Power grid failure

Presentation by:

Sourabh Kothari

Department of Electrical Engineering, CDSE

Introduction

- A power grid is an interconnected network of transmission lines for supplying electricity from power suppliers to consumers. Any disruptions in the network causes power outages. India has five regional grids that carry electricity from power plants to respective states in the country.

- Electric power is normally generated at 11-25kV and then stepped-up to 400kV, 220kV or 132kV for high voltage lines through long distances and deliver the power into a **common power pool called the grid**.
- The grid is connected to load centers (cities) through a sub-transmission network of normally 33kV lines which terminate into a 33kV (or 66kV) substation, where the voltage is stepped-down to 11kV for power distribution through a distribution network at 11kV and lower.
- The 3 distinct operation of a power grid are:-

1. Power generation
2. Power transmission
3. Power distribution.

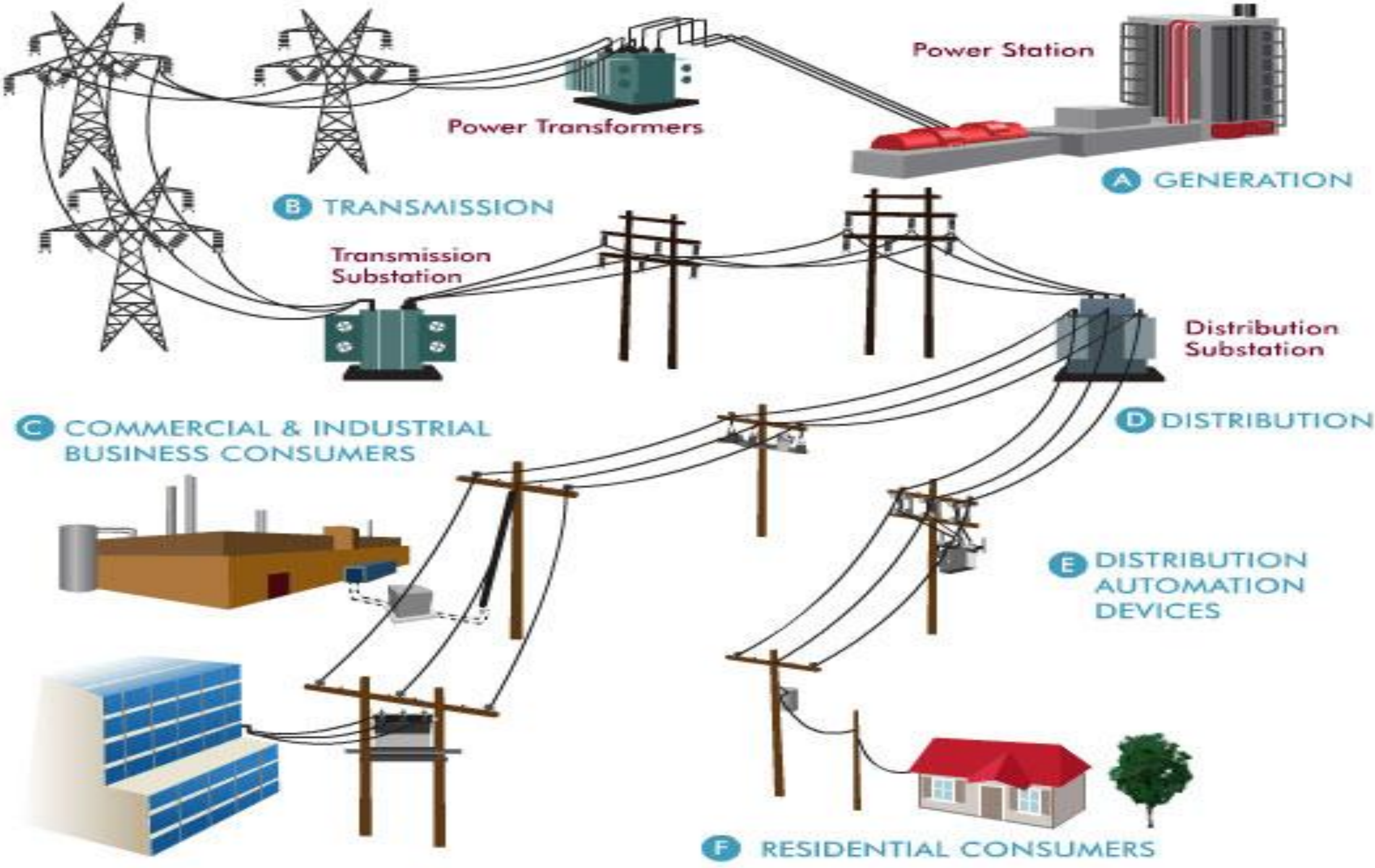
Operations of Power grids

- **Electricity generation** - Generating plants are located near a source of water, and away from heavily populated areas , are large and electric power generated is stepped up to a higher voltage-at which it connects to the transmission network.

- **Electric power transmission** - The transmission network will move the power long distances–often across state lines, and sometimes across international boundaries, until it reaches its wholesale customer.

- **Electricity distribution** - Upon arrival at the substation, the power will be stepped down in voltage—to a distribution level voltage. As it exits the substation, it enters the distribution wiring. Finally, upon arrival at the service location, the power is stepped down again from the distribution voltage to the required service voltage.

Power grid


Power Station
Power Transformers
A GENERATION
B TRANSMISSION
Transmission Substation
Distribution Substation
C COMMERCIAL & INDUSTRIAL BUSINESS CONSUMERS
D DISTRIBUTION
E DISTRIBUTION AUTOMATION DEVICES
F RESIDENTIAL CONSUMERS

Structure of Grids

- The structure or "topology" of a grid depends upon the geology of the land available. The other constraints are of budget, requirements for system reliability, the load and generation characteristics.

- The cheapest and simplest topology for a distribution or transmission grid is **a radial structure** i.e. **a tree shape** where power from a large supply radiates out into progressively LV lines until destination is reached.

- The power network, is the distribution network of 11kV lines or feeders (that carry power close to the load points) downstream of the 33kV substation.

- At these load points, a transformer further reduces the voltage from 11kV to 415V (LT feeders) to individual customers, either at 220V (as 1-phase) or at 415V (as 3-phase).

- A feeder could be either an overhead line or an underground cable. In urban areas, owing to the density of customers, the length of an 11kV feeder is up to 3 km, while in rural areas it is up to 20 km.

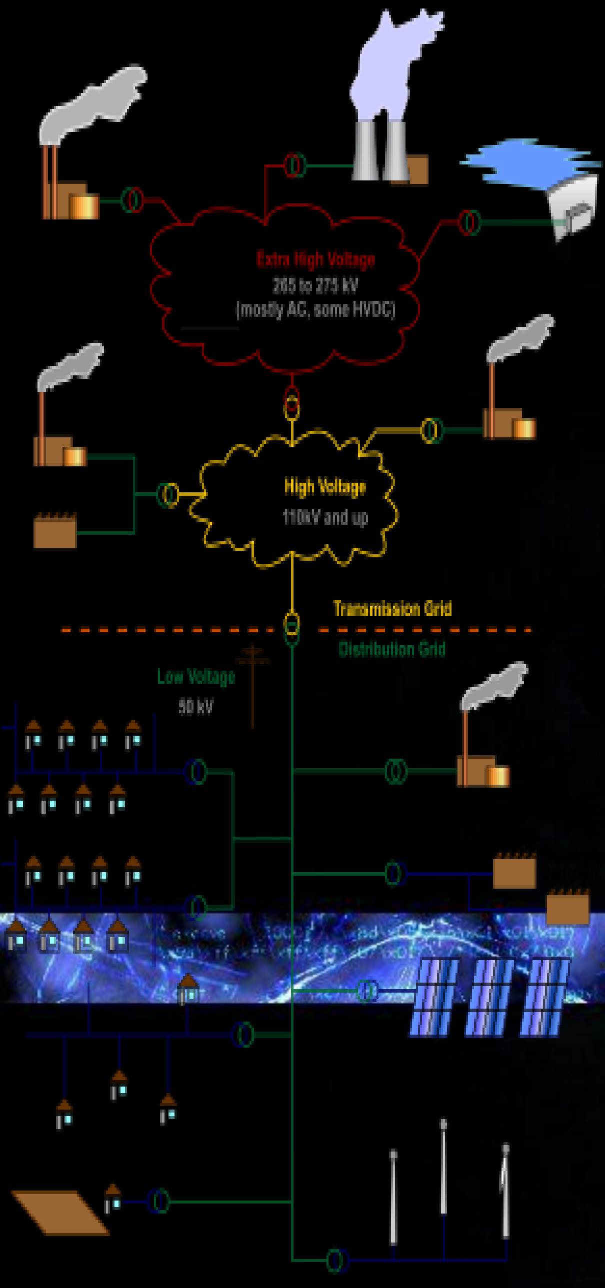
- Most transmission grids require the reliability of mesh networks however the expense of mesh topologies restricts their application to transmission and medium voltage distribution grids.

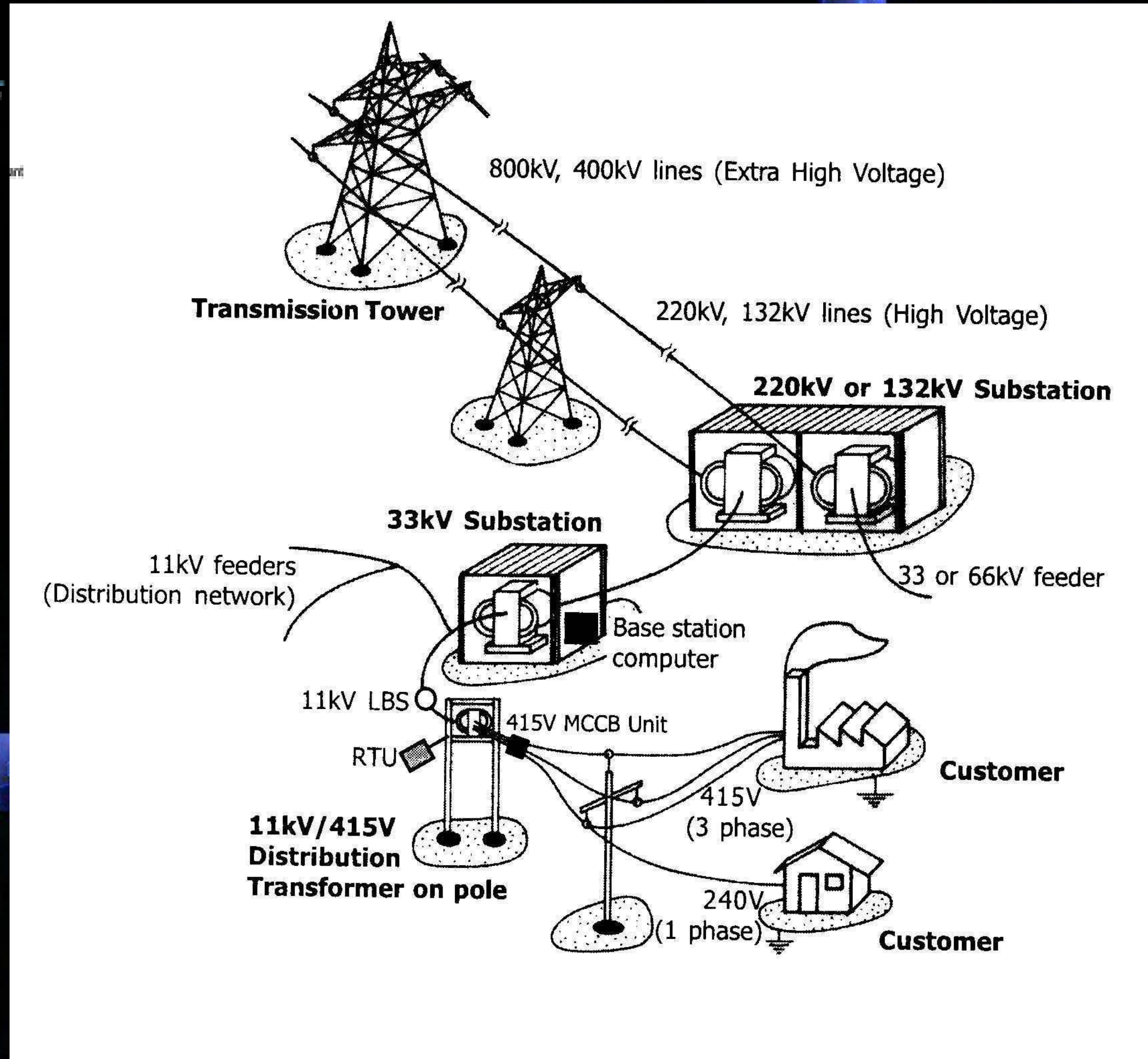
- Redundancy allows line failures to occur and power is simply rerouted while workmen repair the damaged and deactivated line.
- Types of transmission lines:-

Underground transmission lines

Overhead transmission lines

Power grid structure





Need for power grids in India

- Electric-power transmission is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers and it is different from the local wiring between hv substations and customers (which is typically referred to as electric power distribution).

- A key limitation in the distribution of electric power is that, electrical energy cannot be stored, and therefore must be generated as per the requirement. Hence a sophisticated control system is required to ensure that the electric generation matches the demand.

- If the demand for power exceeds the supply, generation plants and transmission equipment can shut down which, in the worst cases, can lead to a major regional blackout, such as occurred in the July 2012 in India.

Power grid regions in India

- There are five power grid regions in India. they are-
- Northern
- Western
- Southern
- Eastern
- North-Eastern.
- Out of all these Regions the NR, ER, WR, and NER are synchronized which is known as NEW Grid.
- Whereas SR is not synchronized with the rest of the regions with AC lines and hence could run on a slightly different frequency. SR is connected with WR and ER with HVDC links only.

What is power grid failure

- In India electricity is transmitted at a frequency of 49-50 Hz. When the frequency reaches its minimum or maximum level, there is a risk of failure of transmission lines.

- Thus, the breakdown of transmission lines due to over or under frequency is called Power Grid Failure.

- The role of Load Dispatch Centre's is to maintain the frequency between minimum 48.5 to maximum of 50.2 Hz. The National Load Dispatch Centre is also responsible for maintaining the Overdraw done by states.

- When the states overdraw power crossing their limits, the same also becomes the cause of grid failure, due to excessive load on the transmission lines.

History of major power grid failures throughout the world

Article	Millions of people affected	Location	Date
July 2012 India blackout	670	India	30–31 July 2012
2005 Java-Bali blackout	100	Indonesia	18 Aug. 2005
1999 Southern Brazil blackout	97	Brazil	11 March 1999
2009 Brazil and Paraguay blackout	87	Brazil, Paraguay	10–11 Nov. 2009
Northeast blackout of 2003	55	the United States, Canada	14–15 Aug. 2003
2003 Italy blackout	55	Italy, Switzerland, Austria, Slovenia, Croatia	28 Sep. 2003
Northeast blackout of 1965	30	the United States, Canada	9 Nov. 1965

2012 blackout in India:-whole episode

- Introduction-

The **July 2012 India blackout** was the largest power outage in history, occurring as two separate events on 30 and 31 July 2012. The outage affected over 620 million people, about 9% of the world population, or half of India's population, spread across 22 states in Northern, Eastern, and Northeast India. An estimated 32 giga watts of generating capacity was taken offline in the outage.

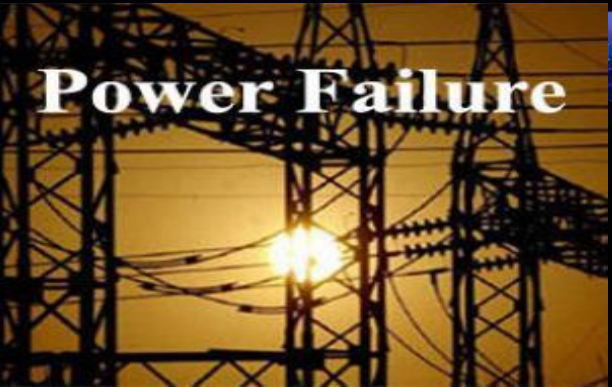
- History of electrical infrastructure in India-
- The Indian electrical infrastructure was generally considered unreliable. The Northern grid had previously collapsed in 2001.
- 27% of power generated was lost in transmission or stolen, while peak supply fell short of demand by an average of 9%.Hence the nation suffered from frequent power outages that could last as long as 10 hours.
- About 25% of the population, about 300 million people, had no electricity at all.

- The power generating stations are hooked onto an interconnected network of transmission lines and substations. These generating stations supply electricity through these transmission lines.

- The **companies responsible for distribution take the power coming through these lines and forward it to** the consumers. This is how electricity reaches millions of homes.

- The stability of the grids depends on a delicate equilibrium of demand-supply chain. The amount of load is directly proportional to the amount of power generated.

- When the equilibrium between power generated and consumed gets disturbed and the load becomes more, it leads to tripping of the line.



Reasons for power grid failure

- In the summer of 2012, leading up to the failure, extreme heat had caused power use to reach record levels in New Delhi leading to coal shortages in the country.(as fossil fuels stocks are rationed by government and are imported offshore.)

- Due to the late arrival of monsoons, agricultural areas in Punjab and Haryana drew increased power from the grid (Farmers using energy-intensive water pumps for irrigation)

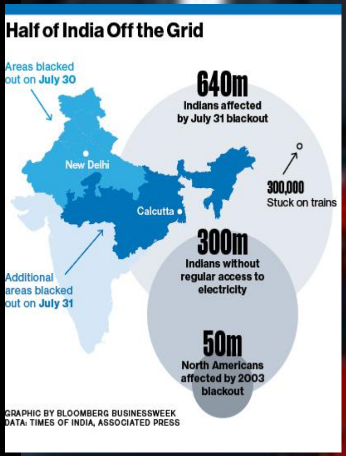
- The late monsoon also meant that hydropower plants were generating less than their usual production and hence the load on thermal power plants increases to support the demand of load.

- Illegal utilization of electricity is also a major reason for power grid failure.

- India's basic energy shortage is compounded by the policy of selling electricity to consumers at politically correct prices i.e. sometimes cheap and even free to voters. Here the government-owned distribution monopolies have failed. This loss estimates up to 1% of gross domestic product in the country.

- *Areas of power grid failure 2012*

Effect of blackout on economy



States affected by the grid failure

- States on the Northern grid: Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Rajasthan, Uttar Pradesh, Uttarakhand
- States on the Eastern grid: Bihar, Jharkhand, Orissa, West Bengal
- States on the Northeast grid: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim.

- Lack of information at the base station (33kV sub-station) on the loading and health status of the 11kV/415V transformer and associated feeders is one primary cause of inefficient power distribution. Due to absence of monitoring, overloading occurs, which results in low voltage at the customer end and increases the risk of frequent breakdowns of transformers and feeders.

- In fact, the transformer breakdown rate in India is as high as around 20%, in contrast to less than 2% in some advanced countries

Current scenario

- In the absence of switches at different points in the distribution network, it is not possible to isolate certain loads for load shedding as and when required. The only option available in the present distribution network is the *circuit breaker* (one each for every main 11kV feeder) at the 33kV substation.

- However, these circuit breakers are actually provided as a means of protection to completely isolate the downstream network in the event of a fault. Using this as a *tool for load management is not desirable*, as it disconnects the power supply to a very large segment of consumers.

- In the event of a *fault* on any feeder section downstream, the circuit breaker at the 33kV substation trips (opens). As a result, there is a blackout over a large section of the distribution network. If the faulty feeder segment could be precisely identified, it would be possible to substantially reduce the blackout area, by re-routing the power to the healthy feeder segments through the operation of switches.

Preventive measures

- *Prior disaster-proofing-*

- Before the grid collapse, the private sector spent $29 billion to build their own independent power stations in order to provide reliable power to their factories. The 5 biggest consumers of electricity in India have private off-grid supplies. Indian companies have 35 GW of private off-grid generation capacity and plan to add another 33 GW to their off-grid capacity.

- Some villages that were not connected to the grid were not affected, such as Meerwada, Madhya Pradesh which has a 14 kW solar power station built by US-based firm for $125,000.

- *Aging power equipment -*

- older equipment have higher failure rates, leading to customer interruption rates affecting the economy and society; also, older assets and facilities lead to higher inspection maintenance costs and further repair/restoration costs. Hence they need to be changed.

- *Obsolete system layout* – older areas require serious additional substation sites and rights-of-way, that cannot be obtained in current area and are forced to use existing, insufficient facilities. So amendments need to be made in this area.

- *Outdated engineering* – traditional tools for power delivery planning and engineering are ineffective in addressing current problems of aged equipment, obsolete system layouts, and modern deregulated loading levels. So it needs to be reformed.

Solutions

- An integrated network of **micro grids** and **distributed generation** connected via a superior smart grid technology which includes automated fault detection, islanding and self-healing of the network was proposed as one of the solutions to prevent another widespread outage i.e.

1. Decentralization of the power transmission distribution system is vital to the success and reliability of this system. Currently the system is reliant upon relatively few generation stations hence they are susceptible to impact from failures.

2. Micro grids would have local power generation, and allow smaller grid areas to be separated from the rest of the grid if a failure were to occur. Furthermore, micro grid systems could help power each other if needed.

3. Generation within a micro grid could be a downsized industrial generator or several smaller systems such as photo-voltaic systems, or wind generation. When combined with Smart Grid technology, electricity could be better controlled and distributed, and more efficient.

4. A ***smart grid*** is an 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 and distribution of electricity.

➢ *Features of smart grid-*

- The smart grid will make use of technologies that improve **fault detection** and allow **self-healing** of the network ensuring more reliable supply of electricity, and reduced vulnerability to natural disasters or attack.

- Next-generation transmission and distribution infrastructure will be better able to handle possible **bidirectional energy flows**, allowing

for **distributed generation** such as from photovoltaic panels on building roofs, but also the use of fuel cells. a smart grid aims to manage these situations.

➢ *Other features of smart grid are-*

- **Higher efficiency and Load adjustment**
- **Sustainability**
- **Market-enabling**
- **Demand response support**
- **Integrated communications**
- **Sensing and measurement**
- **Smart meters**
- **Phasor measurement units**
- **Advanced components**
- **Smart power generation**
- **Improved interfaces and decision support.**

- A *National Grid* would also serve as solution in preventing any power outage in future.

Thank you !