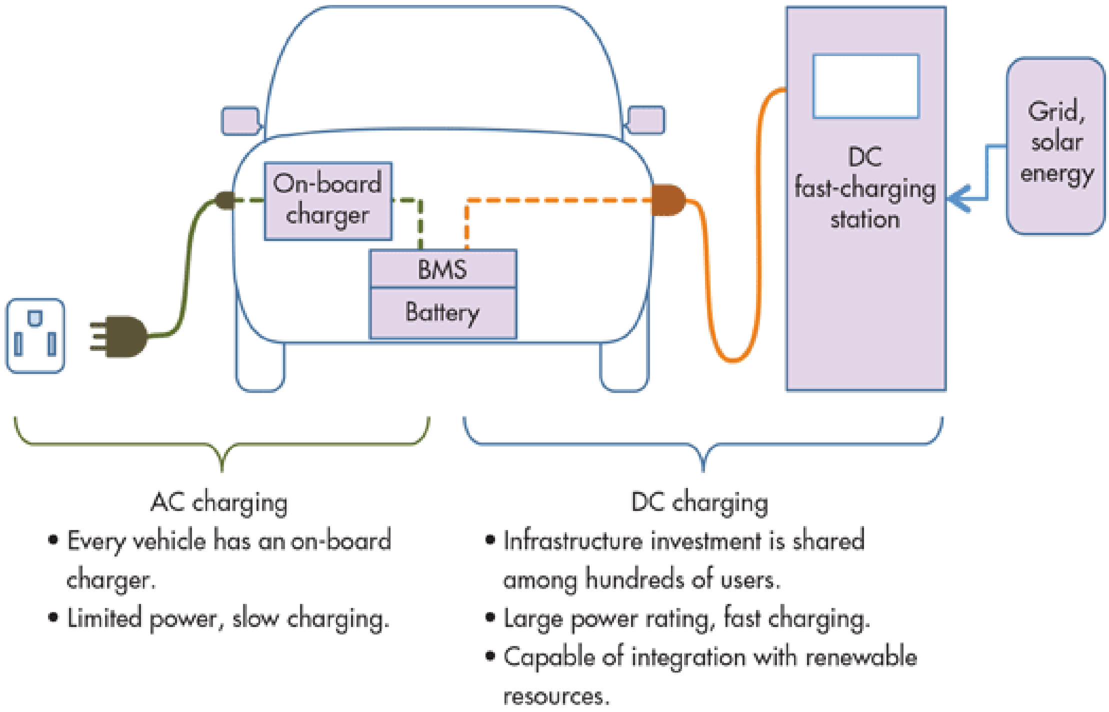


Fig 3.3 Block Diagram of Electric Vehicle Charging Station

3.2.5 Fuel cell for e-cars, types, features, limitations:

A fuel cell vehicle (FCV) or fuel cell electric vehicle (FCEV) is a type of electric vehicle which uses a fuel cell, instead of a battery, or in combination with a battery or super capacitor, to power its on-board electric motor. Fuel cells in vehicles generate electricity to power the motor, generally using oxygen from the air and compressed hydrogen. Most fuel cell vehicles are classified as zero-emissions vehicles that emit only water and heat. As compared with internal combustion vehicles, hydrogen vehicles centralize pollutants at the site of the hydrogen production, where hydrogen is typically derived from reformed natural gas. Transporting and storing hydrogen may also create pollutants.

Fuel cells have been used in various kinds of vehicles including forklifts, especially in indoor applications where their clean emissions are important to air quality, and in space applications. The first commercially produced hydrogen fuel cell automobile, the Hyundai Tucson FCEV, was introduced in 2013, Toyota Mirai followed in 2015 and then Honda entered the market. Fuel cells are also being developed and tested in trucks, buses, boats, motorcycles and bicycles, among other kinds of vehicles. Critics doubt whether hydrogen will be efficient or cost-effective for automobiles, as compared with other zero emission technologies.

Types of Fuel Cell, features, limitations:

The fuel cell will compete with many other energy conversion devices, including the gas turbine in your city's power plant, the gasoline engine in your car and the battery in your laptop. Combustion engines like the turbine and the gasoline engine burn fuels and use the pressure created by the expansion of the gases to do mechanical work. Batteries convert chemical energy back into electrical energy when needed. Fuel cells should do both tasks more efficiently.

A fuel cell provides a DC (direct current) voltage that can be used to power motors, lights or any number of electrical appliances.

There are several different types of fuel cells, each using a different chemistry. Fuel cells are usually classified by their operating temperature and the type of **electrolyte** they use. Some types of fuel cells work well for use in stationary power generation plants. Others may be useful for small portable applications or for powering cars.

The main types of fuel cells include:

i) Polymer exchange membrane fuel cell (PEMFC):

The PEMFC has a high power density and a relatively low operating temperature (ranging from 60 to 80 degrees Celsius, or 140 to 176 degrees Fahrenheit). The low operating temperature means that it doesn't take very long for the fuel cell to warm up and begin generating electricity. We will take a closer look at the PEMFC in the next section.

ii) Solid oxide fuel cell (SOFC):

These fuel cells are best suited for large-scale stationary power generators that could provide electricity for factories or towns. This type of fuel cell operates at very high temperatures (between 700 and 1,000 degrees Celsius). This high temperature makes reliability a problem, because parts of the fuel cell can break down after cycling on and off repeatedly. However, solid oxide fuel cells are very stable when in continuous use. In fact, the SOFC has demonstrated the longest operating life of any fuel cell under certain operating conditions. The high temperature also has an advantage: the steam produced by the fuel cell can be channeled into turbines to generate more electricity. This process is called **co-generation of heat and power (CHP)** and it improves the overall efficiency of the system.

iii) Alkaline fuel cell (AFC):

This is one of the oldest designs for fuel cells; the United States space program has used them since the 1960s. The AFC is very susceptible to contamination, so it requires pure hydrogen and oxygen. It is also very expensive, so this type of fuel cell is unlikely to be commercialized.

iv) Molten-carbonate fuel cell (MCFC):

Like the SOFC, these fuel cells are also best suited for large stationary power generators. They operate at 600 degrees Celsius, so they can generate steam that can be used to generate more power. They have a lower operating temperature than solid oxide fuel cells, which means they don't need such exotic materials. This makes the design a little less expensive.

v) Phosphoric-acid fuel cell (PAFC):

The phosphoric-acid fuel cell has potential for use in small stationary power-generation systems. It operates at a higher temperature than polymer exchange membrane fuel cells, so it has a longer warm-up time. This makes it unsuitable for use in cars.

vi) Direct-methanol fuel cell (DMFC):

Methanol fuel cells are comparable to a PEMFC in regards to operating temperature, but are not as efficient. Also, the DMFC requires a relatively large amount of platinum to act as a catalyst, which makes these fuel cells expensive.

3.3 Smart Home: Features and Components, Illumination and smart appliance control Principles (block diagram/s).

3.3.1 The most common features you might choose to have in a smart home:

i) Lighting; As lighting is an integral part of a building. The user would be able to choose the time of activation, for example, in the home 7pm when it starts to get dark might be a sensible option. If the user wishes to further customize the lighting settings there should be an option available to implement motion detection, which would involve a person actually stepping into a room, in order for the lights to be activated. This could include a specific room in the home or all the rooms. In a voice-controlled format, the user could check if the lights were on in any room of the house by speaking into a Bluetooth headset. The system could then ask the user is the lights are in the required state.

ii) Security:

With the advancements of smart technology, it makes sense to include security features. The user would be able control the arming and disarming of the alarm, as well as edit specific settings of the alarm, such as the key code. The user could also have the option to configure intrusion detection settings. This would work firstly by outside lights detecting motion and then the system would warn the security personnel or house owner of any windows or doors being forced open, through the use of electronic sensors that are connected to the system.

iii) Temperature:

The user would be able to control the heating and cooling of the home, through the use of both time and parameter-based functions. The user may choose for the heating to come on when outside conditions drop below a certain temperature, there would be heat-sensitive sensors placed outside to detect varying conditions.

iv) Appliances:

The power supply to all appliances in the home could be controlled using the smart system. In a large home this would be a very convenient feature because there may be a lot of electrical appliances that are left on standby, hence the system should contain a feature, which searches all power supply links in the home to determine where energy can be saved.

v) Entertainment:

For a fully capable smart home, entertainment features would be an innovative feature to include. The most widely used aspect of entertainment features would probably be the ability for subtle music to air throughout the household, this would be very welcoming especially if a resident has had a stressful day at work.

vi) System Status:

It is worth having an option to verify the current status of the system. This kind of feature would provide the user with the ability to scan the entire system or just parts of it for errors.

vii) Vehicle Detection:

When a vehicle approaches the driveway of a home, the system should be able to alert the homeowner. This is only possible if certain types of smart home technologies are used. It would work very well with a Bluetooth headset because the system announces the arrival of the visitor to the homeowner. It would also work well with more long-range wireless standards, such as, GSM (Global System for Mobile Communications) because the homeowner could receive an SMS (Short Message Service) when someone arrives at the home, which is especially useful when away from the home.

viii) Phone set-up:

A home-based system should be able to initiate with a mobile-phone when the house is empty. The system should provide the ability for the user to enter the name and model number of the phone so it can be verified for use. The user will be able to communicate with the system when approaching home to switch the television or the oven on and any other electrical appliances the house owner may wish to make use of.

ix) Wake up:

A useful feature in a home-based smart system would be alarm clock functionality, for example, the user would be able to choose from a selection of wake-up sounds from more pleasant sounds to more piercing types. At the weekend the more pleasant ones are likely to be selected.

Components of a smart home:

A smart home has its devices interconnected through the internet and gives you on-demand access to control your lighting, home security, thermostat regulation and home theater and entertainment. It can be as simple as saying, "Neha, turn on the living room light." If you're looking to smarten up your home, check out these top five essential systems that can turn your conventional home into one that helps you live in total comfort and convenience.

1. Security system:

The top component for every smart home is the security system. A security system is there to protect you and raise the alarm in a big emergency like a fire or a break-in. But a smart security system doesn't stop there. Thanks to advanced technology, it makes itself useful every single day. It can send you a notification when your teenagers get home from school or their part-time jobs. It can show you who's at your front door, and let you talk to them, how-to-effectively-ensure-your-kids-safety-at-home through a video doorbell. You can see an HD video feed of your kids in the back yard while you're cooking dinner. It can also let you know if a window is open or door is left ajar or if you have a water leak in the basement.

2. Intercom system:

A smart intercom system offers dramatically more features than a conventional intercom system and allows you to communicate with your family through voice 1376657activated devices without having to do anything else. There are a variety of helpful convenient and entertainment options that come with your intercom system so you can connect several rooms within your home. For example, you can use the video chat feature to talk to someone in another room, or someone outside of your front door, such as a deliveryman or mailman. You can set up your entertainment by syncing your music to play through intercoms around your house. You can even send videos around your home through a smart intercom system.

3. Shades, sprinklers and music;

Programming your lawn sprinklers to water your lawn at 5:30 in the morning has never been easier with a smart system. And when you're not asking Neha Get Ready how many ounces are in a cup or who won best picture in 1989, you can control your other home's systems with just your voice. These include motorized shades and blinds, entertainment systems, lawn sprinklers, and lights. Voice activated products for your home can be especially helpful for busy families, if you're recovering from surgery, getting up in age or have physical disabilities.

4. Light up your world:

Arguably the easiest way to upgrade your lighting is with smart bulbs. You can swap out the existinLoan_Programs_1g CFL or LED bulbs in your lamps and lighting fixtures with a Philips Hue, Lifx Mini, EufyLumos LED or many other models. These smart bulbs allow you to control your lights with your phone or through Alexa or Google Assistant. Plus, you can schedule them to turn on at any time and dim them at will, even if you don't have a dimmer switch. If you have a lot of lamps or recessed lighting, smart bulbs can quickly become expensive. The solution? Smart light switches. These control all of the lights wired to one switch, allowing you to turn lights on and off on a schedule or with a smart assistant, without changing your existing light bulbs.

5. Ventilation, heating and air conditioning system:

If you're guilty of rushing out of your house and forgetting to adjust your thermostat on a regular basis, smart technology might just be the ticket. The Nest Learning Thermostat, for example, is an electronic, programmable Wi-Fi enabled thermostat that optimizes heating and cooling of your home to conserve energy. The Nest learns your family's routine, programs itself and adapts to your life and changing seasons (The app also lets you control your thermostat no matter where you are in the world.). It's also ENERGY STAR certified, which means it meets standards set by BEE, but consumes less energy than other products.

3.3.2 Illumination and smart appliance control principles (block diagram/s):

A lighting control system is an intelligent network based lighting control solution that incorporates communication between various system inputs and outputs related to lighting control with the use of one or more central computing devices. Lighting control systems are widely used on both indoor and outdoor lighting of commercial, industrial, and residential spaces. Lighting control systems serve to provide the right amount of light where and when it is needed. Lighting control systems are employed to maximize the energy savings from the lighting system, satisfy building codes, or comply with green building and energy conservation programs. Lighting control systems are often referred to under the term Smart Lighting.

The term lighting controls is typically used to indicate stand-alone control of the lighting within a space. This may include occupancy sensors, timeclocks, and photocells that are hard-wired to control fixed groups of lights independently. Adjustment occurs manually at each device’s location. The efficiency of and market for residential lighting controls has been characterized by the Consortium for Energy Efficiency.

The term lighting control system refers to an intelligent networked system of devices related to lighting control. These devices may include relays, occupancy sensors, photocells, light control switches or touchscreens, and signals from other building systems (such as fire alarm or HVAC). Adjustment of the system occurs both at device locations and at central computer locations via software programs or other interface devices.

Lighting control systems typically provide the ability to automatically adjust a lighting device's output based on:

i. Chronological time (time of day)
ii. Solar time (sunrise/sunset)
iii. Occupancy using occupancy sensors
iv. Daylight availability using photocells
v. Alarm conditions
vi. Program logic (combination of events)
vii. Chronological time
viii. Chronological time schedules incorporate specific times of the day, week, month or year.
ix. Solar time

Solar time schedules incorporate sunrise and sunset times, often used to switch outdoor lighting. Solar time scheduling requires that the location of the building be set. This is accomplished using the building's geographic location via either latitude and longitude or by picking the nearest city in a given database giving the approximate location and corresponding solar times.

Occupancy: Space occupancy is primarily determined with occupancy sensors.

Daylight availability: Electric lighting energy use can be adjusted by automatically dimming and/or switching electric lights in response to the level of available daylight. Reducing the amount of electric lighting used when daylight is available is known as daylight harvesting.

Alarm conditions: Alarm conditions typically include inputs from other building systems such as the fire alarm or HVAC system, which may trigger an emergency 'all lights on' or ' all lights flashing' command for example.

Program logic: Program logic can tie all of the above elements together using constructs such as if-then-else statements and logical operators.

Block Diagrams:

1. Block diagram of Infra-Red Remote Control:

The first remote controllers were developed in the early 1990s, and the first remotes were connected with wires to devices. Nowadays remotes use infrared control and thus are capable of controlling several things at a time. The remotes are not only used for entertainment, but also for industries, military requirements, and recreation. Infrared remote controls were developed in the late 1970s. These remote controls use infrared light and photo receptors and different light frequencies for different functions. These remotes also use invisible light beams to send signals to electronic devices.

Infrared remote control:

IR remote controls today can control several devices at a time as the working abilities of these remotes is such that a light beam is emitted out by the remote control and is received by a photo transistor. These remotes receive signals and transmit signals to devices via radio waves. These remotes can control several appliances, equipment's and gadgets like, radios, TVs, video games, CD/ DVD players, and also applicable in Space. The Infrared remote control-basics operation and applications are explained below.

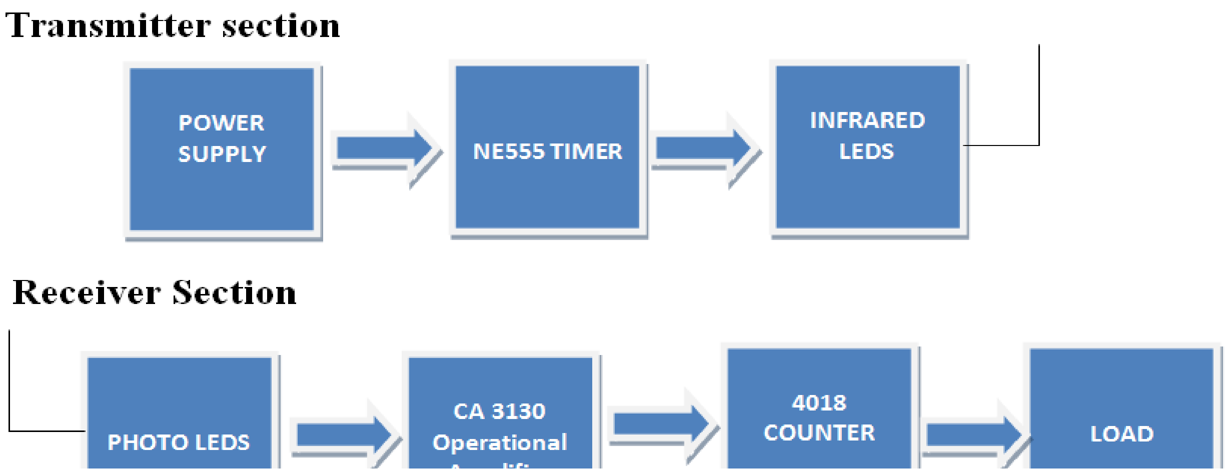


Fig 3.4 Block diagram of Infra-Red Remote Control

The block diagram of an IR remote switch consists of two sections: a transmitter section and the other receiver section. The transmitter section works as a normal remote and the receiver section remains in a stable position, which means, it is connected to any load. The main function of this

Remote-control switch is to control any load like TV, Fan, Radio, light, etc.

In this circuit, there is only one switch to operate the transmitter. By using this switch, one can switch on or off the TV, radio, and home appliances. By adding an extra circuitry to the actual remote, the control circuit can even be used to control the volume of radio, TV and many more appliances.

In the transmitter section, there is a NE555 timer and infrared LEDs. TheNE555 timer is configured in a stable mode, and in infrared LEDs, the IR rays are directed by the source of power, which is from 9V battery and concave lens. In the transmitter section, a switch plays a key role; when the switch is closed, the power from the battery turns on, and the 555 timer acts as a stable multi-vibrator and the output of the 555 timer gets connected to the input of the IR LEDs. Then, the infrared LEDs get high and produce the IR beam through concave lens.

The IR beam in the transmitter section produced by the infrared LEDs is directed to the receiver section. The photo LEDs receive the IR beam and charge the capacitor which increase the input voltage of one pin of the op-amp, and then generates high output. The output of the op-amp is given out to the 4018 counters as an input, and then the counter will drive the load through a relay to switch on or off.

2. Automatic Room Light Controller with a Visitor Counter:

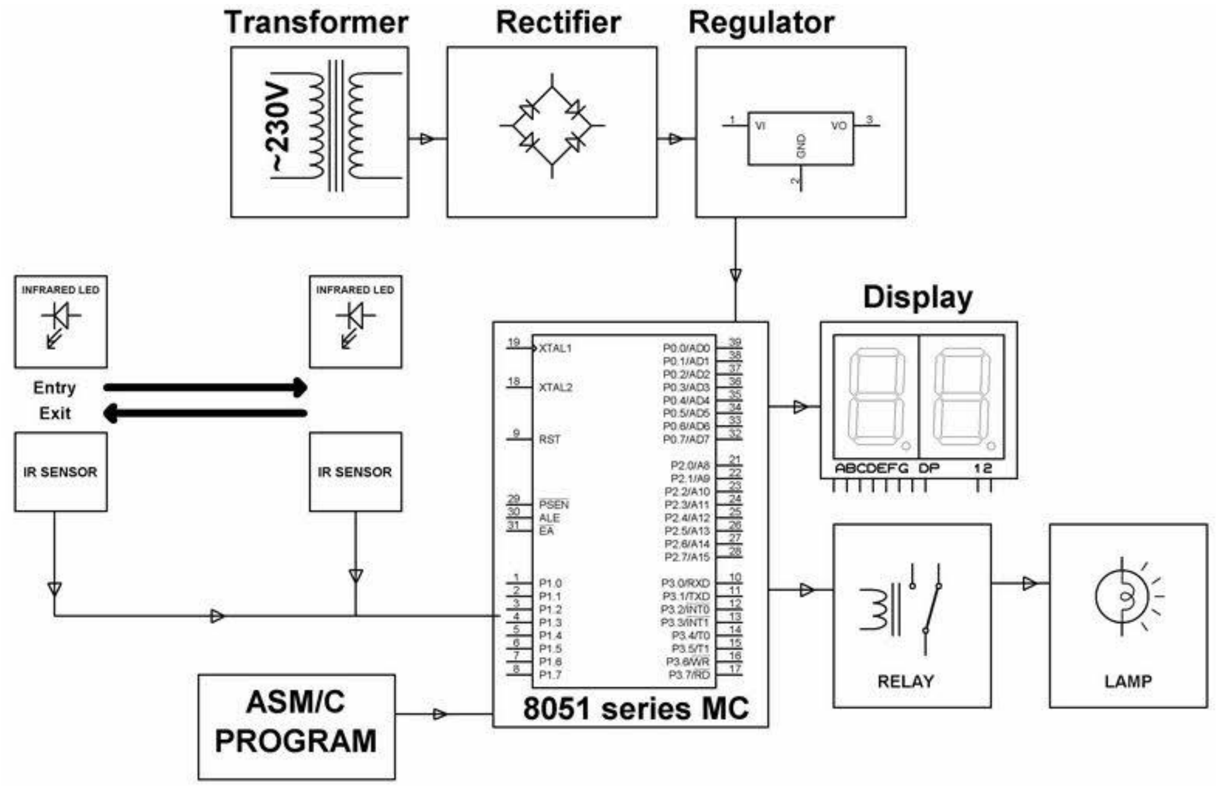


Fig 3.5 Block diagram of Infra-Red Remote Control

This system is designed by using two sets of IR transmitters and receivers. These IR sensors are placed in such a way that they detect a person entering and leaving the room to turn the home appliances. In this optimum energy management system, a microcontroller is the central processing unit of this project which is of 89S51 controller from the 8051 family. This system facilitates a bidirectional visitor counter for displaying the number of persons inside the room.

Automatic Room Light Controller with a Visitor Counter:

When a person enters into the room, an IR beam is obstructed between the IR transmitter and the receiver. This IR obstruction from the sensor-1 gives the corresponding signal to the microcontroller. The microcontroller is programmed in such a way that by the reception of the signal from the sensor-1 it turns on the fans and lights inside the room. Thus, the microcontroller gives command signals to a relay driver which turns the relays such that all these appliances turn on. When the person leaves from this room, another set of IR sensors enable and give control signals to the microcontroller. Furthermore, similar to the above process, this system turns off the appliances like fans and lights. Apart from this, the system also takes account of the number of persons inside the room so that this control operation is varied depending on the persons' availability in the room.

For every person entering and leaving the room, the microcontroller reads the digital input from two receivers, and calculates the number of persons inside the room, and then displays it on the LCD. When the persons' count is greater than one, the microcontroller turns on the room light and when the persons' count is zero, it turns off all the lights and fans.

References:

Sr. No.	Reference books / Websites used
1	https://www.india.gov.in/spotlight/smart-cities-mission-step-towards-smart-india
2	https://en.wikipedia.org/wiki/Charging_station
3	https://www.google.com/url?sa=i&source=images&cd=&ved=2ahUKEwid3YLxm-7kAhUKUI8KHQxwBDQQjRx6BAgBEAQ&url=https%3A%2F%2Fwww.electronicdesign.com%2Fpower%2Foptocouplers-help-promote-safe-efficient-ev-charging-stations&psig=AOvVaw2-ePhmJKPwCVittJ4-JjkW&ust=1569577813351562
4	https://en.wikipedia.org/wiki/Fuel_cell_vehicle
5	https://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/fuel-cell1.htm
6	https://www.amerifirst.com/amerifirst-blog/bid/106899/top-5-components-of-a-smart-home
7	https://en.wikipedia.org/wiki/Lighting_control_system
8	https://www.elprocus.com/infrared-remote-control-switch-working-and-applications
9	https://www.elprocus.com/know-about-working-of-automatic-room-light-controller-and-applications/

MCQs

Sr. No.		Question	Marks
1.		Which of following is features of a smart city? a) Preserving and developing open spaces b) Promoting Rapid Transit system c) Providing Online services d) All of above	2
2.		Retrofitting in smart city means ______________ a) Increase area of city b) Decrease area of city c) Make existing area more efficient and livable d) Increase infrastructure base	1
3.		Electronic service delivery is ____________ part of smart solutions. a) E governance b) Water management c) Energy management d) Urban mobility	2
4.		Bhendi Bazar Project in Mumbai is an example of ___________. a) Retrofitting b) Redevelopment c) Greenfield development d) Pan city development	1
5.		Greenfield Development means a) Implementing greenery in city b) Implemented in city area c) Implemented around city area d) None of above	2
6.		Smart metering is part of ________. a) Water management b)Energy management c) A and B d) None of above	2
7.		Pan city development is related to provide smart solutions for ____ a) Existing infrastructure of city b) New infrastructure of city c) Outside of city d) New city	1
8.		Which of following is not included in Smart City Mission? a) Mumbai b) Nashik c) Kolhapur d) Aurangabad	1
9.		The role of Electric Vehicles in Energy transition is ________ a) Reduce oil consumption	2

Sr. No.		Question	Marks
		b) Increase Energy security c)Reduce carbon emission d) All of above	
10.		BEV stands for a) Basic Electric Vehicle b) Basic Electronic Vehicle c) Battery Electric Vehicle d) Battery Electronic Vehicle	1
11.		Which of following is not part of Electric Vehicle? a) Battery Pack b) IC Engine c) Controller d) Motor	1
12.		When two batteries are connected in series ____ rating is added. a) Voltage b) Current c) Voltage and Current d) Power	1
13.		BMS Controller measures _______ parameters. a) Voltage b) Current c) Temperature d). Voltage, Current and Temperature.	1
14.		__________ give fast pick up of BEV. a) Brushed DC Motors b) BLDC c) AC Induction Motor d) Synchronous Motor	2
15.		Permanent magnets are not present in _____ motor. a) AC Induction b) BLDC c) Both A and B d) Brushed DC Motor	1
16.		Plug-in-Hybrid Electric Vehicle (PHEV) is charged from ________ . a) Power grid b) IC Engine of vehicle c) Both A and B d) Either A or B	2
17.		Hybrid Electric Vehicle ________ drive system. a) Single b) Two c) Both A and B d) None of the above	2

Sr. No.		Question	Marks
18.		______________charging station is known as fast charging station. a) Residential b) Parking c) Public d) Parking and Public	2
19.		The typical charging time for a 50 KW BEV for 100 Km travel is __ a) 1-2 hours b) 2-3 hours c) 10 minutes d) 20-30 minutes	2
20.		A fuel cell vehicle emits ________ . a) Water b) Heat c) Both A and B d) Carbon	2
21.		A fuel cell provides which voltage to electric motor? a) AC b) DC c) Both A and B d) None of above	1

Unit IV

Intelligent Motor Control Centers

4.1 Introduction:

This unit focuses on the following aspects:

- Role of the Motor Control Centre MCC).
- The devices and components used in MCC.
- Roles of the components of the motor control centre (MCC).
- The need for the given type of MCC.
- The roles and functions of the devices /components in Intelligent MCC (IMCC).
- Outline of IMCC.
- The disadvantages of MCC.
- The advantages of IMCC.
- IMCC for typical applications.

4.1 General/Traditional (Conventional) Motor control center:

4.1.1 Role in Motor protection and Motor management:

The AC motor control involves switching the motor on and off as per the requirements. This is often accomplished using a motor starter made up of a contactor and an overload relay.

The contactor is operated by providing the rated supply to it when its contacts are closed to start the motor and opened to stop the motor. This is done electromechanically using start and stop pushbuttons or other pilot devices wired to control the contactor.

The overload relay protects the motor by disconnecting power to the motor when an overload condition exists. Although the overload relay provides protection from overloads, it does not provide short-circuit protection for the wiring supplying power to the motor. For this reason, a circuit breaker or backup fuses are also used.

In many commercial and industrial applications, quite a few electric motors are required, and it is often desirable to control some or all of the motors from a central location. The apparatus designed for this function is the motor control center (MCC).

The **role of MCC** is basically to house in a compact modular manner groups of motor control components along with the relevant electrical distribution.

A Motor Control Center is factory assembled with several motor starters. A motor control center may also include variable frequency drives (VFD), programmable controllers, metering and may also be the electrical service center for motors of a building. The electrical equipment includes PLC, VFD, fuses, switches; transformers and many other necessary components which are must to control the voltage or current for the smooth performance of the device. In other words, a **motor control center** (**MCC**) is an assembly to control some or all electric motors in a central location. It consists of multiple enclosed sections having a common power bus and with each section containing a combination starter, which in turn consists of motor starter, fuses or circuit breaker, and power disconnect. A motor control center can also include push buttons, indicator lights, variable-frequency drives, programmable logic controllers, and metering equipment. It may be combined with the electrical service entrance for the building.

MCC’s are typically found in large commercial or industrial buildings where there are many electric motors that need to be controlled from a central location, such as a mechanical room or electrical room.

The conventional MCC units are electromechanical, with basic functions that include a power switching device, short-circuit and overload protection, local and remote actuation, and controller state indication. The indicators for the motor operation are present in the control panel.

The difference between control panel and MCC lies in the fact that control panel is used to give a signal to the Motor Control Center panel to control the motor. Without control panel, MCC cannot fulfill its function as it needs a signal from the control panel to start the motor and power supply to the equipment on a constant basis.

Summarizing the difference between them it can be said that, both are incomplete without each other. The function of one totally depends on the function of other.

In today’s time, a single panel is used for both control panel and for MCC rather than using the separate ones. The combined panels have the advantage of high-performance and low price.

Motor control centers are simply physical groupings of combination starters (LV MCC) in one assembly.

A combination starter is a single enclosure containing the motor starter, fuses or circuit breaker, and a device for disconnecting power. Other devices associated with the motor, such as pushbuttons and indicator lights may also be included.

4.1.2 General Architecture & Components:

Figure 4.1 shows the general architecture of a simple motor control center that encompasses the most basic components needed for the same. The power circuit and the related control circuit are depicted in it. The power circuit contains the circuit breaker, power contacts (M) on the contactor and the overload relay (OL) power terminals. Whereas the control circuit contains the start/stop push buttons, auxiliary hold on (also called as 'seal in') contact of the contactor across the start push button NO, contactor (relay) coil and NC contact (overload contact) of the overload relay.

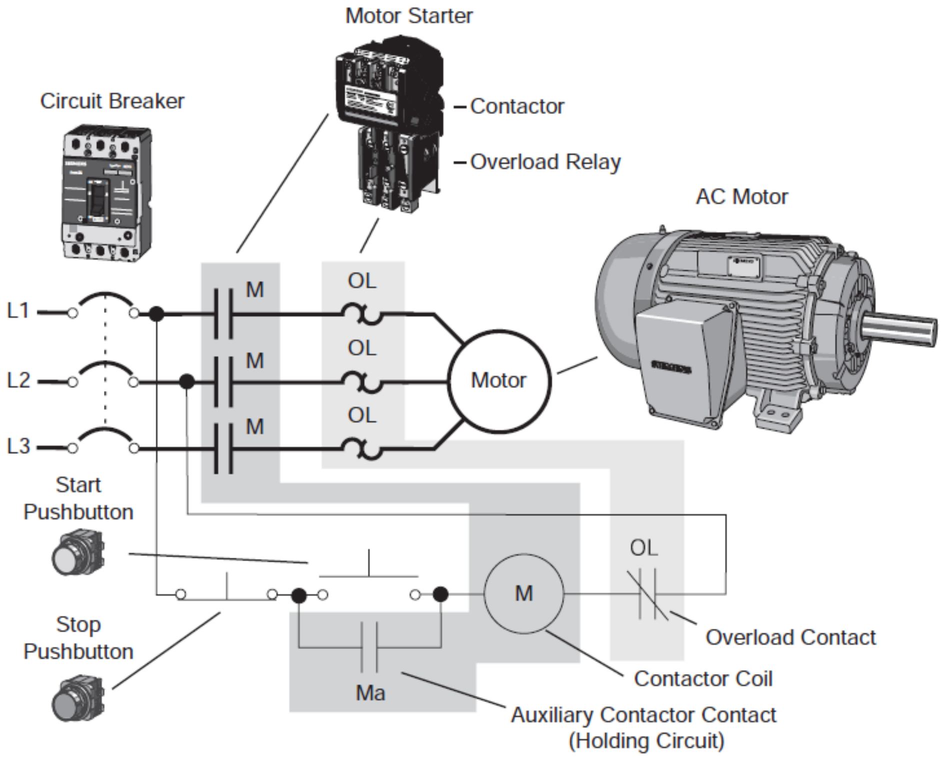
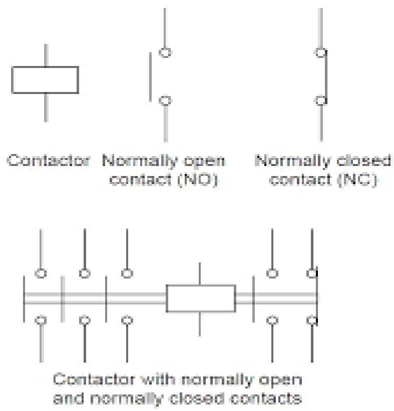
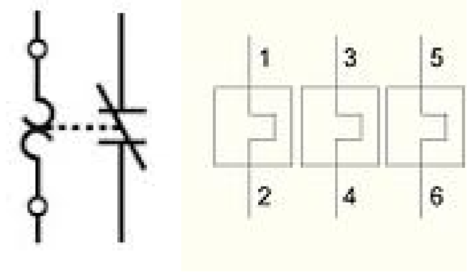
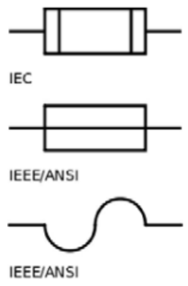
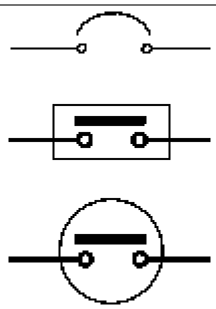
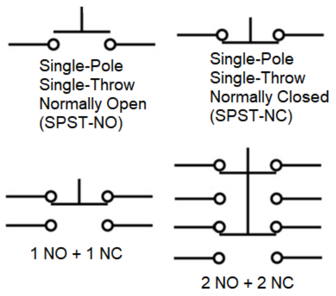
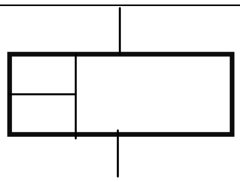


Figure 4.1

The table below shows some important components, their symbols and functions:

Component	Symbol	Functions
1. Contactor		To connect and disconnect the motor from the supply through the power contacts

Component	Symbol	Functions
2. Over-load Relay		To sense the over-load and give trip signal to contactor that disconnect the motor from supply
3. Fuse		To sense the short-circuit fault and disconnect the motor from the supply.
4. Circuit breaker		To connect and / or disconnect the motor from supply manually when required and automatically under abnormal conditions.
5. Push-buttons		To initiate the desired operation i.e. to start and stop the motor.
6. Electromagnetic valve		Electromagnetically operated valve for fluids such as air and other media.

4.1.3 Traditional MCCs: Advantages and Disadvantages.

Advantages:

MCCs have the following advantages:

- Single panel or integrated panels for coordination of components.

- Electrical distribution and motor control equipment can be purchased as a pre-assembled, pre-tested system, usually at a less expensive installed cost when compared to separately mounted components.
- Line side power wiring is less as compared to separate controls. Thus MCCs are easy to install due to lower number of components.
- Modular packaging leads to space saving.
- Configuration can be optimized as per requirements.
- Area of maintenance gets restricted.
- Excellent fault containment.
- Excellent electrical component isolation.
- Fast installation at a lower cost – with its own power bus and factory-wired and tested units, field wiring and testing are minimized.
- Reduced planning and downtime – standardized sections and units simplify design and training; plug-in units can be easily replaced and rearranged.
- Expandability – sections and units can be added to existing MCCs.
- Increased level of safety – fault containment is part of MCC design, and units can be easily unplugged to service at a workbench, away from hazardous voltages.
- Faster delivery – entire system arrives ready to install as a single entity, with no additional design or components to coordinate.
- Serviceable with power ON at adjacent starters – the inherent isolation of MCC units makes it possible to work on a given unit without de-energizing any adjacent units, and still conform to the standards.

Disadvantages:

- Less effective controls.
- Less coordinated controls.
- Errors due to hard wiring.
- Less diagnostic facilities.
- Less protective functionality.
- Under-utilization of control components.

4.2 Intelligent or Smart MCCs (IMCCs):

Intelligent Motor Control Center (IMCC) is a smart MCC panel to control some or many electric motors in a central location. IMCC consists of multiple feeders having a common power busbar and with each section containing combination starters. Intelligent MCC panel is a type of MCC panel with advance features and enhanced work ability by using communication capable motor management device that monitors the motors. At the heart of an IMCC is a communication-capable motor manager device that monitors the motor and other key process variables, providing core data required by the process control system.

4.2.1 Need of IMCC:

- To overcome the disadvantages of traditional MCCs, the intelligent MCCs are developed.
- To optimize the use of various control components and also to increase the cost effectiveness, “intelligence” features are incorporated.
- To increase the flexibility of application of the MCC over a wider range of motors.
- To increase the safety of working personnel and machines.

4.2.2 Requirements of IMCCs:

- Extensive functionalities that are not available in traditional MCCs.
- Components for inclusion of proper diagnostic features.
- Effective communication networks with high bandwidths for enhanced operational features.
- Extensive process data for features as optimization, precision and protection.

4.2.3 Role of IMCCs as compared to traditional MCCs:

The IMCCs provide the following features compared to the traditional MCCs:

- Increased productivity due to finer controls of time bound activities.
- Minimized downtime due to optimal use of the different components that leads to lesser wear and tear of machines.
- Efficient energy management due to optimization of processes and hence powering on of component devices as per requirements.
- Preemptive and predictive maintenance modeling due to intelligent machine condition prediction systems.
- Proactive condition monitoring due to the intelligence factor associated.
- Improved level for personnel safety.
- Enhanced quality controls

4.2.4 Functional/block diagram:

<table>
<tr><td>Power monitoring</td><td>AC drives</td><td rowspan="3">Networking cables</td></tr>
<tr><td>Motor starters and intelligent overload relay</td><td>Controller unit (eg. PLC)</td></tr>
<tr><td colspan="2">Motor Control Centre</td></tr>
</table>

OR

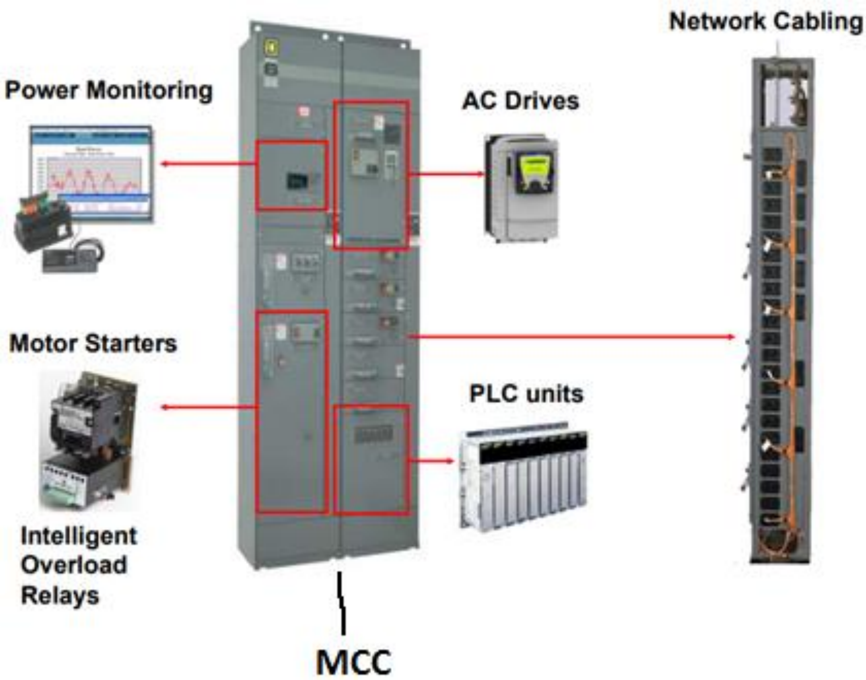


Figure 4.2

The figure 4.2 represents a simplified diagram of the components of the MCC. Its important to note that the networking cables carry communication signals of the circuit operating conditions (motor operating condtions) for decision making to the controller which gives the relevant section the signal to operate.

4.3 Devices and Components typical to IMCCs:

4.3.1 Intelligent Relays:

The most common device in the MCC is the motor starter, which comprises intelligent overload relay and contactor. The components therein will be

•Built-in communication facility.

•Input terminals to monitor the connection (disconnect or selector switch)

•Output terminal points (to control the contactor/s)

•Status indicators which are normally LEDs.

•Protective functions covered –overload, underload, jam, current imbalance, stall, phase loss, ground fault (zero sequence currents) and PTC thermistor input.

•Programmable parameters for the protective functions – trip level, warning level, time delay, and inhibit window. The program that incorporates these features avoids the nuisance trips that often led to users disabling protective functions. Warning alarms alert users to a potential trip, and allow actions to avert impending downtime. Time delays and inhibit windows allow recognition of abnormal current loads (e.g. extended starting times with high currents), without nuisance tripping.

•Current Monitoring – phase, average, full load, ground fault, imbalance percent, and percent thermal capacity used are important monitoring features.

•Diagnostics – device, warning, and trip status; time to overload trip; history of last five trips; time to reset.

4.3.2 Fuses:

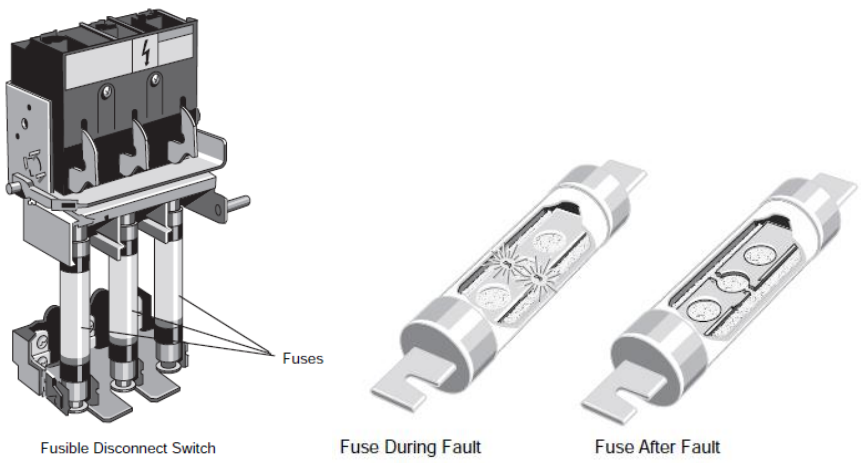


Figure 4.3

A **fusible disconnect switch** is one type of device used to provide overcurrent protection. Properly sized fuses located in the switch open the circuit when an overcurrent condition exists.

A **fuse** is a one-shot device. The heat produced by overcurrent causes the current carrying element to melt open, disconnecting the load from the source voltage.

The fuses used are HRC types due to their advantages over the re-wirable ones.

Non-time-Delay Fuses:

Non-time-delay fuses provide excellent short-circuit protection. When an overcurrent occurs, heat builds up rapidly in the fuse. Non-time-delay fuses usually hold 500% of their rating for approximately one-fourth second, after which the current-carrying element melts. This means that these fuses should not be used in motor circuits which often have inrush currents greater than 500%.

Time-Delay Fuses:

Time-delay fuses provide overload and short-circuit protection. Time-delay fuses usually allow several times the rated current to flow for a short time to allow a motor to start.

Fuse Classes Fuses are grouped into classes based on their operating and construction characteristics. Each class has an interrupting rating in amperes, which is the amount of fault current this class of fuses is capable of interrupting without destroying the fuse casing. Fuses are also rated according to the maximum continuous current and maximum voltage they can handle. Underwriters Laboratories (UL) establishes and standardizes basic performance and physical specifications to develop its safety-test procedures. These standards have resulted in distinct classes of low-voltage fuses rated at 600 volts or less. The following chart lists some of the fuse classes and their ratings.

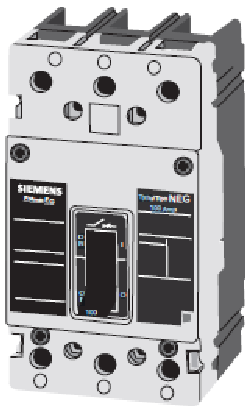
Sr. no	Fuse class	Fuse overload characteristics	Current ratings(A)	AC voltage rating(V)	Interrupting current rating(A)
1	H	Re-wirable, fast acting	1 – 600	250, 600	10,000
2	K5	Fast acting	1 – 600	250, 600	50,000
3	J	Time delay	0.8 – 600	600	200,000
4	J	Fast acting	1 – 600	600	200,000
5	RK1	Time delay	0.1 – 600	250, 600	200,000
6	RK1	Fast acting	1 – 600	250, 600	200,000
7	RK5	Time delay	0.1 – 600	250, 600	200,000
8	T	Fast acting	1 – 1200	300V, 600V	200,000
9	L	Time delay	200 – 6000	250V, 600V	200,000

4.3.3 Control devices:

a) Circuit-breaker:A device used for overcurrent protection is the circuit breaker. In addition to providing overcurrent protection, a circuit breaker provides a manual means of energizing and de-energizing a circuit. Figure 4.4 shows a sample circuit breaker used for motor circuits.

One key advantage of a circuit breaker is that it allows a circuit to be reactivated quickly after a short circuit or overload is cleared by simply resetting the breaker.

Ampere Rating: Like fuses, every circuit breaker has ampere, voltage, and interrupting current ratings. The ampere rating is the maximum continuous current a circuit breaker can carry. In general, the circuit breaker ampere rating should not exceed the conductor ampere rating. For example, if the conductor is rated for 50 amps, the circuit breaker rating should not exceed 50 amps. Also the temperature of the conductor at which the current rating is valid needs to be kept in view. If a conductor with a higher temperature rating is used, the ampere capacity of the conductor must be figured on its working temperature.



Circuit Breaker

Figure 4.4

Voltage Rating: The voltage rating of the circuit breaker must be at least equal to the supply voltage. The voltage rating of a circuit breaker can be higher than the supply voltage, but never lower.

Fault-Current: Circuit breakers are also rated according to the level of fault.

Interrupting Current Rating: Because potential fault currents vary depending on the electrical service and the position of a circuit breaker within a distribution system.

b) Sensors, Actuators &Switches:

It covers a wide range of sensing options for any application from sophisticated non-contact sensing solutions to rugged mechanically actuated switches. It includes photoelectric sensors, inductive/capacitive proximity sensors, power sensors, limit switches, pressure valves, temperature sensors etc. The sensors provide feedback information in the motor-control loop. The limit switches are operated by the displacement of mechanical parts of the machine systems. Whereas the proximity sensors sense the closeness of a machine part/ or completion of a set task to a certain point and initiate or give the signal for further sequential operation. These sensors also improve reliability by detecting fault conditions that can damage the motor.

c) Push-buttons:

These are used to initiate control operations such as start, stop, inch etc.

d) Pneumatic Valves:

Pneumatic valves control the flow of compressed air in specified paths. The direction of flow is indicated by an arrow. Actuation may take place manually, mechanically, pneumatically or electrically. Automated systems generally use solenoid-actuated valves that form the interface between pneumatic and electrical control. The valves are switched by means of the output signals from the control section. They close or open connections in the pneumatic power section. They also have directional characteristics. The main functions of electrically-actuated directional control valves include:

- connecting or shutting off the compressed air supply,
- retracting and advancing cylinder drives.

4.3.4 Programmeable Logic Controller (PLC):

This is a specialised computer used to control machines and processes. It uses a programmable memory to store instructions and specific functions which include ON/OFF control, timing, counting, sequencing, calculating and data handling related to the industrial processes. PLCs operate in real time which means that an event taking place in the field results in coressponding operation occuring with it. Machines that process thousands of items per second can be implemented only by the PLC capability.

4.3.5 AC Drives:

The schematic diagram of an AC drive is shown in figure 4.5. In these drives for motors, power electronic devices are used to convert the electric source voltage into the required form in terms of magnitude and frequency. These converted or derived quantities are fed to the motors to achieve the relevant torque-speed characteristics as per the requirements of the loads. The motor parameters such as torque, speed etc. are sensed (sensor) and fed to the controller that generates the values of the driving parameters of voltage and frequency.

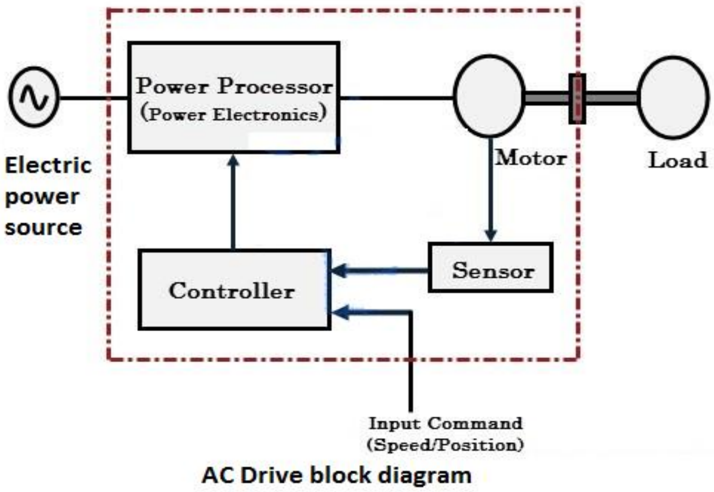


Figure 4.5

These drives convert the power from the source into proper values in terms of voltage, current and frequency which control the motor driving the load as per its requirements in terms of torque, speed and direction.

4.3.6 Power Monitoring Unit:

These units have the required circuitary to carry out the functions such as protection, operation, measurement, and monitoring for power distribution and switching facilities, into one compact unit at the specified voltage levels.

4.3.7 Network Cabling:

Network cabling is needed to implement the required functions by communication signals between the various components of the system. This may be achieved by the Ethernet/IP networking.

4.3.8 Softwares:

Intelligent MCCs are characterised by dedicated software that operates in a known computer operating environment such as Windows. It controls the motors and other related equipment.

Intelligent MCC software is characterised by:

- **Ability to operate in a GUI environment**: for example the software will be easiest to use if it works in known popular operating environments, e.g. Windows.
- **Has unique MCC documentation to initialize screens**: Every MCC is unique. The application program, upon installation, should access specific information to generate screens containing data pertinent to that MCC.
- **Initiates network communication**: Establishing devices as recognized entities on a network may sometimes be the most time-consuming step. Upon installing the MCC and

software, the user only needs to sit back and let the software poll the pre-configured devices to match the device information with the user database.

- **Displays pre-configured screens showing most common parameters:** Intelligent MCC software can access the user's specific data files and build the corresponding screens. The following pre-configured software screens are useful:
    - **MCC line-up (elevation) view:** Realistic dynamic display that shows unit type, nameplate information, and status of units.
    - **Unit View:** Supplies dynamic information about the unit and network device. Data can be displayed digitally, on meters or trend graphs.
    - **Event Logging:** Automatically logs preset and user-defined faults and warnings, and accepts manual entries such as maintenance activities and equipment updates.
    - **Spreadsheet View:** Ideal for viewing the most information at a glance. Sorting and filtering capabilities help users organize pertinent data.
- **Includes all user-specific documentation:** A comprehensive documentation database speeds up the working and reduces fatigue of handling data. Valuable documentation components are:
    - Unit wiring diagrams
    - As-built drawings of the MCC line-up
    - Product user manuals
    - Spare parts list Databases that allow users to add and change information, especially wiring diagrams.
    - Can be accessed at any network level: The user should be able to view the MCC by plugging into any network level, such as Ethernet. This feature gives the user flexibility to locate the software on a maintenance laptop, in a control room, or at an engineer's desk.

The following data fields are to be easily made available in respect of motor management strategies by the software used with the appropriate interfacing.

1.	Number of Overload Trips	11.	Individual Event Messages (62)
2.	Number of Parameterizations	12.	Individual Warning Messages (33)
3.	Motor Stop Time	13.	Individual Trip Messages (48)
4.	Operating Hours	14.	Motor Current (%FLA)
5.	Device Operating Hours	15.	Motor Voltage

6.	Number of Starts	16.	Motor Power (W & VA)
7.	Number of Starts Left	17.	Power Factor (COS Phi)
8.	Number of Starts Right	18.	Time to Trip
9.	Consumed Energy (kWh)	19.	Cool Down Period
10.	Individual Status Messages (29)	20.	Last Trip Current

Based on the above data, following features may be made available by the use of the software:

- Real time, dynamic motor and load data to facilitate Predictive motor and load maintenance.
- Enhanced monitoring and protective functions.
- Allow selected responses to monitored motor or load conditions.
- Alert the user to an impending problem and prevent unwanted shutdowns.
- Alerts the user to the cause of a trip or warning, simplifying maintenance.
- Tailormade protective functions for the load.
- Get warnings of developing problems before a trip occurs.
- Gather dynamic load information.
- Select the response of the protective device to the relevant input conditions.
- Know the cause of device tripping.
- System operations governed by securedly linked and encrypted communications from the authorized system operator.

4.4 Basiccomponents of Intelligent systems (refer fig 4.6):

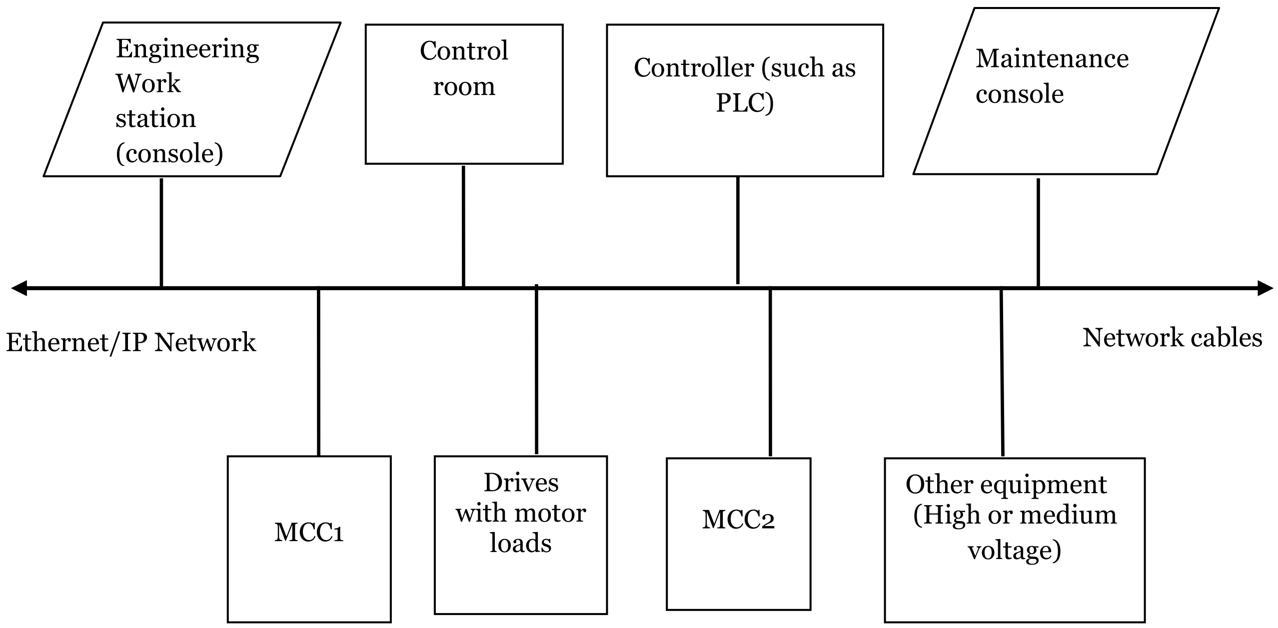


Fig 4.6

The intelligent motor control systems integrate multiple components an example of which is shown in the figure. We see that the Ethernet cable network connects different sections such as the work station console (terminal), more than one MCC (each MCC may contain starters, relays, fuses etc. of motors it controls), controller, maintenance console (terminal), drives etc. The state (values) of circuit outputs of the different sections and the programmed controller software are coordinated to communicate for achieving optimal operational advantages in terms of precision, energy management/saving and predictions for pre-emptive or predictive maintenance. The controller is a microprocessor/microcontroller/computer based system that works as the brain of the whole intelligent system.

4.5 Selection of MCC:

The criteria for selection of MCC for different types of motor control applications (that decide the complexity level of the controls), govern the choice of the type of MCC to be implemented (traditional or intelligent control).

These criteria can be grouped into two major classes:

4.5.1 Basic Motor Operation functions:

a. Start/stop indication and controls.

b. Overload protection.

c. Earth leakage protection for large rating motors (normally above 40 HP).

d. Under voltage protection.

e. Single phasing protection.

f. Current indication/meter (ammeters).

g. Voltage indication/meter (voltmeters).

h. Transmission of signals/ communication signals between different sections.

4.5.2 Enhanced Motor Operation functions:

a. Energy condition monitoring or measurement.

b. Motor winding state/condition (windings too hot or wet).

c. Motor bearing state/condition (worn out and noisy bearings).

d. Restarting after sudden voltage dips.

e. Low current condition protection.

4.5.3 Conventional or Intelligent, the Selection Criteria:

The required control functions for a specified motor decide the type and complexity of the MCC; this decides the choice of the MCC to be preferred i.e Conventional or Intelligent type.

Conventional MCCs are a better choice when:

- limited information of motor operating parameters are to be exchanged with the DCS (Distributed Control Systems).

- Standard starters (with overload functionality) are sufficient to get the requiste work done without much loss of accuracy.

- the personnel working on the systems would need very expensive and extensive training to handle complex equipment.

- Component obsolescence will not be faced even after 12-15 years of operation.

Intelligent MCCs are a better choice when:

- A huge amount of MCC data is communicated to the DCS. For example for a remotely operated facilitydata made be needed regarding the reasons for operation of the trip devices saving visits by personnel to the remote location.

- More than the standard starter functionality is required (The greater the number of additionalfunctions required the greater the benefit over a conventional solution)

- It is expected that a significant number of changes to controls will be required over thelifetime of the MCC (simplified engineering and field modifications)

- It is wished to use data such as loading, number of starts and running hours to assist in decidingon maintenance strategies.

Often in making such comparisons there are compromises to be made, as rarely in practice are there only benefits and no dis-advantages in choosing one solution over the other.

The main driver in choosing between the technologies is "which approach gives an lower overall cost to the project?" Often this is influenced by the ability to allow process engineering and electrical design to overlap and thereby contribute to reducing or at least holding theproject duration. Benefits of early completion or achieving planned completion dates can be very, very large and far outweigh the difference in equipment costs.

MCQs

		Choose the correct option for each of the following:	Marks
1.		Motor control involves…. a) Starting the motor. b) Stopping the motor.	1

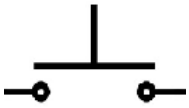
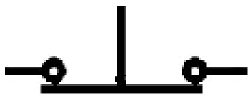
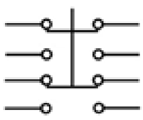
		c) Direction and speed controls of the motor. d) All of the above.	
2.		Identify the component of the motor-starter. a) Fuse. b) Circuit breaker. c) Over-load relay. d) Main Switch.	1
3.		Identify the component/s of the motor-supply circuit. a) Circuit-breaker. b) Fuse. c) Power Contacts. d) All of the above.	1
4.		Fuse is used in the circuit to… a) Protect the circuit components from short circuit faults b) Limit the starting current. c) Disconnect the circuit from supply mains in the event of any fault d) All of the above	1
5.		Contactor is …. a) Manually operated switch b) Protection device c) Electromagnetic coil d) Electromagnetically operated circuit breaker	1
6.		Overload relay protects the motor from… a) Over-voltage condition b) Over-current condition c) Excessive speeding d) Undesirable oscillations	1
7.		Fuse protects the motor from… a) Under-voltage condition b) Excessive speeding. c) Short-circuit condition. d) Undesirable oscillations.	1
8.		NO contact means…	1

		a) Number One contact b) Neutral On contact c) Normally On contact d) Normally Open contact	
9.		NC contact means… a) Neutral Cut contact b) Normally Cut contact c) Normally Closed contact d) No Closed contact	1
10.		Red push-button is generally used to… a) Start the motor b) Accelerate the motor c) Decelerate the motor d) Stop the motor	1
11.		Green push-button is generally used to… a) Start the motor b) Accelerate the motor c) Decelerate the motor d) Stop the motor	1
12.		Motor rotation of three-phase induction motor can be reversed by. a) Interchanging R & Y phases b) Interchanging Y & B phases c) Interchanging B & R phases d) Any one of the above	1
13.		Motor Control Centre (MCC) is…. a) Compact assembly b) Modular assembly c) Integration of motor control & distribution components d) All of the above	1
14.		PLC stands for… a) Phase Load Centre b) Programmable Logic Controller c) Phase Locked Contactor	1

		d) Programmable Load Contactor	
15.		VFD stands for…. a) Very Fast Drive b) Variable Fastest Drive c) Variable Frequency Drive d) Voltage Frequency Drive	1
16.		On control panel, the operating state is shown by. a) Push-buttons b) Circuit-breaker c) Indicator lamps d) Overload-relay	2
17.		A combination starter is a single enclosure comprising… a) Motor starter b) Fuse c) Circuit breaker or disconnecting switch d) All of the above	2
18.		The push buttons are used for … a) Stopping motors b) Starting motors c) Jogging or inching of motors d) All of the above	2
19		A conventional MCC unit is …. a) Purely Electrical unit b) Purely magnetic unit c) Electromagnetic unit d) Electromechanical unit	2
20		Traditional MCC offers… a) Well-coordinated control b) Better protective functionality c) Highly effective controls d) None of the above	2
21		Intelligent MCC is smart MCC because. a) It has multiple feeders	2

		b) It has a common power busbar c) It has multiple combination starters d) It has communication capable motor management device	
22		Difference between MCC and IMCC lies in…. a) Multiple feeders b) Common power busbar c) Intelligent relays d) Circuit breaker	2
23		The heart of IMCC is… a) Smart circuit breaker b) Fast acting fuse c) Smart motor management device d) All of the above	2
24		IMCC offers… a) Optimized use of control components b) Increased control flexibility c) Improved safety d) All of the above	2
25		IMCC requires… a) Effective communication networks with high bandwidths b) Extensive process data c) Components for Proper diagnostic features d) All of the above	2
26		As compared to MCC, the IMCC offers… a) Increased downtime b) Inferior quality control c) Proactive condition monitoring d) Unpredicted maintenance	2
27		Protective functions offered by Intelligent relay include. a) Phase loss b) Current imbalance c) Overload d) All of the above	2

28		A relay is said to be intelligent if it has the feature/s of a) Built-in network communication b) Programming facility to set the protective parameters c) Diagnostics d) All of the above	2
29		Identify the non-contact type sensor… a) Photoelectric sensor b) Inductive proximity sensor c) Capacitive proximity sensor d) All of the above	2
30		Limit switch is operated by… a) Displacement limit b) Current limit c) Voltage limit d) Speed limit	2
31		IMCC has dedicated software that… a) Delivers known computing environment in MCC b) Generates screens for effective control implementation and monitoring c) Tests the entire system for accurate functions and communication d) Does all of the above.	2
32		The following is not a Basic Motor function: a) Under voltage protection. b) Single phasing protection. c) Detecting motor bearing condition. d) Voltage and current indicating meters.	2
33		Conventional MCCs are preferred when: a) The components therein do not become obsolete over 12 to 15 years of time. b) Very huge amount of data/information needs to be communicated to the DCS. c) The cost effectiveness of equivalent IMCC is very poor. d) A very large number of additional functions need to be	2

		incorporated in the starter sections	
34		Identify the symbol below:  a) 1 NO power contact b) 1 NC auxiliary contact c) NO – Push button switch d) NC – Push button switch	1
35		Identify the symbol below:  a) 1 NC power contact b) 1 NO auxiliary contact c) NC – Push button switch d) NO – Push button switch	1
36		Identify the symbol below:  a) 2 NO Push button b) 2 NC Push button. c) 2 NO + 2 NC Push Button. d) None of the above.	2
37		Time delay fuses are recommended for applications wherein a) The inrush current is more than 500% b) The inrush current is very low of the order of 150% c) The inrush currents are absent. d) The normal rated currents are expected not to be exceeded.	2
38		Non-time delay fuses are recommended for applications wherein a) The over currents are more than 500% for a very long time b) The over currents are equal to 500% for a very long time	2

		c) The over currents are slightly less than 500% for a very long time d) The over currents are around 500% for a fraction of a second.	
39		A combination starter contains a) Starter with overload relay b) Fuses c) Switch for disconnection d) All of the above	2
40		IMCCs are a better choice when, a) conventional MCCs are very cheap b) a significant number of changes are going to be needed to be made in the controls c) conventional MCCs are very costly d) no major significant changes are going to be needed to be made in the controls	2
41		Time delay fuses provide following protection to motors: a) over voltage and short circuit protection b) under voltage and short circuit protection c) overcurrent and short circuit protection d) under current and short circuit protection	2
42		Non-time delay fuses provide following protection to motors: a) quick over voltage protection b) quick short circuit protection c) quick under voltage protection d) quick lightening protection	2
43		Fuses are rated by a) maximum continuous current they can handle b) maximum continuous voltage they can work at c) both a) and b) d) none of the above.	2
44		The circuit breakers are rated such that their rated current (continuous) a) exceeds the current rating of the fuses in the related circuit b) exceeds the voltage rating of the fuses in the related circuit c) does not exceed the cable conductor current rating used in the	2

		circuit d) does not exceed the cable conductor voltage used in the circuit	
45		The power monitoring unit has circuitary that does not cover the following in MCC: a) protection b) operation c) measurements d) load characteristics	
46		Network cabling does not a) carry communication signal from intelligent relay b) carry communication signal to PLC c) carry communication signal to AC drives d) carry communication signal to coupled mechanical load	2
47		In automated systems solenoid actuated valves form the interface between a) pneumatic and electrical control b) Magnetic and electrical controls c) Electronic communication systems d) Landline and mobile communication networks.	2
48		The following is not a basic motor operation function: a) Current indication b) Energy condition monitoring c) Overload protection d) Single phasing protection	2
49		The following is not an enhanced motor operation function: a) Energy condition monitoring b) Motor bearing condition monitoring c) Overload protection d) Restarting after sudden voltage dips	2
50		Intelligent MCCs are a better choice when: a) A huge amount of data is communicated to the DCS b) Personnel working on the systems need expensive training. c) Component obsolescence will not be faced for a long period	2

		d) Standard starters are sufficient for the work to be done.	

Resources:

1) Intelligent motor control: https://www.youtube.com/watch?v=mgoZSL2u6Jw
2) Intelligent motor control using neural network technology: https://www.youtube.com/watch?v=nVyU4YCO4CM
3) Handbook of Electrical Motor Control Systems: by U. S. Eshwar (Tata McGraw-Hill Publications, ISBN-13: 978-0-07-460111-2, ISBN-10: 0-07-460111-3.
4) Hand book by: Siemens-STEP-Series-Basics-of-Motor-Control-Centers.

Answer key to Unit 4 MCQs

1-d, 2-c, 3-d, 4-a, 5-d, 6-b, 7-c, 8-d, 9-c, 10-d, 11-a, 12-d, 13-d, 14-b, 15-c, 16-c, 17-d, 18-d, 19-d, 20-b, 21-d, 22-c, 23-c, 24-d, 25-d, 26-c, 27-d, 28-d, 29-d, 30-a, 31-d, 32-c, 33-a, 34-c, 35-c, 36-c, 37-a, 38-d, 39-d, 40-b, 41-c, 42-b, 43-c, 44-c, 45-d, 46-d, 47-a, 48-b, 49-c, 50-a.

Unit V

Tariff, Metering and Billing

5.1 Tariff

Power purchase agreement (PPA)

A **power purchase agreement** (**PPA**), also known as **electricity power agreement**, is a contract between two parties..

1. Which generates electricity (**the seller**) and
2. Which is looking to purchase electricity (**the buyer**).

The buyer typically is an utility or trader of electricity.

The PPA defines all of the commercial terms for the sale of electricity between the two parties, it includes

- The time of commercial operation of the project starts begins
- Schedule for delivery of electricity
- Penalties for under delivery
- Payment terms
- Termination

A PPA is the principal agreement that defines the revenue and credit quality of a generating project and is thus a key instrument of project finance. There are many forms of PPA in use today and they vary according to the needs of buyer, seller, and financing counter parties.

A PPA is a legal contract between an electricity generator (provider) and a power purchaser (buyer).

Contractual terms may be of 5 to 20 years, during this period the power purchaser buys energy, and sometimes also capacity and/or ancillary services, from the electricity generator.

Such agreements play a key role in the financing of independently owned (i.e. not owned by a utility) electricity generating assets. The seller under the PPA is typically an independent power producer, or "IPP."

In the case of distributed generation (where the generator is located on a building site and energy is sold to the building occupant), commercial PPAs have evolved as a variant that enables businesses, schools, and governments to purchase electricity directly from the generator rather than from the utility. This approach facilitates the financing of distributed generation assets such as photovoltaic, micro-turbines, reciprocating engines, and fuel cells.

Power cost/ Pricing

Electricity rates are agreed upon as the basis for a PPA. Prices may be flat, escalate over time, or be negotiated in any other way as long as both parties agree to the negotiation. In a regulated environment, an Electricity Regulator will regulate the price. A PPA will often specify how much energy the supplier is expected to produce each year and any excess energy produced will have a negative impact on the sales rate of electricity that the buyer will be purchasing. This system is intended to provide an incentive for the seller to properly estimate the amount of energy that will be produced in a given period of time.

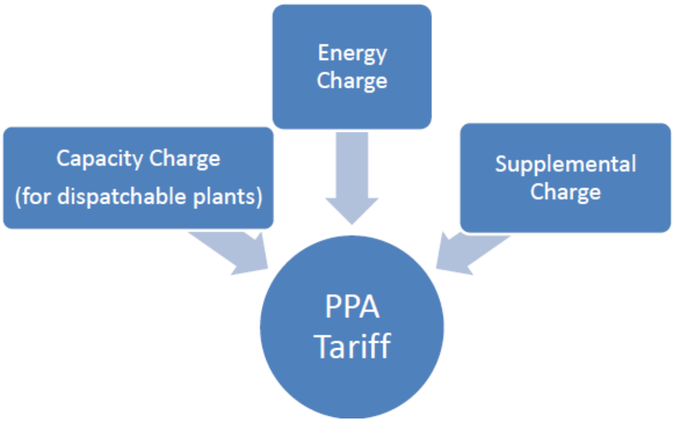


Fig 5.1 Structure of Pricing

5.1.1 Tariff Design:

Key factors for Tariff Design

A tariff structure is a set of rules and procedures that determines how to charge different categories of consumers.

Typical tariff structures include:

i) flat-rate tariff

ii) Volumetric tariff based on actual metered consumption: having different variables as, constant volumetric tariff, increasing block tariff, linear progressive tariff and peak-load pricing

iii) multi-part tariffs : including two-part tariffs, where users pay both a monthly fee for access and a usage fee for consumption such as in the water and electricity sectors, and optional tariffs where customers are offered a menu of pricing plans.

Tariff structures depend on many factors, including the network's characteristics and the objectives pursued via pricing policy.

The charges may differ between customer classes (such as residential, commercial and industrial).

Designing an efficient tariff structure can be done through a step-wise approach:

i) Gathering information about operator's activity and demand forecasts

ii) Evaluating the effectiveness of the current tariff structure and the need for reform

iii) Announcing the reform

iv) Implementing the proposed reform

Step One: Gather information

When starting a review of the tariff structure, the operator or regulator needs to gather information about the current activity of the utility (present and projected operating costs, assets, and investment plans), the demand forecasts (trend analysis, statistical analysis) and feedback from consumers on the actual service and price.

Consumers' inputs can be gathered through consultation, public hearings, focus groups, appointment of a consumer representative to the regulatory agency board or consumers' associations.

Step Two: Evaluate the effectiveness of the existing tariff structure and the need for reform

- Assess whether the operator is predicting an excessive level of operating costs and investments and estimate the corrected cost of service, covering all justified costs and accounting for all inefficiencies.
- Evaluate economic efficiency: the volumetric charge should be set in alignment to the short-run marginal costs of bringing an additional unit of service.
- Calculate the revenue requirements: even though there are several definitions, revenues from tariffs are generally expected to cover operating and maintenance costs, depreciation and a return on capital.
- Evaluate whether current tariffs are sufficient to cover costs or whether there needs to be an overall tariff increase or decrease in order to move towards cost-covering tariffs. If so in a regulated sector, the regulating entity needs to implement some form of price control. In all cases, the operator / regulator need to evaluate whether an equal tariff increase should be implemented across tariff categories or whether an overall rebalancing is needed between services or customer groups.
- If revenues from tariffs do not cover the full cost of service, then subsidies have to cover the difference. Existing subsidies should be identified and their targeting performance evaluated (based on an evaluation of the underlying error of inclusion and error of exclusion. These should then be adjusted accordingly.

Step Three: Publish tariff decisions (allowing for possible appeals on these decisions)

- Present the results of this evaluation to a broad range of stakeholders so as to build support for reform, with built-in participation mechanisms. For example, the regulator may publish draft determinations first, then organize a formal consultation process on these with sector stakeholder before publishing final determinations. Such an approach allows for better consensus building along the way.
- Provide opportunities for an appeal if the operator disagrees with the price determinations.

Step Four: Implement the proposed tariff reforms

- Identify potential winners and losers from proposed reforms and potentially design compensation or transitional measures (for example, phasing in changes in tariff structure, leaving time for people to adjust their consumption, especially for poor consumers).
- Monitor the impact of tariff reform over time so as to be able to carry out potential adjustments over time.

Particular attention should be paid to poor and unconnected customers, who are most likely to suffer the most from an ineffective tariff structure. It is worth mentioning the option of additional or new services, in particular pre-paid meters to mitigate negative impacts.

Cross subsidy

There may various views on the meaning of cross-subsidisation, but they have generally involved the idea that a set of customers receives favorable prices at the expense of other customers.

Specifically, a product is receiving a cross-subsidy if it is priced below its average incremental cost, and a product is generating a cross-subsidy if it is priced above it’s per unit stand-alone costs.

It is the difference between the applicable average tariff of a consumer category and the cost of supply to that consumer category.

The cost of supplying electricity to all categories of consumers is same. However, the tariff charged from them is different.

The cross-subsidy for a consumer category is the difference between the cost to serve that category of consumers and average tariff realization of that category of consumers.

Cross-subsidies are to be calculated with reference to the category-wise cost of supply and not average cost of supply.

The tariff for different categories of a consumer may progressively reflect the cost of electricity to the consumer category but may not be a mirror image of cost to supply to the respective consumer categories.

Cross-subsidies involve a group of consumers paying more than the general cost of supply and the surplus is used to subsidize the provision to the other group at a price that is lower than the cost of supply to the subsidized group.

Cross-subsidies therefore, can be defined as a mechanism whereby some consumer groups are charged a higher tariff as compared to the cost of supplying power to them.

The additional revenue generated from them is used to tide over the revenue shortfall from other consumer groups, who are charged lesser tariff as compared to the cost of supplying power to them.

In India, cross-subsidies are pervasive where commercial and industrial consumers of electricity pay higher rates of supply to cover the shortfall in revenue of domestic and agriculture electricity consumers. Most of the distribution utilities have a lower tariff for consumers residing in rural or hilly areas in comparison to consumers residing in urban areas without factoring in the cost of supply. In some cases, consumption at higher tariff slabs generates cross-subsidies for the consumer whose consumption falls in lower slabs.

Slabs in billing

For billing purpose the consumers are categorized as LT and HT consumers. Further they are grouped as LT1 to LT X and HT1 to HT IX. These consumers are charged for the energy used per kWH. In addition to these charges other charges such as Fuel Adjustment costs, Electricity duty and tax on sale of electricity, power factor penalty (if any), penalty for exceeding contract demand.

Incentives are given for improved Load Factor and Power Factor.

Major Components of an Electricity Bill

Following are the major components of an energy bill…

Fixed charges: Operation & Maintenance Expenses; Depreciation; Interest on Loan Capital; Interest on Working Capital; Return on Equity Capital; Income Tax;

Energy charges: The Energy Charges shall cover landed cost of primary fuel and secondary fuel oil and shall be worked out on the basis of total energy scheduled to be supplied to the Beneficiary/ies during the calendar month on ex-power plant basis, at the Energy Charge Rate of the month (with fuel price adjustment)

Electricity Duty: The **duty** is charged on consumption at the applicable rate per unit of **electricity** consumed. ... Certain states the **duty** is charged on the total charges. The only way to reduce the **duty** is to reduce the consumption per month. This ensures that efficient energy conservation measures are taken.

Charges:

Wheeling charges: Distribution company has to pay the transportation **charges** to the **Transmission** company. These **charges** are known as **Wheeling Charges**. The fee associated with **wheeling** is referred to as a "**wheeling charge**." This is an amount in $/MWh which transmission owner recovers for the use of its system. If the resource entity must go through multiple [transmission owner]s, it may be **charged** a **wheeling charge** for each one.

FAC Charges: **FAC** (Fuel Adjustment **Charge**) or FCA (Fuel Cost Adjustment) or FPPCA (Fuel and Power Purchase Cost Adjustment) is amount that utilities apply on **bills** based on varying price of fuel or Coal.

Additional charges: Additional Supply Charge (ASC) at the rate of Rs. 5.36 per unit (kWh) shall be levied on specified consumer categories to compensate for the costly power purchase undertaken to reduce load shedding.

Capacitor penalty—for agriculture

p.f. penalty : An **electric** rate may also include additional **charges** when the customer has a **power factor** less than some preset limit, typically between 80 and 90 percent. This is called a **power factor penalty** since it is a **penalty** assessed on the customers **electrical bill** for lower than optimum **power factor**.

M.D. Penalty : Maximum demand register (kW or kVA). This is the maximum power value, usually the average of 15 minutes, reached during the billing period (this average time may vary depending on the country). Once the value is higher than the contracted power, the customer will pay a **penalty** on the **electricity bill**.

Abbreviations:			
ABR-	Average Billing Rate	MNRE-	Ministry of New and Renewable Energy
ACoS-	Average Cost of Supply	NPCIL-	Nuclear Power Corporation of India Limited
ARR-	Annual Revenue Requirements	NTPC-	National Thermal Power Corporation
CEA-	Central Electricity Authority	O&M-	Operations & Maintenance
CERC	Central Electricity Regulatory Commission	PPA-	Power Purchase Agreements
DISCOM-	Distribution Company	SLDC-	State Load Dispatch Centre
MERC-	Maharashtra Electricity Regulatory Commission	T&D -	Transmission and Distribution

5.1.2 Special tariffs:

5.1.2.1 Average Billing Rate (ABR):

The ratio of the average billing rate for a consumer category (ABR) to the overall average cost of supply (ACoS) is an indicator of tariff rationalization for that category of consumers. Going forward, some rationalization is expected in both the scenarios.

The ABR values are derived from the category-wise revenues available to the DISCOM. Average Billing Rate (ABR) consist of fixed and energy charges, which are reflected in the electricity bills of the consumers as per their contracted demand.

The actual ACoS for the DISCOMs could vary beyond the lower and higher estimates. The factors that could affect the cost (ACoS) further are rise in fuel prices, change in generation mix, increased generation tariff due to higher or unexpected expenditures (for example, the impact of salary hikes by the Pay Commission), increased capital inflow for repair and maintenance, etc. The formula for the ABR calculation is:

ABR (for a particular consumer category) = **Revenue** expected from the respective category in INR (given in the tariff order)/**Approved sales** in MU (million units) (given in the tariff order)

For example, if INR 100 crore in revenues is expected from the industrial category consumer of a DISCOM, and if the approved sales are 100 MU for the same year, then the ABR is:

= 100*10/100

= INR 10/kWh

5.1.2.2 Aggregate Revenue Requirement (ARR):

Definition: Aggregate Revenue Requirement (ARR**)**means the annual revenue requirement comprising of allowable expenses and return on capital pertaining to the Generating Entity, for recovery through tariffs, in accordance with these Regulations.

Explanation: As per Regulation No. 4 of 2005, the licensee is required to file the Aggregate Revenue Requirement (ARR) for Retail Supply Business and Tariff proposal for the entire control period i.e., for the period from FY 2014-15 to FY 2018-19.

The responsibility of the MERC is to show the licensees, the ways and means of recovering the approved Aggregate Revenue Requirement (ARR) through revenue and charges, to the extent of energy quanta specified in the relevant tariff order. The tariff changes should normally be applied for to take effect from the 1st day of ensuing financial year and hence the application shall be filed before 30th November of Current Year along with Aggregate Revenue Requirement (ARR).Aggregate Revenue Requirement (ARR) is prepared by MSEDCL with projections based on the actuals in the previous year(s), Power procurement

(PPAs and Short term purchases), Distribution MYT9 (multi year tariff) Order, Transmission Tariff Order, SLDC Tariff Order etc. The expected revenue from charges is based on sales projections and approved tariff rates that are currently applicable for different consumer categories and slabs.

The detailed estimation process is shown in figure 5.2.

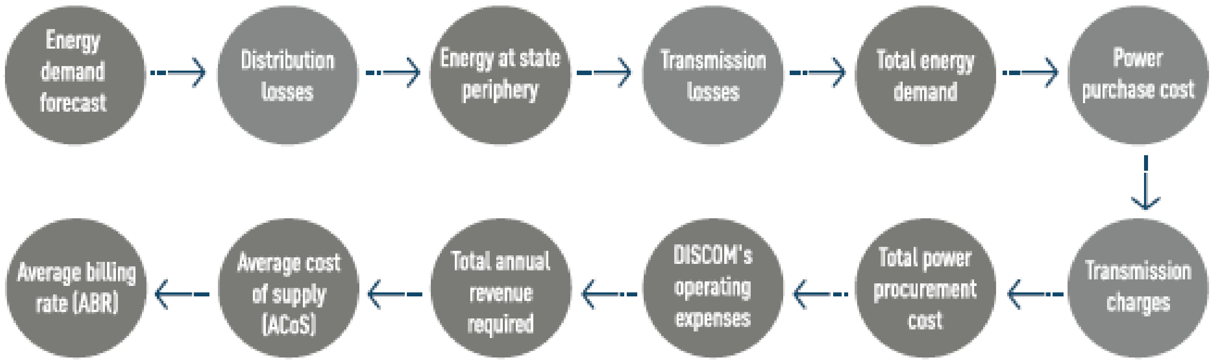


Fig. 5.2 Regulatory process of Estimating ARR

Parameters for determination of ARR

The Aggregate Revenue Requirement for the Distribution Business of the Distribution Licensees for each year of the Control Period shall contain the following financial parameters:

a) Operation and Maintenance expenses;
b) Capital Investment Plan;
c) Depreciation
d) Contingency Reserves;
e) Interest on Loan;
f) Interest on Working Capital;
g) Return on Equity;
h) Income Tax;
i) Non-Tariff Income; and
j) Income from Other Business

5.1.2.3 Availability Based Tariff (ABT):

In power system network the system frequency is a continuously changing variable and its control needs continuous balance between system demand and generation. If demand is less than the generation the frequency rises while if the demand is greater than the generation the frequency falls. The control of frequency can be managed by either changing the demand.

Availability Based Tariff (ABT) is introduced by Central Electricity Regulatory Commission (CERC) for suggesting improvement in bulk power tariff in India. Options from the various utilities like State Electricity Boards, DVC, NTPC, NHPC etc. were taken and then arrived at a decision which suited the best under Indian conditions. It may be defined as the market mechanism for centralized scheduling and dispatch of Central Sector generation and State Sector drawals and decentralized scheduling for state sector generation. It may also be defined as merit order operation of the units to attain higher levels of economy in terms of production of electricity. To comply with that the centralized merit order dispatch of all the centralized generating units should be controlled centrally by Regional Load Dispatch Centre (RLDC) while State Sector Generating Units will be operated on merit order independently by each State Sector Load Dispatch Centre. RLDC will dispatch only the drawals of the state level beneficiaries of Central Sector Power Station.

Need of Availability Based Tariff (ABT):

Indian Power System is characterized by low frequency system due to continuous power deficit for most of the time. There is always supply and demand mismatch. The power demand is always more than the power supply. Due to this the frequency of Grid remains on lower side. Before the introduction of Availability Based Tariff, Generating Stations used to deliver the same amount of MW in spite of need for lower MW demand during the period of lower power demand. This causes the Grid frequency to be at higher side. Similarly during the period of higher power demand, Generating Stations used to supply same MW. Subsequently, the Grid frequency reduces. This type of Grid operation did not have any provision to maintain a discipline.

Availability Based Tariff (ABT) is a frequency based pricing scheme adopted in Indian Power Sector to maintain Grid discipline by implementing incentive / disincentive during unscheduled power interchange. This scheme was introduced in the year of 2002. It is imperative here to understand the need for ABT, for better understanding the concept.

Structure of Availability Based Tariff (fig 5.3):

Availability Based Tariff is a three part pricing scheme i.e. Fixed charge, Variable charge and Unscheduled Power Interchange (UI) Incentive / Penalty. The following elements are considered for deriving tariff in ABT mode of operation. They are

1. Capacity or fixed charges.
2. Energy Charges.
3. Unscheduled Interchange (UI) Charges.

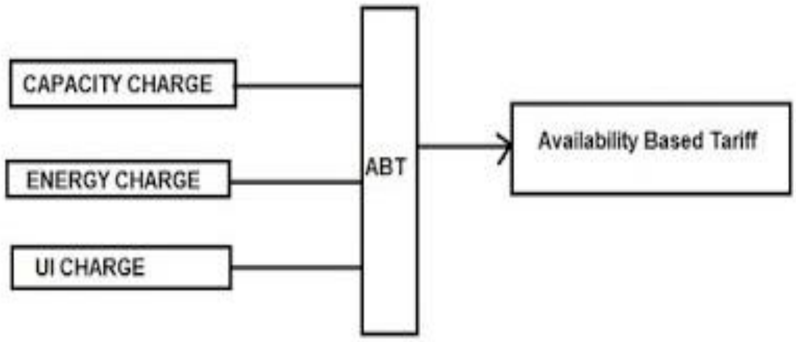


Fig.5.3 Structure of Availability Based Tariff

1) Fixed Cost is basically imposed on beneficiaries in proportion to their entitled power from the generating station. This means fixed cost is directly proportional to the plant capacity shared by the beneficiaries. This is the reason Fixed Charge is often called Capacity Charge. But this does not mean that Generating Station can claim any amount of fixed cost irrespective of its availability. The reimbursed Fixed Charges payable to Generating Station is dependent on the availability of plant. If the plant availability for a year is more than the set norm, the generating station gets paid higher. In case the plant availability is less than the set norm over a year, the generating station is going to be paid lower. This is why this tariff is called Availability Based Tariff. In earlier tariff, fixed charge was dependent on Plant Load Factor but in Availability Based Tariff, it is linked with Plant Availability.

2) Variable charge is the cost incurred by Generating Station to produce MW day to day. Variable charge is also called Energy Charge. It comprises of Fuel charge (like coal for thermal power plant, Nuclear Fuel Bundle for Nuclear Power Plant, Gas for Gas Power Plant etc.), Operating expenses etc.

3) Unscheduled Interchange Charge (UI Charge): Unscheduled Interchange means deviation from the scheduled generation of plant or deviation from scheduled drawl of power by beneficiary. Suppose a generating station is scheduled to deliver 600 MW but actually on a day it is supplying 700 MW, even then the station will be paid Energy Charges for scheduled generation i.e. for 600 MW. For surplus 100 MW, the rate of energy charge will depend upon the prevailing Grid frequency at the time. This energy charge for surplus supply i.e. 100 MW (for our example) is called Unscheduled Interchange Charge (UI Charge). The UI charge is linked with Grid frequency. If the Grid frequency is higher i.e. more than 50.2 Hz, the rate of UI charge is zero. This means Generating Station will not be paid for excess generation of 100 MW when Grid frequency is more than 50.2 Hz. Thus the station is forced to reduce its generation to maintain Grid frequency.

Similarly when the Grid frequency is lower, the generating station is paid incentive for excess generation at UI rate. Let us say the Grid frequency at that time is 49.4 Hz. In this case, a UI charge at the rate of around 875 Paisa / kWh is paid to the station. This encourages to supply excess power into the Grid by the stations so that Grid frequency do not decrease further. The rate of Unscheduled Interchange Charge versus Grid frequency is shown in figure below.

The distinct merits of ABT are:

(a) Facilitating grid discipline;

(b) Facilitating trading in capacity and energy; and

(c) Facilitating merit order dispatch as and when made effective

5.1.2.4 Time of Day Tariff (ToD):

Time of Day (or TOD) tariff is a tariff structure in which different rates are applicable for use of electricity at different time of the day. It means that cost of using one unit of electricity will be different in mornings, noon, evenings and nights. This means that using appliances during certain time of the day will be cheaper than using them during other times.

Time of Day (TOD) tariff, is recognized globally across electricity industries, as an important Demand Side Management (DSM) measure which is used as a means of incentivizing consumers to shift a portion of their loads from peak times to off-peak times, thereby improving the system load factor by reducing the demand on the system during peak period.

Electricity grids can be compared to road or highway that can accommodate only a certain number of vehicles at a time. During peak hours highways are jammed, similarly during peak hours, electricity grids are jammed. Drive on highway during off peak hours is like a breeze, similarly flow of electricity during off peak hours is a breeze. What if people are charged differently for using highways during different times and also charged as per size of their vehicles. People with either prefer to go through highway at a time when traffic is less (off peak) or would like to use a two-wheeler. Similarly, with TOD tariff, people will either switch to a time when prices are less or will start using efficient appliances (with lesser electricity consumption).

5.3.5 Recent ToD Structure:

TOD tariff Consumers charged dynamic price for electricity consumed during peak and off-peak period to reduce the negative slope in the load curve. The very basic purpose of TOD tariff is to shift the load from peak to off-peak hours and avoid spikes in the demand pattern. Hence, no changes has been proposed in the rebate of non-peak hours i.e. 2200 hrs. To 0600 hrs. Revision in ToD tariffs on other slots have been proposed keeping in view the existing demand pattern as well as the trend in change of consumption pattern of the consumers in last few years and to encourage the consumers to shift their load to non-peak hours in order to achieve the desired load curve.

ToD Structure for LT and HT Consumers:

1) LT II: LT – Non-Residential or Commercial (LT II (A): 0 - 20 kW)

This tariff category is applicable for electricity used at Low/Medium voltage in non-residential, non-industrial and/or commercial premises for commercial consumption meant for operating various appliances used for purposes such as lighting, heating, cooling, cooking, washing/cleaning, entertainment/ leisure and water pumping in, but not limited to, the following premises:

a) Non-Residential, Commercial and Business premises, including Shopping Malls and Showrooms;

b) Combined lighting and power supply for facilities relating to Entertainment, including film studios, cinemas and theatres (including multiplexes), Hospitality, Leisure, Meeting/Town Halls, and places of Recreation and Public Entertainment;

c) Offices, including Commercial Establishments;

2) LT II (B): > 20 kW and ≤ 50 kW and (C) > 50 kW

Applicability: As per the applicability described in LT II (A) and for the Sanctioned Load in the range applicable in this sub-category, i.e. LT II (B) and LT II (C).

Consumption Slab (kWh)	Fixed/Demand Charge (Rs/kVA/month)	Wheeling Charge (Rs/kWh)	Energy Charge (Rs/kWh)
LT II (B) > 20 kW and ≤ 50 kW	350.00	1.30	9.30
LT II (C) > 50 kW		1.30	11.60
TOD Tariffs (in addition to above base Tariffs)			
2200 Hrs-0600 Hrs			-1.50
0600 Hrs-0900 Hrs & 1200 Hrs-1800 Hrs			0.00
0900 Hrs-1200 Hrs			0.80
1800 Hrs-2200 Hrs			1.10

Table: ToD Structure for LT Consumers

3) HT I (A): Industry – General

This tariff category is applicable for electricity for Industrial use at High Voltage for purposes of manufacturing and processing.

4) HT I (B): Industry - Seasonal

Applicable to Seasonal consumers, who are defined as those who normally work during a part of the year up to a maximum of nine months.

Table: ToD Structure for HT Consumers

Demand/Fixed Charge and Energy Charge (for all Supply Voltage Levels)

Consumer Category	Demand Charge (Rs/ kVA/ month)	Energy Charge (Rs/kWh)
HT I: HT – Industry		
HT I (A): Industry - General	350.00	7.10
HT I (B): Industry - Seasonal	350.00	7.40
ToD Tariffs (in addition to above base Tariffs)		
2200 Hrs-0600 Hrs		-1.50
0600 Hrs-0900 Hrs & 1200 Hrs-1800 Hrs		0.00
0900 Hrs-1200 Hrs		0.80
1800 Hrs-2200 Hrs		1.10

Advantages of ToD:

1. Incentivizes consumers to shift demand to off peak period thereby reducing peak demand
2. Advantage to (Additional revenue/ Cost Reduction for Utility) Utility:
3. Additional revenue on account of TOD surcharge during peak hours
4. Reduction in cost of power purchase due to reduction in peak consumption
5. Revenue gain due to increase in sales during of peak hours (shifting of load from peak hours to peak)

5.1.3kVAhTariff

5.1.3.1 Introduction

kVAh based tariff use to motivate industrial and non-domestic consumers to maintain power factor. Consumers billed at kVAh (apparent energy) and not at kWh (active energy) whereby the reduction of reactive energy becomes the prerogative of the consumer. The prime objective of kVAh-based billing is to encourage the consumers to maintain near unity power factor to achieve loss reduction, improve system stability, power quality and improve voltage profile. By kVAh billing, the consumers will be encouraged to adopt energy efficiency programs and will be benefited by reduced electricity bills.

5.1.3.2 kVAh Billing Method for HT and LT Consumers

The Commission intends to implement kVAh billing to all HT consumer and LT consumers having load above 20 kW from 1 April, 2020. All Distribution Licensees in State are required to take necessary steps such as meter replacement, if required, preparedness of billing software etc.

Load Factor Incentive: MSEDCL submits that the reason behind introduction of the load factor incentive was to motivate consumers towards utilization of 100% sanctioned/contracted load. However, rationalization of energy charge including bulk consumption discount and revision in billing demand will act as a motive for consumers to effectively plan and utilize the power. Therefore, MSEDCL proposed the LF incentive upto 7%. It is also important to note that various SERCs in other States have given very low or no incentives for Load factor.

5.1.3.3 kVAh Metering methodology:

Concept of kVAh Tariff:

The electricity billing commonly is consisted of three variable components plus at least one constant charge. The variable components are as follows:

a. Electrical Energy has two components viz. Active Energy (kWh) and Reactive Energy (kVArh). Vector sum of these two components is called as Apparent Energy & is measured in terms of kVAh.

b. In kVAh based billing, fixed/ demand charges are levied on apparent power (kVA) and energy charges are levied on apparent energy (kVAh). In future, energy charges will be levied based on this apparent energy (kVAh) consumption which eliminates requirement of charging active and reactive energy separately.

Existing Tariff:

At present, Consumers are billed on Active Energy Consumption measured in kWh along with the fixed charges and other charges. kWh consumption when multiplied by the applicable tariff for the consumer will give energy charges payable by the consumer. The effect of reactive energy is considered through Power Factor penalty / incentive mechanism. Penalty is levied to consumers for Power Factor (PF) below 0.90 (for Lead as well as Lag PF) and incentive is provided for P.F. above 0.95 (for Lead as well as Lag PF).

Necessity of kVAh Tariff:

Both Active (kWh) and Reactive (kVArh) energies are consumed simultaneously. Reactive Energy (kVArh) occupies the capacity of electricity network and reduces the useful capacity of system for generation and distribution & hence its consumption also needs to be billed. kWh based billing is associated with PF incentive /penalty mechanism. Considering that the kVAh based billing has an inbuilt incentive /penalty mechanism and separate mechanism for the same is no more required; instead of billing two energies separately, billing of kVAh energy is preferred as a commercial inducement.

Implementation of kVAh tariff in Maharashtra State:

As per MERC Order in Case no. 195 of 2017 dated September 12, 2018, The Commission intends to implement kVAh billing to all HT consumer and LT consumers having load above 20 kW from 1^{st} April, 2020.

Difference in kVAh tariff and Existing tarrif:

kVAh billing has an inherent mechanism to incentivize or penalize consumers according to their power factor. The Prime Objective of the kVAh based billing is to encourage the consumers to maintain near unity Power factor to achieve loss reduction, improve system stability, power quality and improve voltage profile. At the national level, emphasis is being given to Energy Conservation, Energy Efficiency and Demand Side Management (DSM) to optimize the energy usage. Through kVAh billing, the consumers will be encouraged to adopt energy efficiency programs and will be benefited by reduced electricity bills.

Reactive Power and its effects on system:

1). In case of inductive loads like motors, electrical energy can't directly be converted into useful work (rotation of motor shaft in this particular case). This is because, to convert electrical energy into rotational energy, magnetic field has to be created in between the gaps of stator and rotor of Motor. Hence, some amount of energy has to be used in creating magnetic field. The portion of power that contributes in creating magnetic field is known as Reactive Power.

2) Though reactive power is needed to run many electrical devices, it can cause harmful effects on your appliances and other motorized loads, as well as electrical infrastructure. Since the current flowing through your electrical system is higher than that necessary to do the required work, excess power dissipates in the form of heat as the reactive current flows through resistive components like wires, switches and transformers.

Power Factor (PF) Impact on Electrical Power:

a. Desired Power Factor is unity i.e. 1, and its range is Zero Lag – unity Zero Lead. For purely capacitive loads PF is Zero Lead and for purely inductive loads PF is zero Lag.

b. Unity Power Factor signifies that there is no reactive power exchange between consumer and grid.

c. Power Factor is an indicator for efficiency of Energy Conversion. If PF is 0.85 it means that 15% of power is not resulting in actual work. If PF is 0.85 lagging it means that 15 % of power is used by inductive elements and If PF is 0.85 leading it means that 15 % excess reactive power is supplied by capacitive elements. In both the aforementioned cases 15 % of power is not resulting in to actual work. Both Leading and lagging power factor are equally harmful to the power system.

Advantage of kVAh Tariff:

1. kVAh billing will ensure that the consumers who will utilize the power efficiently will be paying less energy charges as compared to others who are not using the power efficiently.
2. The new billing methodology will be much simpler to understand as number of parameters viz. PF, RkVAh (lead/lag), kWh units) will be reduced.
3. The kVAh based billing has an inbuilt incentive/penalty mechanism and therefore separate mechanism for the PF incentive/penalty is no more required. It will encourage the consumers to improve the power factor by way of reactive power compensation at the load point itself.
4. With better power factor, the line loading shall be lower for the same kW requirement leading to lower transmission as well as distribution losses.
5. Power supply quality will be improved.
6. It is beneficial for both - consumers and MSEDCL

5.1.3.4 kVAh Based Tariff Calculation:

Calculation of PF by Old Tariff:

While the average PF measurement is not possible through the installed meter, the following formula for calculating the average PF during the billing period were applied.

Average PF = Total (kWh)/ Total (kVAh)

Wherein the $kVAh = [\sqrt{\sum(kWh)2 + \sum(RkVAh)2}]$

Where kVAh is square root of the summation of the square of kWh and RkVAh)

Calculation of PF by kVAh based Tariff:

MSEDCL introduce kVAh billing system with the prime objective to encourage the consumers to maintain near unity PF to achieve loss reduction, improve system stability, power quality and voltage profile.

Now as per MTR order dated 12 September 2018 lead component of reactive energy i.e. RkVAh lead is also considered in the old formula and PF is calculated accordingly as below

Average PF = kWh/$\sqrt{\sum(kWh)2 + \sum(RkVAhLag + Rkvahlead)2}$

Guidelines for implementation of kVAh based tariff.

a) If PF level is less than 0.90 then penalty shall be as per percentage given in MERC order.

b)If PF level is greater than 0.95 and RkVAh lag consumption is greater than RkVAh lead consumption then PF incentives shall be given as per MERC order.

c) If PF level is greater than 0.95 and kVAh Lag consumption is less than RkVAh lead consumption then incentives shall not be applicable.

d) If the RkVAh lead reading is not available then old procedure of PF computation will be followed.

Commission has decided to reduce the existing Power Factor Incentive / Penalty by 50%. Accordingly, maximum Power Factor Incentive, which is 7% at Unity Power Factor, has been reduced to 3.5%. Similarly, Penalty for lower Power Factor has been rationalized.

Sl.	Range of Power Factor	Power Factor Level	Incentive
1	0.951 to 0.954	0.95	0%
2	0.955 to 0.964	0.96	0.5%
3	0.965 to 0.974	0.97	1.0%
4	0.975 to 0.984	0.98	1.5%
5	0.985 to 0.994	0.99	2.5%
6	0.995 to 1.000	1.00	3.5%

Sl.	Range of Power Factor	Power Factor Level	Penalty
1	0.895 to 0.900	0.90	0%
2	0.885 to 0.894	0.89	1.0%
3	0.875 to 0.884	0.88	1.5%
4	0.865 to 0.874	0.87	2.0%
5	0.855 to 0.864	0.86	2.5%
6	0.845 to 0.854	0.85	3.0%
7	0.835 to 0.844	0.84	3.5%
8	0.825 to 0.834	0.83	4.0%
9	0.815 to 0.824	0.82	4.5%
10	0.805 to 0.814	0.81	5.0%
...	...	...	...

are contrary (opposite); however their addition for billing is must because of following The formula used in kVAh based tariff in which both the RkVAh Lag and Lead parameters reasons.

1) RkVAh Lag and Lead cannot occur simultaneously and for every time instance the resultant of both RkVAh lag and lead energies (being contrary parameters) is computed and get registered in either register (RkVAh lag or RkVAh lead) according to the predominance at respective instances.

2) As both are recorded at different time spans/slots and both (lead & lag) are responsible to deviate the system from Unity PF (UPF) and hence, both are liable for penalty.

For example, during an hour,

kWh = 4, RkVAh *Lag* = 3, then kVAh = 5.

During next hour,

kWh = 4, RkVAh *Lead* = 3, then kVAh = 5.

This does not mean that both Reactive energies should cancel each other and resultant reactive energy should be consider for billing purpose is equal to Zero, because as they are recorded at different time instances both are equally responsible for loading the system (either lead or lag) with 5 kVAh apparent power.

Reference web links:

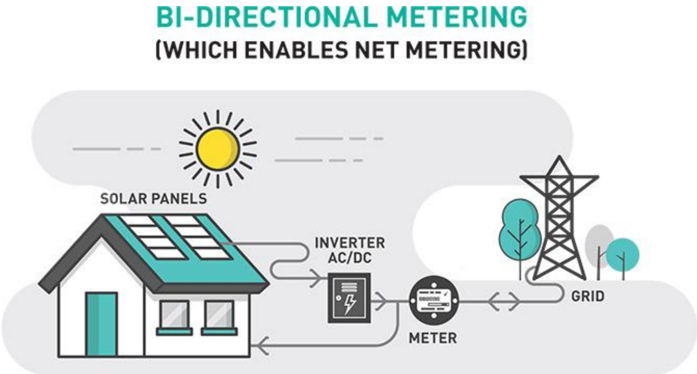
1) https://www.mahadiscom.in/consumer/wp-content/uploads/2018/10/Comm_Cir_311.pdf
2)http://www.forumofregulators.gov.in/Data/Reports/Report-Meteringissues%20august%202009.pdf.
3) http://www.mercindia.org.in/pdf/Order%2058%2042/Order48%20of%202016-03112016.pdf
4) http://www.mercindia.org.in/pdf/Order%2058%2042/Order195%20of%202017-12092018.pdf

5.2 Metering and Bill Management:

Net metering

Net metering is a billing mechanism that credits solar (or other) energy system owners for the electricity they add to the grid.

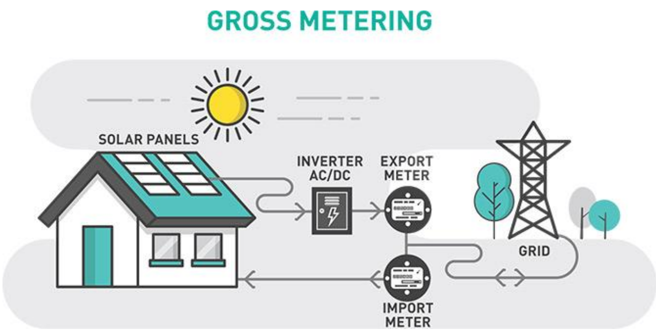
Let's say your rooftop solar system generates 10 units (kWh) of electricity during the day, but you only consume 8 units for powering your various devices/appliances. You are left with 2 excess units. This excess energy is fed into the grid.



At night, without the sun powering your rooftop system, you again need electricity. Let's say you consumed 2 units from the grid at night. Your day's grid electricity consumption form the grid is zero. In some cases, if you supply more power to the grid than you draw from it, you can even earn money.

Gross Metering

In this mechanism of billing, the billing is done separately for the power consumed from the grid and the power fed to the grid. The handy thing about gross



metering is that your electricity bill tells you exactly how much electricity your solar system has generated without the ambiguity of the net metering approach. Gross metering also records the entire amount of electricity that is consumed by your home.

MERC Rules for Net Metering (2015)

A. Net Metering arrangement shall be permitted by the Distribution Licensee (a person granted a License to operate and maintain a distribution system for supplying electricity to consumers in his area of supply) on a non-discriminatory and 'first come, first serve' basis to the Eligible Consumer who intends to install a Rooftop Solar system connected to the network of Distribution Licensee; Provided that the interconnection of such system with the network of the Distribution Licensee is undertaken in accordance with the standards and norms specified in the Central Electricity Authority (CEA) (Technical Standard for Connectivity of the Distributed Generation Resources) Regulations, 2013.

B. The Distribution Licensee shall allow Net Metering arrangement to Eligible Consumers so long as the cumulative capacity utilized at a particular distribution transformer does not exceed 15% of the rated capacity of that distribution transformer.

C. The Distribution Licensee shall provide yearly, on its website and to the Commission, information regarding the distribution transformer level capacity available for connecting Rooftop Solar system under Net Metering arrangements.

D. The maximum Rooftop Solar system capacity to be installed at any Eligible Consumer's premises shall be governed by the available capacity of the service line connections of the Eligible Consumer's premises and the cumulative capacity utilized at particular distribution transformer.

E. Provided that the capacity of the Rooftop Solar system to be connected at Eligible Consumer's premises shall not exceed his Contract Demand or connected load of the Eligible Consumer.

F. The capacity limits for the connectivity of Rooftop Solar system to the network of Distribution Licensee are as follows:

Sr. No.	Voltage Level	Threshold limit of Rooftop Solar PV system
01	230/240 V (1Φ)	Less than 8 kW/40 A
02	400/415 V (3Φ)	Less than 80kW/100 kVA Less than 150kW/187 kVA (Municipal Corporation areas)
03	11 kV and above	Up to 1000 kVA

MCQs

No.		Choose the correct option for each of the following:	Marks
1.		PPA is the a) MOU between two parties b) Mode of behavior between two parties c) Contract between two parties d) Conditions for terminating the contract between two parties	1
2.		Duration of PPA is generally a) Upto Six Months b) One Year c) 1-2 Years d) 5-20 Years	1
3		In PPA the party which generates the electrical power is a) Seller b) Buyer c) Operator d) Organizer	1
4		In PPA the party which is looking to purchase electricity is a) Seller b) Buyer c) Operator d) Organizer	1
5		Cross-subsidies can be defined as a) A mechanism of charging consumer at different tariffs. b) A mechanism of identifying types of consumer. c) A mechanism of penalizing consumer for electrical theft. d) A mechanism of charging consumer at different tariffs.	1
6		Flat-rate tariff , Volumetric tariff, multi-part tariffs are a) Types of subsidies b) Slabs of billing c) Key factors for Tariff Design d) Types of consumers	1

7		The only way to reduce Electricity Duty is a) To reduce consumption per unit. b) To reduce generation c) To reduce the power factor d) To reduce the maximum demand	2
8		FAC Charges is the amount a) that utilities apply on bills based on kWh use of the consumer b) that utilities apply on bills based on p.f. of the consumer. c) that utilities apply on bills based on the MD of the consumer. d) that utilities apply on bills based on varying price of fuel or Coal.	1
9		Electricity rates charged to the consumer as agreed in a) PPA b) MOU c) National Power Policy d) None of the above	1
10		Wheeling charges in consumers electricity bill are for a) the electricity transportation charges to be paid to the transmission company b) the transportation charges towards use of four wheelers used for officers c) the transportation charges to be paid to the Toll agencies d) None of the above	2
11		Average billing rate consist of a) Fixed and Energy charges b) O & M charges c) Labor charges d) Transmission charges	2
12		Overall Average Cost of Supply (ACoS) not depends on **a)** Fuel prices b) Salary hikes c) Capital inflow d) Tariff	1

13		Unit of the Average billing rate is **a)** kVAh b) INR /kWh c) kWh/INR d) INR	1
14		Aggregate Revenue Requirement (ARR) is prepared by a) DISCOM b) State Government c) Central Government d) Central Electricity Authority	1
15		Which following parameter not use for determination of ARR a) Interest on Loan b) Depreciation c) Income Tax d) Profit	2
16		Availability Based Tariff (ABT)is introduced by a) National Thermal Power Corporation b) State Distribution Companies c) Central Electricity Regulatory Commission (CERC) d) Maharashtra Electricity Regulatory Commission (MERC)	1
17		Objective of Availability Based Tariff is a) To maintain Grid frequency b) Available energy as per consumer demand c) Supply energy when it is available d) Make Availability of energy at high cost	2
18		Which of following in not a function of ABT a) Facilitating grid discipline; b) Facilitating trading in capacity and energy; and c) Facilitating merit order dispatch as and when made effective d) Facilitating consumers to purchase energy	2
19		The energy rates in Time of Day (or TOD) tariff a) Are fixed during day time b) Are fixed during night time	2

		c) Are not fixed during night time d) Are not fixed during time of the day	
20		Time of Day (TOD) tariff give incentive to consumer during a) Off-peak times b) Peak times c) Off-peak and peak times d) Complete day time	1
21		Basic purpose of ToD tariff is to a) Shift the load from off-peak to peak hours b) Shift the load from peak to off-peak hours c) Keep tariff rate different for day d) Attract consumers to consume more energy	2
22		In TOD tariff the non-peak hours are a) 0600 hrs To 2200. b) 0900 hrs To 1200 Hrs c) 2200 hrs. To 0600 d) 1800 hrs To 2200 hrs	1
23		For LT and HT Consumers the non peak and peak hours are a) Different b) Same c) Peak hours same but non peak hours different d) Peak hours different but non peak hours same	1
24		Which state is incorrect in relation to ToD a) Reduction in cost of power purchase due to reduction in peak consumption b) Advantage to Utility c) Incentivizes to consumers is same for entire day d) Additional revenue on account of TOD surcharge during peak hours	2
25		kVAh based tariff encourages consumer to a) Maintain power factor near unity b) Constant Maximum demand c) Maintain constant Voltage d) Maintain constant frequency	1

26		kVAh based tariff is applicable to consumers a) All consumers b) Consumer having load below 20kW c) Consumer having load above 20kW d) It is not depends on consumer load	1
27		In kVAh based tariff PF incentive to consumers a) Are remove b) Reduced to 50% c) Not change d) Are increase	2
28		Which statement is wrong in connection with kVAh based tariff a) If PF level is less than 0.90 then penalty shall be given. b) If PF level is greater than 0.95 PF incentives shall be given. c) Both kVAh Lag and Lead consumption is consider for incentives d) Both kVAh Lag and Lead consumption is not consider for incentives	2
29		In kVAh based tariff the kVAh is calculated by a) Square root of the summation of the square of kWh and RkVAh b) Total (kVAh)= = Total (kWh)/Average PF **c) ∑(□□□□*h*□□□+□□□□*h*□□□□)2** d) kWh /√∑(□□*h*)2+ ∑(□□□□*h*□□□+□□□□*h*□□□□)2	2
30		Resultant reactive energy is not equal to zero in kVAh based tariff calculation a) RkVAh Lag and Lead occurs at same time b) RkVAh Lag and Lead cannot occur simultaneously c) RkVAh Lag and Lead value have not same amplitude d) Because of the error in PF calculation	2
31		Net metering means a) the billing mechanism for solar & grid power combinedly b) the mechanism for billing the internet users c) the billing mechanism for solar & grid power separately. d) the mechanism for billing the industrial consumer	1

32		Gross metering means a) the billing mechanism for solar & grid power combinedly b) the mechanism for billing the internet users c) the billing mechanism for solar & grid power separately. d) the mechanism for billing the industrial consumer	1
33		As per MERC rules the solar power generated by the consumer shall not exceed (2M) a) 10% of the rated capacity of that distribution transformer b) 15% of the rated capacity of that distribution transformer **c)** 25% of the rated capacity of that distribution transformer d) 50% of the rated capacity of that distribution transformer	

Appendix B

Answer key of sample questions

Unit No.	Name of the Unit	Answer key to MCQs
1	Digitization beyond automation	1-a, 2-c, 3-b, 4-d, 5-c, 6-d, 7-b, 8-c, 9-a, 10-b, 11-a, 12-a, 13-b, 14-b, 15-a, 16-d, 17-d, 18-d, 19-d, 20-d, 21-d, 22-a, 23-a, 24-c, 25-b, 26-c, 27-b, 28-b, 29-c, 30-d, 31-a, 32-d, 33-d, 34-d, 35-b, 36-a, 37-b, 38-a.
2	Smart Grid	1-d ; 2- a ; 3-d ; 4-b ; 5-c ; 6-c ; 7-b ; 8-b ; 9-a ; 10-a ; 11-b ; 12-c ; 13 –b ; 14- b ; 15-b ; 16- b ; 17 –b ; 18-a ; 19-c ; 20-d ; 21-b
3	Smart City (Electrical Features)	1-d, 2-c, 3-a, 4-b, 5-c, 6-c, 7-a, 8-c, 9-d, 10-c, 11-b, 12-a, 13-d, 14-a, 15-a, 16-c, 17-b, 18-c, 19-d, 20-c, 21-b
4	Intelligent Motor Control Centers	1-d, 2-c, 3-d, 4-a, 5-d, 6-b, 7-c, 8-d, 9-c, 10-d, 11-a, 12-d, 13-d, 14-b, 15-c, 16-c, 17-d, 18-d, 19-d, 20-b, 21-d, 22-c, 23-c, 24-d, 25-d, 26-c, 27-d, 28-d, 29-d, 30-a, 31-d, 32-c, 33-a, 34-c, 35-c, 36-c, 37-a, 38-d, 39-d, 40-b, 41-c, 42-b, 43-c, 44-c, 45-d, 46-d, 47-a, 48-b, 49-c, 50-a.
5	Tariff, Metering and Billing	1-c, 2-d, 3-a, 4-b, 5-a, 6-c, 7-a, 8-d, 9-a, 10-a, 11-a, 12-d, 13-b, 14-a, 15-d, 16-c, 17-a, 18-d, 19-d, 20-a, 21-b, 22-c, 23-b, 24-c, 25-a, 26-c, 27-b, 28-d, 29-c, 30-b, 31-a, 32-c, 33-b.