Unit 1: The Smart Grid

(4 Hrs.)

- **Objectives:**

1. To make students understand concept of smart grid
2. To provide an understanding of why Smart Grids are critical to the Sustainability and growth of India's electricity network.

- **Outcomes: After completing this unit, student –**

1. Can able to understand concept of smart grid
2. Can able to understand working of main components involved in Smart Electric Grid.

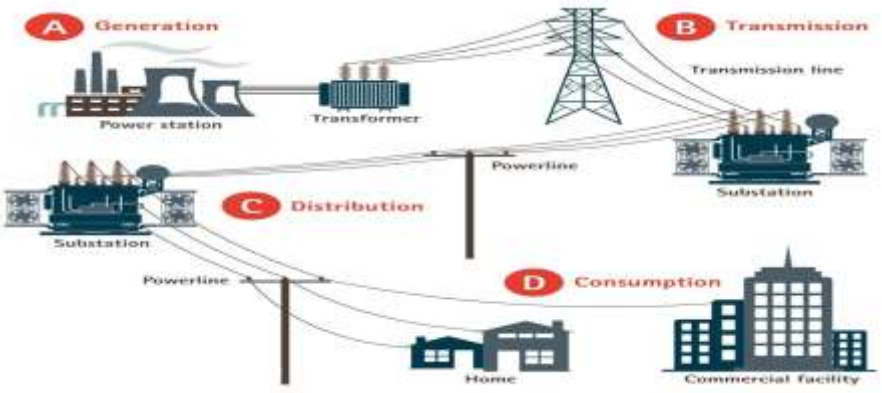
Unit Content:

Introduction, Why implement the Smart Grid now? , What is the Smart Grid? Overview of how Indian power market is organized operated and challenges being faced, Overview of the technologies required for the Smart Grid.

Introduction:

What is Electrical Grid?

"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."



The electrical grid is divided into three main components

1. **GENERATION –** There are two types of generation – centralized and decentralized. Centralized generation refers to large-scale generation far from consumption. This includes coal, nuclear, natural gas, hydro, wind farms and large solar arrays. The grid connects centralized power to consumers. Decentralized generation occurs close to consumption, for example rooftop solar.
2. **TRANSMISSION and DISTRIBUTION-** Transmission includes transformers, substations and power lines that transport electricity from where it is generated to points of consumption. When electricity is at high voltages, transmission losses are minimized over long distances and resistive transmission lines. Therefore, at the point of generation, substations contain transformers that step-up the voltage of electricity so that it can be transmitted. Transmission is achieved via power lines and can occur either overhead or underground. When it arrives at points of consumption, another substation is found to step-down the voltage for end-use consumption
3. **CONSUMPTION –** There are various types of consumers; namely industrial, commercial and residential consumers. Each of these consumers has different needs but in general electricity delivers important energy services like light and power for appliances.

It is 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.

A smart grid is a technology that divides the electricity grid into a two-way flow of data and electricity. The technology includes energy measures ad operations such as smart appliances, smart meters, energy-efficient resources, and more. The technology of the smart grid aims to support and integrate renewable energy into the conventional energy source. Not only does it use alternative energy sources, but the smart grid technology also allows consumers to monitor energy consumption.

Why implement the Smart Grid now?

Smart grids are needed for several reasons, including:

1. **Increased energy efficiency:** Smart grids use advanced technologies to optimize energy distribution and reduce energy losses, resulting in increased energy efficiency.
2. **Integration of renewable energy sources:** Smart grids can effectively integrate renewable energy sources such as solar and wind power into the grid, enabling efficient and reliable distribution of these intermittent sources of energy.
3. **Improved reliability and resiliency:** Smart grids enable the real-time monitoring and control of the energy grid, allowing for quick identification and resolution of any problems that may arise, reducing the likelihood of outages and improving the grid's overall reliability and resiliency.
4. **Cost savings:** Smart grids can help reduce the overall cost of energy by optimizing energy usage, reducing waste and improving energy distribution efficiency.
5. **Enhanced customer engagement:** Smart grids enable customers to actively monitor and control their energy usage, empowering them to make informed decisions about their energy consumption and reduce their energy costs.

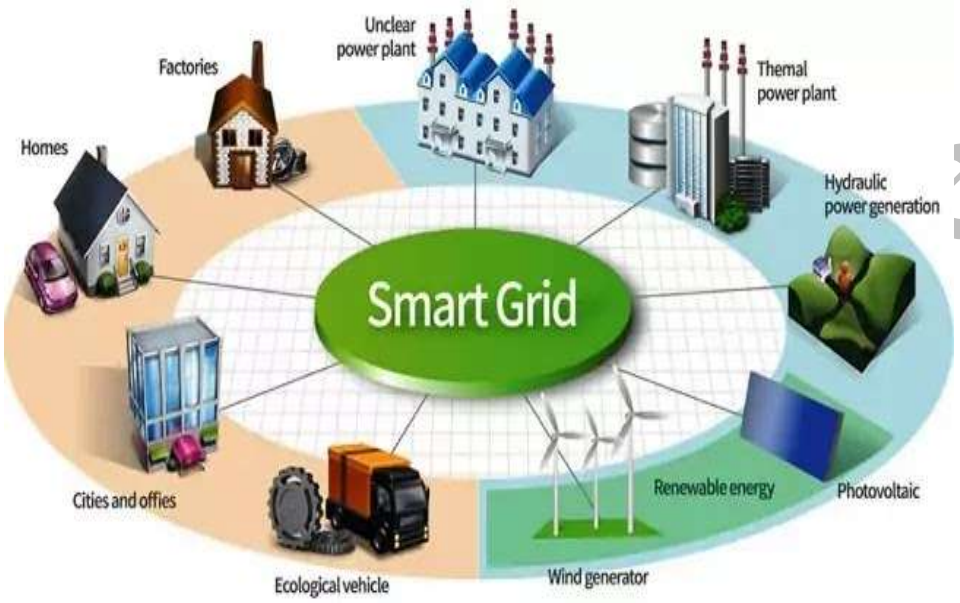
Overall, smart grids are essential for ensuring that our energy infrastructure is reliable, efficient, and capable of supporting the integration of renewable energy sources, thereby reducing our carbon footprint and moving towards a more sustainable energy future.

What is the Smart Grid?

A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users.

A smart grid is an electricity network enabling a two-way flow of electricity and data with digital communications technology enabling to detect, react and pro-act to changes in usage and

multiple issues. Smart grids have self-healing capabilities and enable electricity customers to become active participants.



What is the main aim of smart grid?

The concept of smart grid is to add monitoring, analysis, control and communication capabilities to the national electrical delivery system to maximize the throughput of the system while reducing the energy consumption.

A Smart Grid should include the following upgrades:

1. There should be fully automated and integrated two-way communication between all the components of the grid system.
2. Automatic controlling of power at each and every point of an electrical network.
3. Auto-detection and correction of faults.
4. There should be increased total system efficiency and security to ensure clean, safe and quality power.
5. Advance management panel and updated supporting software.
6. Accurate measurement and sensing technology

Advantages of Smart Grid

A smart grid performs lots of smart work. So Advantages of the smart grid are as mentioned below.

1. The smart grid provides better power management technologies through its integrated systems. This provides a better user interface.
2. It has also provided with a better protective management system in case of emergency.
3. It also provides a better supply and demand management.
4. It has reduced Carbon emission Technology.
5. Better Quality power.
6. Lower cost of operation, maintenance, and management for both utility and consumers.
7. It provides more efficient and improved security and protection.
8. It has also provided the convenience of reading meters remotely. Meter readers will not have to appear physically to check the meter readings. It will all be done through IT resources.

Disadvantages of Smart Grid

1. Privacy Problems
2. Grid Volatility

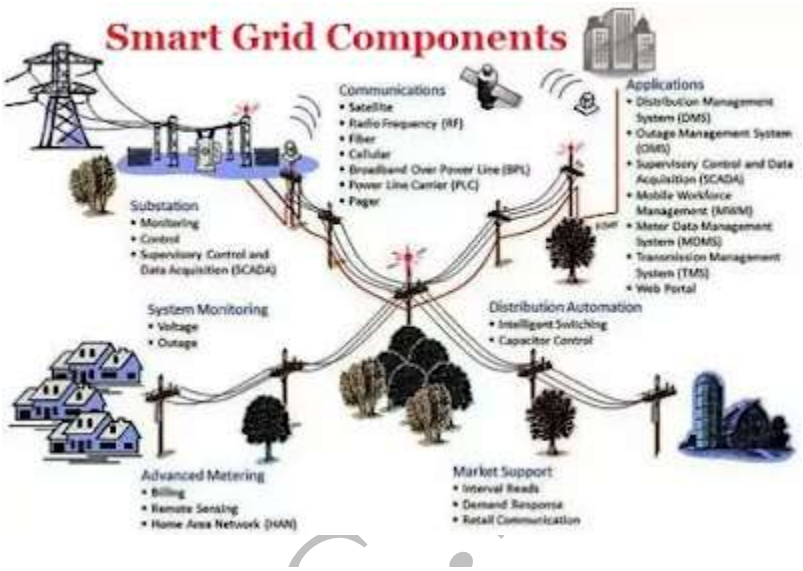
Applications of Smart Grid

These are the **Applications of the smart grid**.

1. Quick recovery after any disturbances in the transmission network.
2. Reduction of generation coast.
3. Reduction in peak demands.
4. They improve the adeptness of transmission networks.
5. They possess the ability to integrate other renewable energy sources through distributed generations and micro-grids.

Smart Grid Components

Smart Grid components are a group of intelligent appliances and heavy equipment that plays an important role in the generation, transmission, and the distribution of electrical energy. These appliances are smart enough to understand the working and how to utilize them.



A. Intelligent Appliances

Intelligent appliances become capable of deciding when to consume energy based on customer pre-set values.

This can reduce the electricity generation costs by reducing peak loads of plants. For example, a temperature sensor which is used in thermal stations to control the boiler temperature according to predefined temperature levels.

B. Smart Energy Meters

The smart energy meters provide two-way communication between power suppliers and consumers. It automates billing data collections, detects system failures and sends repairing team much faster to the fault location. As soon as the system has any faults and power failure then service provider notified immediately.

C. Smart Substations

Substations are installed for monitoring and controlling of critical and non-critical operational data such as power status, power factor performance, circuit breaker operation, security, transformer status, etc.

Smart substations are necessary for splitting the electricity flow directions according to the need. Smart substations require large and very expensive equipment to operate, which includes transformers, capacitor banks, circuit breakers, a network protected relays, current and voltage measuring devices, switches and several others.

D. Integrated communication system

An integrated communication system is the key to smart grid technology. It must be fast and accurate to meet the real-time needs of the system. Depending upon the need, many different technologies are used in smart grid communication like Programmable Logic controller (PLC), Supervisory Control and Data Acquisition System (SCADA) and Energy Management System (EMS).

E. Phasor Measurement Units (PMU)

Phasor measurement is a technology that can help to maintain stability in the power grid. PMU is a device that is used to measure the electrical waves on an electricity grid using a common time source for synchronization.

PMU is also referred to as Synchro-phasor. Synchro-phasors collect the data from various locations of the grid to get a coherent picture of the whole network by using GPS technology and transmit it for analysis to central locations.

Overview of how Indian power market is organized operated and challenges being faced

Evolution of Indian National Grid

In early Sixties:

- Grid management on regional basis started.
- State grids were inter-connected to form regional grid
- India was demarcated into 5 regions namely Northern, Eastern, Western, North Eastern and Southern region.

October 1991

- North Eastern and Eastern grids were connected.

March 2003

- WR and ER-NER were interconnected.

August 2006

- North and East grids were interconnected thereby 4 regional grids Northern, Eastern, Western and North Eastern grids are synchronously connected forming central grid operating at one frequency.

31st December 2013

- Southern Region was connected to Central Grid in Synchronous mode with the commissioning of 765kV Raichur- Solapur Transmission line thereby achieving 'ONE NATION'- 'ONE GRID'-'ONE FREQUENCY'.

Regulatory authorities in Indian Power Sector

1. **Ministry of Power:** Deals with planning, policy formulation, processing and implementation of projects, enactment of legislation in regards to power generation, transmission and distribution.
2. **PGCIL:** Responsible for national and regional power transmission planning.
3. **CEA:** Advises on matters related to National Electricity policy and formulation of short term and perspective plans for development of power system.
4. **CERC & SERC:** Regulates tariff, formulates policies regarding subsidies and promotion of efficient and environmental policies at central and state level respectively.
5. **CTU & STU:** Development of efficient, coordinated and & STU economical system of interstate and intrastate transmission lines.

Challenges of Power Sector in India

1. **Insufficient Electricity Generation-** in India, the installed capacity to produce electricity is not enough to support an annual economic growth of 7 to 8 percent. Currently, India only adds 20,000 MW a year to generate power.
2. **Poor Management**-The State Electricity Boards (SEBs) incurred losses of more than Rs.500 million because of improper transmission of electricity, wrong pricing, and other incompetence. Few scholars have come to the conclusion that the main reason for the losses is the circulation of power to farmers (they have to only pay minimum

chargers or is free), electricity is stolen, that result in losses under the account of SEBs.

3. **Lack of Investments-** When it comes to power and energy, the private sector do not play any part or there are any foreign investors. The public sector is almost having a monopoly in the power generation sector.
4. **Poor Infrastructure-** Too many power cuts in various parts of the country and huge power tariff.
5. **Shortage of Raw Material -** In India, the thermal power plant the main source of generating power is facing a high deficit of coal and raw materials supplies.

Problems faced by the power sector in India	
(1)Insufficient Electricity Generation	• India's installed capacity to generate electricity is not sufficient to fulfill the needs of annual economic growth of 7 percent.
(2)Underutilization Of Capacity	• Capacity utilization of a plant is denoted by Plant Load Factor. • In 2001-02, PLF in India was 60%, this means 40% of electricity goes waste. • PLF has improved to 75% in 2012-13 and 65% in 2014-15.
(3)Poor Performance Of State Electricity Boards(Seb's)	• SEBs which distributes electricity incurred losses, they are not able to pay a bill of the electricity purchased by them. • In 2007-08, these boards suffer a loss of Rs. 21391 Crore, which has reduced to Rs.624.6 Crore in 2014. • This was due to 1. Transmission and distribution losses,2. Theft of electricity.3. Wrong pricing of electricity4. Other

	operational inefficiencies.
(4) Limited Role Of Private And Foreign Entrepreneurs	• The public sector is almost having a monopoly in the power generation sector. • Due to the lack of management facilities, the public sector is not able to cope up with challenges of power generation. • Private and foreign entrepreneurs have not got a chance to prove their capabilities.

What technologies are used in the smart grid?

Smart grid technology combines the electric network with the advanced digital communication network. Thus, it can provide a better power distribution that is easy to control. Some of the basic technologies of the smart grid include:

1. Intelligent appliances
2. Smart meters
3. Smart substations
4. Superconducting cables
5. Integrated communications

1. **Intelligent Appliances:** Intelligent appliances have capable of deciding when to consume energy based on customer pre-set preferences. This can lead to going away along toward reducing peak loads which have an impact on electricity generation costs. For example, smart sensors, like temperature sensor which is used in thermal stations to control the boiler temperature based on predefined temperature levels.
2. **Smart Power Meters:** The smart meters provide two-way communication between power providers and the end user consumers to automate billing data collections, detect device failures and dispatch repair crews to the exact location much faster.

Smart Grid Components

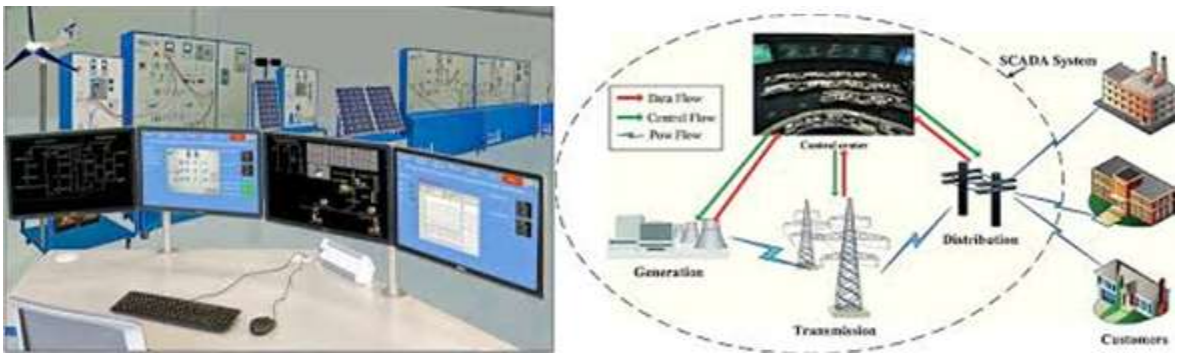
3. **Smart Substations:** substations are included monitoring and control non-critical and critical operational data such as power status, power factor performance, breaker, security, transformer status, etc. substations are used to transform voltage at several times in many locations, that providing safe and reliable delivery of energy. Smart substations are also necessary for splitting the path of electricity flow into many directions. Substations require large and very expensive equipment to operate, including transformers, switches, capacitor banks, circuit breakers, a network protected relays and several others.

Smart Substations

4. **Super Conducting Cables:** These are used to provide long distance power transmission, and automated monitoring and analysis tools capable of detecting faults itself or even predicting cable and failures based on real-time data weather, and the outage history.

Super Conducting Cables

5. **Integrated communications:** The key to a smart grid technology is integrated communications. It must be as fast as enough to real-time needs of the system. Depending upon the need, Many different technologies are used in smart grid communication like Programmable Logic Controller (PLC), wireless, cellular, SCADA (Supervisory Control and Data Acquisition), and BPL. Key Considerations for Integrated Communication.



SCADA

Key Considerations for Integrated Communication

- Ease of deployment
- Latency
- Standards
- Data carrying capacity
- Secure
- Network coverage capability

Technology Comparison and Risk Profile								
Technology	Deployability	Cost – Capital	Cost - Ops	Latency	Speed	Regulatory	Standards	Coverage
Wireless								
Cellular	H	L	H	H	<100Kbps	L	L	L
900MHz	M	L	L	M	<1Mbps	L	L	M
WiFi/WiMAX	L	M	L	M	2-30+Mbps	L	M	M
Licensed	M	H	M	M	2-30+Mbps	M	L	M
Microwave	M	H	L	L	10-500Mbps	L	L	H
Wired								
PLC	L	L	L	M	<100Kbps	L	M	M
DSL	M	L	M	M	<3Mbps	L	L	M
BPL	M	M	L	M	2-30+Mbps	M	H	M
Fixed line	M	L	H	L	2-30+Mbps	L	L	H
Fiber	H	H	M	L	>Gbps	L	L	H

Key Considerations for Integrated Communication

6. **Phasor Measurement Units (PMU):** This is used to measure the electrical waves on an electricity grid using a common time source for synchronization. The time synchronizer allows synchronized real-time measurements of multiple remote measurement points on the grid.

Comparison between Conventional and Smart Grid

Conventional Power Grid	Smart Grid
Electromechanical	Digital
One-way communication	Two-way communication
Centralized generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices

Smart Grid Functions:

1) Real time monitoring of grid conditions.
2) Solve automatically grid disturbances.
3) Automated responses to grid failure that will isolate disturbed zones and prevent cascading blackouts.
4) "Plug and play" ability to connect new generating plants to the grid.
5) Automatic restoration of power by a combination of sensors, computer analysis and advanced substation components.
6) Enhancing ability to manage large amounts of solar and wind power.

Describe the opportunities and challenges relate to smart grid.

Smart Grid Issues and Challenges:

1. **Cost:** Initial Cost is high.
2. **Communication and IT:** 1.Inoperability 2. Limited OEMs
3. **Manufacturers:** 1.Modular Design 2.Integration of monitoring Device in the equipment 3.Limited indigenous Manufacturers.
4. **Other:** 1. Cyber Security, 2. Governing Standards, 3.Capacity Building in Skilled Manpower 4.Lack in R&D.

Smart Grid Opportunity:

Opportunities in the future Indian power system is facing high AT&C Losses, poor distribution network, wide demand – supply gap of energy, poor asset management etc. Smart grid technology will bring solutions to all of the mentioned problems and sustainability by way of demand side management, demand response, outage management, reduction in AT&C losses and improved customer satisfaction. Large investment is expected for Smart Grid Applications in distribution in 12th and 13th Plan, which will provide huge business prospects in coming years.

ASSIGNMENT NO:01
THE SMART GRID

1. What is smart grid system?
2. Define Smart Grid and give its functions.
3. Why implement the Smart Grid now?
4. Define smart grid concept and explain its necessity.
5. Define smart grid. Differentiate between conventional grid and smart grid.
6. Explain the stages on evaluation of smart grid.
7. What is the need of Smart Grid? What will be the components of Smart Grid?
8. What is the Smart Grid? Overview of How Indian power market is organized, operated and challenges being faced.
9. Explain how the automatic meter reading can make the system smarter.
10. Explain the concept of robust and self-healing grid.
11. Explain functions of smart grid components.
12. What are the initiatives taken by Indian economy for smart grid?
13. Describe the opportunities and challenges relate to smart grid.
14. What are the major points which are the forced drivers for demanding smart grid
15. What are the different opportunities and Barriers of Smart Grid in India
16. Give present development and international policies in smart grid.