interconnecting transformer, HVDC back-to-back pole) or grid disturbances involving tripping of a large number of grid elements simultaneously or even a total blackout.

- **Economy**

  Economy comes by merit order generation, optimisation of hydro resources, minimisation of losses and judicious inter-regional exchanges. It envisages getting the cheapest power to the customers through minimization of transmission losses and ensuring that the cheapest generation is used first, then the next costly generation and so on.

- **Quality in Electric Supply**

  Quality in electric supply is facilitated by the inertia of a large grid, which smoothes over variations in frequency and power due to sudden changes in load.

Check Your Progress 8

How does a Grid improve reliability?

2.9 QUALITY OF ELECTRIC SUPPLY

QUALITY in electric supply is now gaining importance.

The parameters of quality are *frequency*, *voltage* and *harmonics*.

Quality parameters of Electric Supply.

Frequency is a global phenomenon, i.e. it is the same at all points of a grid, which is operating in synchronous operation. Frequency is an indication of the balance between generation and load in a grid. If the generation exactly matches the load, the frequency would be the nominal frequency, i.e. 50 Hz. If generation is more than the load in a grid as a whole, the system frequency would be greater than 50 Hz. If generation is less than the load, the system frequency would be less than 50 Hz.

Voltage is a local phenomenon, i.e. it can be different at different points of the grid. Therefore, the grid operator has to ensure that the proper voltage profile is maintained at all points of the grid. For ensuring proper voltage profile, capacitors or reactors are installed at different points in the grid. If

it is observed that the voltage is low at a particular point in the grid, then capacitors are installed at that point. Similarly, if voltage is observed to be high, as per the studies, then reactors are installed at that point. The basic purpose of these elements is to ensure that the reactive power requirement of the load or transmission lines is met.

Besides this, there are also other voltage phenomena like unbalanced voltage in the three phases, voltage dip, etc. Voltage unbalance in the grid could be caused due to the tripping of one of the phases of a transmission line or due to unbalanced load in the three phases emanating from the distribution systems or bulk loads. Voltage dip, on the other hand, is a transient phenomenon caused by a transient fault or tripping of an element at a remote location of the grid. Stormy weather could also cause flashover between arcing horns, resulting in voltage dip.

Harmonics is recently becoming an issue in the modern world, due to a number of electronic devices connected in the grid as well as in the distribution system, which converts AC to DC through rectifiers or which chop an AC wave for voltage or current control. In the grid, harmonics are caused by HVDC stations, which convert AC to DC and back from DC to AC.

In the distribution system, harmonics are caused by power supplies and inverters which are installed to supply emergency power to computers and all household appliances using digital technology, which have permeated our lives. For this, standards have been laid down in the Regulations for Technical Standards for Connectivity to the Grid. As per the provisions of these Standards, the limits for individual and total harmonics distortion have been given.

2.10 LET US SUM UP

In this unit, we learnt about the Electric Power System. We now know that electricity system is organized in three major parts, namely, Generation, Transmission and Distribution. We have learnt that power is generated wherever feasible, and the generating plant may not be close to the user or consumer. Hence power is transmitted over long lines at high voltage to cover this distance. These lines form the Transmission system and the set of the lines is named as the grid. Once the power is brought close to the user, it is converted to lower voltages and over the distribution system, supplied to the end user.

In regard to Generation, we learnt the various sources of energy, which are employed to generate electric power. We know now that thermal power (mainly coal) forms the largest source, followed by hydropower. We

understand that depending on the source, we classify power generation as renewable or not. In general, electric power is generated as AC or Alternating Current.

Under Transmission we understand that long transmission lines are required to carry the generated power up to the user location. We have learnt that transmission voltages generally range from 132 kV and higher. This helps in reducing power loss. We also know that more interconnecting lines are usually provided to enable redundancy in the system. The complete set of these lines is referred to as the Grid. Grid has high inertia and hence help to reduce variations in the operating parameters, such as frequency and voltage.

Under distribution system we understand that part of the system, which is closer to the end user. Hence, we can afford to use lower voltages, typically, below 66 kV. The residential consumer gets power at 230 V.

We know the difference between single-phase supply (phase to neutral) and three phase supply (phase to phase). The lowest 3-phase voltage is 400 V. We understand that 3-phase supply is normally provided to industrial consumers. Against this, the normal residential user gets single-phase power at 230 V.

We have learnt about the objectives of Grid management, which implies Reliability, Security, Economy and Quality. We have also learnt that frequency, voltage and harmonics are the factors that affect the quality of power supply.

2.11 KEY WORDS

Electric Power System : System that generates, transmits, and distributes electric power to the end user.

Energy : Capacity to perform work.

Capacitor : A capacitor is a device for storing a large quantity of electric charge.

Efficiency of Power Transfer : Ratio of the power delivered to the power supplied by the source.

Alternatively Current : The current where magnitude changes with time and the direction reverses periodically is known as alternatively current.

Transformer : It is a device to change low alternating voltage at high current into high voltage at low current and vice-versa.

High Voltage Power Transmission : Use of voltages greater than 100 kV to keep low resistive losses (I^2R) on the transmission lines.

Passive Elements : Element that absorbs energy.

Phase Voltage : Voltage of each phase of a three-phase system.

Power Factor : Equal to cos ϕ, where ϕ is the phase angle difference between the sinusoidal steady-state voltage and current.

2.12 TERMINAL QUESTIONS

(a) Why do we need Transmission lines?

(b) What voltages are common in a distribution system?

(c) Why is high voltage preferred for transmission lines?

(d) What are the three quality parameters of electric supply?

1.6 ANSWERS TO CHECK YOUR PROGRESS

Ans. 1

State Electricity Boards/ Departments.

Ans. 2

Generation, Transmission and Distribution.

Ans. 3

25%

Ans. 4

High Voltage Direct Current.

Ans. 5

400 V

Ans. 6

Theft of Electrical Power and Inefficient use of electricity.

Ans. 7

Grid is the total set of Transmission lines, from Generation Plants up to the Distribution location, including the cross-connect and redundant lines.

Ans. 8

The Grid is very much larger than any user load or generation plant. The grid can be said to have inertia to change directed by the failure of any generator or user load. Since the grid has multiple sources of power and many loads, any single failure is but a fraction of the total power available. Hence it leads to only a minor change in the grid related parameters, such as frequency or voltage.

Electrons are very particles with a unit negative charge, whereas, Protons have a unit positive charge and are many times heavier than the electrons. Also, Protons reside in the nucleus of an atom, while Electrons revolve around it.

2.14 ANSWERS TO TERMINAL QUESTIONS

(a) As stated, the generating plants are normally not located close to the load point due to various economic/ operational reasons. This brings the need to carry power to the load, efficiently. Such a carrier is the transmission line. Stated otherwise, Transmission lines are needed to transmit bulk power over long distances, economically.

(b) The lowest voltage in a distribution system is 230 V, single phase, or 400 V, 3-phase. The other common voltages are 3.3 kV, 6.6 kV, 11 kV, 33 kV, 66 kV and in some cases, even 132 kV.

(c) As we recall, Power is voltage $\times$ current. Hence, by increasing the line voltage, we achieve lower line current, for the same amount of power. The lower current causes lower resistive losses in the line. Hence higher voltage is preferred for power transmission.

(d) Three main quality parameters are :

- Frequency
- Voltage
- Harmonics