BEYOND
SMART CITIES
ELECTRICAL POWER SYSTEMS - CEM
REFRESHER TRAINING
KRISHNAJI PAWAR, LEED AP BD+C,GSAS CGP,ISO 14001:2015,GCP
FOR ENERGY MANAGEMENT AND EFFICIENCY PROFESSIONALS

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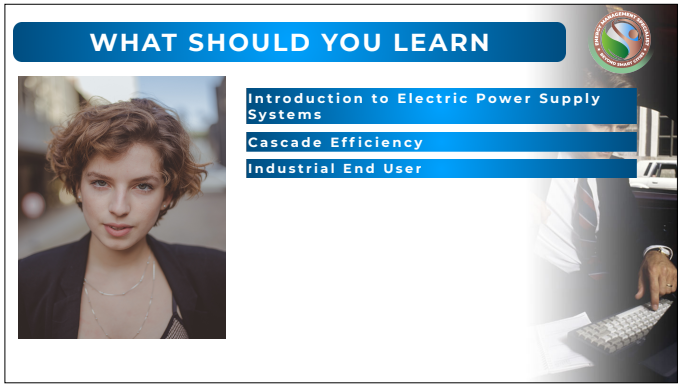
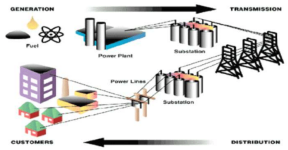
ELECTRIC POWER SUPPLY SYSTEMS -1
FOR ENERGY PROFESSIONALS
KRISHNAJI PAWAR, LEED AP BD+C,GSAS CGP,ISO 14001:2015,GCP
ENERGY SPECIALIST CURRICULUM


WHAT SHOULD YOU LEARN
Introduction to Electric Power Supply Systems
Cascade Efficiency
Industrial End User

INTRODUCTION

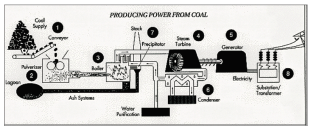
Electric power supply system in a country comprises of generating units that produce electricity; high voltage transmission lines that transport electricity over long distances; distribution lines that deliver the electricity to consumers; substations that connect the pieces to each other; and energy control centers to coordinate the operation of the components.



The Figure 1.1 shows a simple electric supply system with transmission and distribution network and linkages from electricity sources to end-user.

POWER GENERATION PLANT

The fossil fuels such as coal, oil and natural gas, nuclear energy, and falling water (hydel) are commonly used energy sources in the power generating plant. A wide and growing variety of unconventional generation technologies and fuels have also been developed, including cogeneration, solar energy, wind generators, and waste materials.



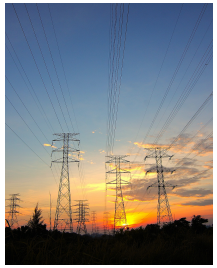
About 70 % of power generating capacity in India is from coal based thermal power plants. The principle of coal-fired power generation plant is shown in Figure 1.2. Energy stored in the coal is converted in to electricity in thermal power plant. Coal is pulverised to the consistency of talcum powder. Then powdered coal is blown into the water wall boiler where it is burned at temperature higher than 1300°C. The heat in the combustion gas is transferred into steam. This high-pressure steam is used to run the steam turbine to spin. Finally turbine rotates the genera- tor to produce electricity.

POWER GENERATION PLANT

In India, for the coal based power plants, the overall efficiency ranges from 28% to 35% depending upon the size, operational practices and capacity utilization. Where fuels are the source of generation, a common term used is the "HEAT RATE" which reflects the efficiency of generation.

"HEAT RATE" is the heat input in kilo Calories or kilo Joules, for generating 'one' kilo Watt-hour of electrical output. One kilo Watt hour of electrical energy being equivalent to 860 kilo Calories of thermal energy or 3600 kilo Joules of thermal energy. The "HEAT RATE" expresses in inverse the efficiency of power generation.

TRANSMISSION AND DISTRIBUTION LINES



The power plants typically produce 50 cycle/second (Hertz), alternating-current (AC) electricity with volt- ages between 11kV and 33kV. At the power plant site, the 3-phase voltage is stepped up to a higher voltage for transmission on cables strung on cross-country towers.

High voltage (HV) and extra high voltage (EHV) transmission is the next stage from power plant to transport A.C. power over long distances at voltages like; 220 kV & 400 kV. Where transmission is over 1000 kM, high voltage direct current transmission is also favoured to minimize the losses.

TRANSMISSION AND DISTRIBUTION LINES

Sub-transmission network at 132 kV, 110 kV, 66 kV or 33 kV constitutes the next link towards the end user. Distribution at 11 kV / 6.6 kV / 3.3 kV constitutes the last link to the consumer, who is connected directly or through transformers depending upon the drawl level of service.

The transmission and distribution network include sub-stations, lines and distribution transformers. High voltage transmission is used so that smaller, more economical wire sizes can be employed to carry the lower current and to reduce losses. Sub-stations, containing step-down transformers, reduce the voltage for distribution to industrial users. The voltage is further reduced for commercial facilities. Electricity must be generated, as and when it is needed since electricity cannot be stored virtually in the system.

TRANSMISSION AND DISTRIBUTION LINES +

There is no difference between a transmission line and a distribution line except for the volt- age level and power handling capability. Transmission lines are usually capable of transmitting large quantities of electric energy over great distances. They operate at high voltages. Distribution lines carry limited quantities of power over shorter distances.

Voltage drops in line are in relation to the resistance and reactance of line, length and the current drawn. For the same quantity of power handled, lower the voltage, higher the current drawn and higher the voltage drop. The current drawn is inversely proportional to the voltage level for the same quantity of power handled.

The power loss in line is proportional to resistance and square of current. (i.e. PLOSS=I2R). Higher voltage transmission and distribution thus would help to minimize line voltage drop in the ratio of voltages, and the line power loss in the ratio of square of voltages. For instance, if distribution of power is raised from 11 kV to 33 kV, the voltage drop would be lower by a factor 1/3 and the line loss would be lower by a factor (1/3)2 i.e., 1/9. Lower voltage transmission and distribution also calls for bigger size conductor on account of current handling capacity needed.

CASCADE EFFICIENCY

The primary function of transmission and distribution equipment is to transfer power economically and reliably from one location to another.

Conductors in the form of wires and cables strung on towers and poles carry the high-volt- age, AC electric current. A large number of copper or aluminium conductors are used to form the transmission path. The resistance of the long-distance transmission conductors is to be minimised. Energy loss in transmission lines is wasted in the form of I2R losses.

Capacitors are used to correct power factor by causing the current to lead the voltage. When the AC currents are kept in phase with the voltage, operating efficiency of the system is maintained at a high level.

Circuit-interrupting devices are switches, relays, circuit breakers, and fuses. Each of these devices is designed to carry and interrupt certain levels of current. Making and breaking the cur- rent carrying conductors in the transmission path with a minimum of arcing is one of the most important characteristics of this device. Relays sense abnormal voltages, currents, and frequency and operate to protect the system.

CASCADE EFFICIENCY

Generation Efficiency η_1	Efficiency ranges 28 – 35 % with respect to size of thermal plant, age of plant and capacity utilisation
▼ Step-up Station η_2	Step-up to 400 / 800 kV to enable EHV transmission Envisaged max. losses 0.5 % or efficiency of 99.5 %
▼ EHV Transmission & Station η_3	EHV transmission and substations at 400 kV / 800 kV. Envisaged maximum losses 1.0 % or efficiency of 99 %
▼ HV Transmission & Station η_4	HV transmission & Substations for 220 / 400 kV. Envisaged maximum losses 2.5 % or efficiency of 97.5 %
▼ Sub-transmission η_5	Sub-transmission at 66 / 132 kV Envisaged maximum losses 4 % or efficiency of 96 %
▼ Distribution Station η_6	Step-down to a level of 11 / 33 kV. Envisaged losses 0.5 % or efficiency of 99.5 %
▼ Primary Distribution η_7	Distribution is final link to end user at 11 / 33 kV. Envisaged losses maximum 5 % of efficiency of 95 %
▼ End user Premises	**Cascade efficiency from Generation to end user = $\eta_1 \times \eta_2 \times \eta_3 \times \eta_4 \times \eta_5 \times \eta_6 \times \eta_7$**

Transformers are placed at strategic locations throughout the system to minimize power losses in the T&D system. They are used to change the voltage level from low-to-high in step- up transformers and from high-to-low in step-down units.

The power source to end user energy efficiency link is a key factor, which influences the energy input at the source of supply. If we consider the electricity flow from generation to the user in terms of cascade energy efficiency, typical cascade efficiency profile from generation to 11 – 33 kV user industry will be as below:

The cascade efficiency in the T&D system from output of the power plant to the end use is 87% (i.e. 0.995 x 0.99 x 0.975 x 0.96 x 0.995 x 0.95 = 87%)

INDUSTRIAL END USER

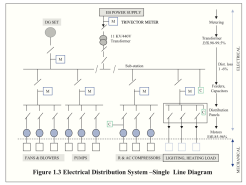


Figure 1.3 Electrical Distribution System –Single Line Diagram

At the industrial end user premises, again the plant network elements like transformers at receiving sub-station, switchgear, lines and cables, load-break switches, capacitors cause loss- es, which affect the input-received energy. However the losses in such systems are merger and unavoidable.

A typical plant single line diagram of electrical distribution system is shown in Figure 1.3

After power generation at the plant it is transmitted and distributed over a wide network. The standard technical losses are around 17 % in India (Efficiency = 83%). But the figures for many of the states show T & D losses ranging from 17 – 50 %. All these may not constitute technical losses, since un-metered and pilferage are also accounted in this loss.

INDUSTRIAL END USER

When the power reaches the industry, it meets the transformer. The energy efficiency of the transformer is generally very high. Next, it goes to the motor through internal plant distribution network. A typical distribution network efficiency including transformer is 95% and motor efficiency is about 90%. Another 30 % (Efficiency =70%)is lost in the mechanical system which includes coupling/ drive train, a driven equipment such as pump and flow control valves/throttling etc. Thus the overall energy efficiency becomes 50%. (0.83 x 0.95x 0.9 x 0.70 = 0.50, i.e. 50% efficiency)

Hence one unit saved in the end user is equivalent to two units generated in the power plant. (1Unit / 0.5 Eff = 2 Units)