

## UNIT 5

### ELECTRICAL INSTALLATION AND BATTERY

#### 5.1 Components of LT (Low Tension) Switchgear

Switchgear is the combinations of electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment during any fault. The components used in switchgear are

**5.1.1 FUSE:** Fuse is the simplest and cheapest device used for interrupting an electrical circuit under short circuit or overload. It is connected in series with the circuit and must be connected in line (live) wire.

**Principle:** The action of a fuse is based on the heating effect.

**Working:** In normal condition when the current flowing through the circuit is within the safe limit, the heat developed in the fuse element is dissipated into the surrounding air, and therefore, fuse element remains at a temperature below its melting point.

When any short circuit occurs or load connected in the circuit exceeds the limit, the current exceeds the limiting value, the heat generated in the fuse element due to this excessive current cannot be dissipated fast and the fuse element heated, melts and breaks the circuit.

The fuse element has inverse time-current characteristic. Higher the current flowing in the fuse element then lowers time required by the element to melt.

The various type of fuse is commonly available:

- (i) Round type fuse unit
- (ii) Kit kat type fuse unit
- (iii) Cartridge type fuse unit
- (iv) HRC type fuse unit
- (v) Semiconductor fuse unit

**5.1.2 SWITCH FUSE UNIT (SFU):** It has one switch and one fuse combined in a unit. As per Indian rule a SFU is to be provided just after the meter. The switch fuse unit is also called iron clad switch. They are of following types.

- (i) DPIC (Double Pole Iron Clad): It has double pole for controlling the single phase two wire circuit. Its rating is 240 V, 16 A approved by IS.
- (ii) TPIC (Triple Pole Iron Clad): It has three poles for controlling the three phase three wire circuit. Its rating is 500 V, 32/63/100/150 or higher A approved by IS.
- (iii) TPNIC (Triple Pole with Neutral link Iron Clad): It has three pole and a neutral link for controlling the three phase four wire circuit. Its rating is 415 V, 32/63/100/150 or higher A approved by IS.

**5.1.3 MINIATURE CIRCUIT BREAKER (MCB):** It is electromechanically operated automatic circuit protection device. They are used to serve two functions.

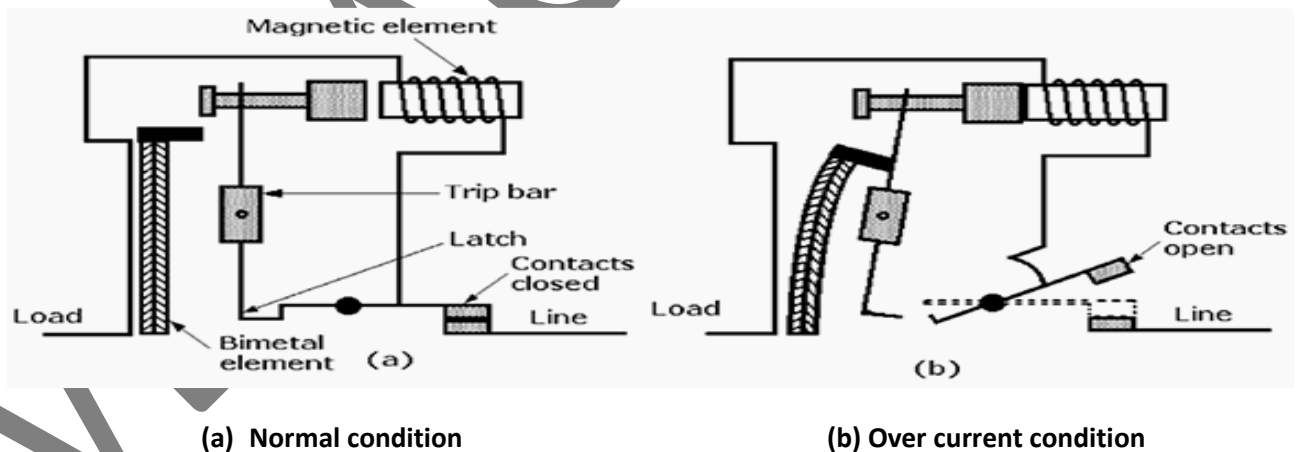
- (i) Switching: MCB can be switched ON and OFF manually.
- (ii) Over current Protection: When equipment is overloaded or short circuited it draw more current from the source. In both the condition MCB open the contact and isolate the equipment from supply.

**Construction of MCB:** the construction of MCB is shown in fig. It consist the following parts.

- (i) External casing: External casing hold all the internal components and protect them from dust. It is made by insulating material such as plastic or ceramic etc.
- (ii) Contacts: A pair of contacts can be found inside an MCB. One of them is fixed and other is movable.
- (iii) Knob: MCB can be turned on and off using this knob.
- (iv) Latch: A latch arrangement is made inside MCB to hold the contact at ON position.
- (v) Bimetallic strip: It provides overload protection by sensing long flow of current greater than its rated current.
- (vi) Solenoid: It provides short circuit current protection by instantaneous releasing the mechanical latch.

**Principle:** The action of a MCB is based on the Heating-Magnetic effect.

**Working:** The working of the MCB as follow



**Fig. 5.1**

Fig. 5.1 (a) shows the normal condition of the MCB the contacts are closed and supply is connected to the load.

In the case of overload, a current more than the rated current is driven through the MCB. As the current flows through the bimetallic strip, its gets heated up and deflects by bending and releases the mechanical latch as shown in fig. 5.1 (b). Deflection time of the bimetallic strip depends on the amount

of current flowing through the bimetallic strip. Higher the current faster will be the deflection of bimetallic strip.

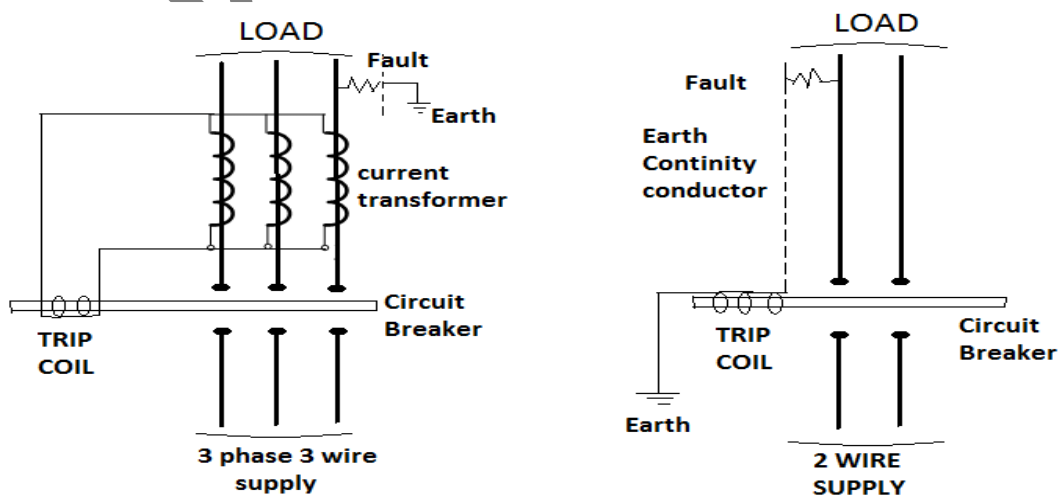
During short circuits, a very high current flowing through the solenoid forces the plunger towards the latch. This action instantaneously releases the mechanical latch and opens the contact immediately.

Advantage of MCB over fuse

- (i) It can be act faster during short circuit.
- (ii) MCB offer better overload protection.
- (iii) MCB can be reset after clearance the fault, But fuses needs to be rewired.
- (iv) Knob makes operation of MCB much easier than fuse.
- (v) MCB can be turned off whenever we want.

**5.1.4 EARTH LEAKAGE CIRCUIT BREAKER (ELCB):** It is a device which provides protection against earth leakage. When somebody gets an electric shock or the current of the circuit exceeds the fixed value, ELCB cuts off the power supply and automatically protecting the personal safety and preventing the equipment from the fault. There are two types of ELCB.

- (i) **Current Operated Earth Leakage Circuit Breaker:** A 3 phase 3 wire current operated earth leakage circuit breaker is shown in fig. 5.2(a). In normal condition when there is no earth leakage the algebraic sum of the current in the three coils of the current transformer is zero, and no current flows through the trip coil. In case of any earth leakage, the currents are unbalanced and the trip coil is energized and thus the circuit breaker is tripped.
- (ii) **Voltage Operated Earth Leakage Circuit Breaker:** A 1 phase 2 wire voltage operated earth leakage circuit breaker is shown in fig. 5.2(b). When the voltage between the earth continuity conductor and earth electrode rises to a sufficient value, the trip coil will carry the required current to trip the circuit breaker.



(a) Current Operated ELCB

(b) Voltage Operated ELCB

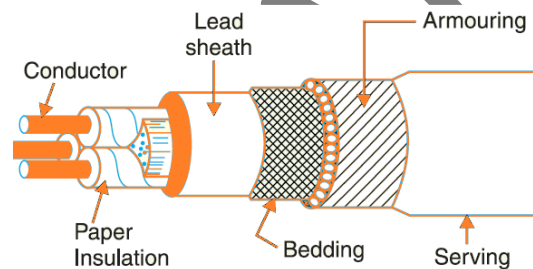
Fig. 5.2

**5.1.5 MOLDED CASE CIRCUIT BREAKER (MCCB):** It is a protection device used for the wide range of voltage. The main difference between MCB and MCCB are that the MCCB can have current rating up to 2500 ampere and its trip setting is normally adjustable. An MCCB has three main functions.

- (i) Protection against overload: If the current above the rated value for longer time then circuit should be break.
- (ii) Protection against fault: During a fault such as short circuit or line fault, there are extremely high current that must be interrupted immediately.
- (iii) Switching a circuit on and off: This is a less common function of circuit breaker, but they can be used as a switch if there is no separate switch available.

**5.2 WIRE or CABLE:** A cable is an assembly of two or more electrical conductors usually held together with an overall sheath. The cable is used for transmission of electrical power.

**5.2.1 CONSTRUCTION OF CABLE:** Fig 5.3 shows the general construction of the cable. Its various parts are



**Fig. 5.3**

- (1) Conductor or Core: This section consists of single conductor or more than one conductor. The conductor is also called cores. A cable with three conductors is called three core cables. The conductors used are aluminum or copper. The conductor is stranded in order to provide flexibility to the cable.
- (2) Insulation: Each conductor or core is covered by insulation of proper thickness. The commonly used insulating material is varnished, vulcanized bitumen and paper.
- (3) Metallic sheath: The insulated conductor covered by lead sheath or aluminum sheath. This provides the mechanical protection but mainly restricts moisture and other gases to reach to the insulation.
- (4) Bedding: The metallic sheath is covered by another layer called bedding. These bedding consists of paper tape compounded with a fibrous material lime jute strands. The purpose of bedding is to protect the metallic sheath from corrosion and from mechanical injury resulting due to armoring.
- (5) Armoring: This layer consists of the layers of galvanized steel provides protection to the cable from the mechanical injury.
- (6) Serving: The last layer above the armoring is serving. It is a layer of fibrous material like jute cloth which protects the armoring from the atmospheric condition.

**5.2.2 TYPES OF CABLE:** The cable may be divided into different groups on the different basis. These bases are

- (1) Conductor Used: According to the conductor material used in cable, the cables are divided into two classes known as copper conductor cable and Aluminum conductor cable.
  - (i) Copper conductor cable: In this type of cable the material used in conductor are copper.
  - (ii) Aluminum conductor cable: In this type of cable the material used in conductor is Aluminum.
- (2) Number of Cores: According to the number of cores in cable, the cables are divided into classes known as single core cable, twin core cable, three core cable etc.
  - (i) Single core cable: if there is only one conductor in the cable that is known as single core cable.
  - (ii) Twin core cable: if there are two conductors in the cable that is known as twin core cable.
  - (iii) Three core cable: if there are three conductors in the cable that is known as three core cable.
- (3) Voltage level: According to voltage level for which it is manufactured the cable are divided into three class known as Low Tension (LT) cable, Medium or High Tension (HT) cable and Super Tension (ST) cable
  - (i) LT cable: These are used for voltage level up to 6.6 kV.
  - (ii) HT cable: These are used for voltage level up to 66 V.
  - (iii) ST cable: These are used for voltage level from 132 kV to 275 kV.
- (4) Insulation: According to type of insulation used in cable the cable are divided into different classes as follow
  - (i) Vulcanized Indian Rubber (VIR) cable: These cables consist of either copper or aluminum conductor covered with a layer of vulcanized Indian Rubber (VIR) insulation. The thickness of rubber insulation depends upon the voltage level for which the cable is required. Over the rubber insulation cotton tape sheathed covering is provided with moisture resistant wax or some other insulating material for making the cables moisture proof.
  - (ii) Tough Rubber Sheath (TRS) Cable: These cables are nothing but a vulcanized rubber insulated conductor with an outer protective covering of tough rubber, which provide additional insulation and protection against wear and tear. These cables are water proof.
  - (iii) Lead sheathed cable: The lead sheathed cable is a vulcanized rubber insulated conductor covered with a sheath of lead. The lead sheath provides very good protection against the absorption of moisture and sufficient protection against mechanical injury.
  - (iv) Poly Vinyl Chloride (PVC) cable: These cables consist of either copper or aluminum conductor covered with a layer of Poly Vinyl Chloride (PVC) insulation. PVC cable does not required cotton taping and braiding over it for mechanical and moisture protection.

- (v) **Weather Proof Cable:** These cables are used for outdoor wiring and for power supply. These cables are either PVC insulated or vulcanized rubber insulated conductor compounded with weather resisting material.

Advantage of PVC cable over VIR cable:

- (1) PVC insulation has better insulating qualities.
- (2) PVC insulation provides better flexibility.
- (3) PVC insulation has no chemical effect on metal of the wire.
- (4) Thin layer of PVC insulation will provide the desired insulation level.
- (5) PVC coated wire gives smaller diameter of cable.

**5.3 EARTHING:** It is the process of transferring the immediate discharge of electricity directly to the earth by a low resistance wire. It can be done by connecting the neutral point of a supply system or the non-current carrying parts of electrical apparatus to the earth.

**5.3.1 NECESSITY OF EARTHING:** The earthing is necessary for the following reasons.

- (i) It keeps the people safe by preventing electric shocks.
- (ii) It prevents damage to electrical appliances and devices by preventing excessive current running in the circuit.
- (iii) It prevents risk of fire due to the leakage current through unwanted paths.
- (iv) It provides the easiest path to the flow of short circuit current.

**5.3.2 TYPES OF EARTHING:** The various types of earthing are

(1) **Plate Earthing:**

In this type of earthing plate either of copper of dimensions 60 cm × 60 cm × 3 mm or of G.I. (galvanized iron) of dimensions 60 cm × 60 cm × 6 mm is buried into the ground at a depth of not less than 3 meters from ground level.

The earth plate is embedded in an alternative layer of coke and salts for a minimum thickness of about 15 cm.

The earth wire (copper wire for copper plate and G.I. wire for G.I. plate) is bolted to an earth plate with the help of bolt, nut and washer made of copper in case of copper plate earthing and of G.I. in case of G.I. plate earthing.

(2) **Pipe Earthing:**

Pipe earthing is the best form of earthing and it is cheap also.

In this type of earthing a G.I. pipe of 40 mm diameter and 2 meters length is embedded vertically in ground to work as earth electrode. The depth depends upon the soil condition. Also the wire is embedded up to the wet soil.

The earth wire is connected to the top section of the pipe with nut and bolts.

The pit area around the G. I. pipe is filled with salt and coal mixture for improving the soil conditions and efficiency of the earthing system.

(3) Rod Earthing:

In this type of earthing 12.5 mm diameter solid rod of copper or 16 mm diameter solid rod of G.I. or steel of length not less than 3 meters are driven vertically into the earth.

To increase the length of electrode under the ground, more than one rod section are hammered one above the other.

This system of earthing is suitable for areas which are sandy in character. This system of earthing is very cheap.

(4) Strip or wire earthing:

In this system of earthing wire electrode of cross section not less than 25 mm × 16 mm for copper or 25 mm × 4 mm for G.I. are buried in horizontal of minimum depth 0.5 m.

If round conductor is used their cross sectional area shall not be smaller than 3 mm<sup>2</sup> for copper or 6 mm<sup>2</sup> for G.I. is used.

The length of the conductor shall be sufficient to give the required earth resistance.

The electrode shall be widely distributed as possible in a single straight or circular trenches radiating from a point. This type of earthing is used in rocky earth.

**5.3.4 EARTH RESISTANCE:** The earth resistance is the resistance offered by the soil and the electrode to the flow of earth leakage current. The value of earth resistance should be kept as small as possible, so leakage current can be easily flow through the earth. The importance of the earth resistance value is

- (1) Earth resistance value is directly proportional to the soil resistivity value.
- (2) Soil resistivity directly affects the design of the earthing system.
- (3) When designing an effective earthing system, it is advice to locate the area of lowest soil resistivity in order to achieve the economical earthing system.
- (4) The value of soil resistivity should be low because the earth resistance value is directly proportional to soil resistivity value.
- (5) The main purpose of keeping the earth resistance to a very low value is to give easy path to the flow of leakage or fault current.

**5.3.5 IMPORTANT SAFETY ISSUES:** The important safety issues are

- (1) Inspect tools, power cords and electrical fitting for damage.
- (2) Repair or replace damaged equipment immediately.

- (3) Use cords or equipment that is rated for the level of ampere or wattage.
- (4) Always use the correct size of fuse.
- (5) Be aware that unusually warm or hot outlet is a sign that unsafe wiring condition exists
- (6) Do not block access to circuit breaker or fuse.

**5.4 BATTERY:** A battery is a source of electrical energy, which is provided by one or more electrochemical cells after conversion of stored chemical energy. There are two types of battery.

**(1) Primary Battery:** A primary battery is a disposal kind of battery. Once used it cannot be recharged because the chemical reactions in these battery are irreversible. The cost of the primary battery is very less. There are different types of primary battery.

(i) Alkaline Batteries:

It consists of a zinc anode and manganese dioxide cathode in an alkaline electrolyte (potassium hydroxide).

Alkaline batteries are non rechargeable, high energy density and having long life span. It has 1.5 V output voltages.

It works with high efficiency, due to low internal resistance. The reaction is as follow



Application: remote controls, clocks, radios, digital camera, MP3 players.

(ii) Zinc-carbon battery:

These batteries are also known dry cell.

It consist a carbon rod cathode surrounded by a mixture of carbon powder and manganese dioxide. The whole combination is packed in a zinc container acting as anode. The electrolyte is a mixture of ammonium chloride and zinc chloride.

The output voltage is little less than 1.5 V. They are durable and long life. The reaction is as follow

Application: flash light, remote control, toys and table clocks.

(iii) Mercury batteries:

It contains mercury oxides anode with manganese dioxides as cathode.

They are deep discharge battery and voltage level not fall below 1.35 V.

These batteries are less popular because mercury is toxic and can cause hazards for human.

Application: electronic devices.

(iv) Zinc chloride battery:

It is a modified form of zinc carbon battery.

It has little chance of liquid leakage because the cell consumes water along with electrolyte.

(v) Silver oxide battery

This battery consists of a zinc anode, silver oxide cathode and potassium or sodium hydroxide electrolyte.

It is typically available as 1.5 V

Application: Hearing aids, camera, watches

**(2) Secondary Battery:** Secondary batteries are rechargeable battery. It can be used, recharged and reused again because the chemical reactions in these batteries are reversible. They are also called accumulators. The cost of the secondary battery is very high.

**(i) Lead Acid batteries:**

Lead acid batteries are the rechargeable kind of batteries. These large, heavy weight batteries find the major application in automobile as these fulfill the high current requirements of the heavy motors.

The composition of lead acid battery changes in charged and discharged states.

A combination of Pb (negative) and  $PbO_2$  (positive) as electrode with  $H_2SO_4$  as electrolyte in charged form and  $PbSO_4$  and water in discharged form.

Application: Application of lead acid battery is in starting, lightning and ignition systems of automobiles.

It can also be used as backup power supply for high end servers, personal computers, telephone exchange and in off grid homes with inverters.



**(ii) Lithium batteries**

Lithium batteries are rechargeable batteries, where lithium in its pure ion compound form is used.

Depending on the design and chemical compounds used, lithium batteries can produce voltages from 1.5 volts to 3.7 volts.

The most common type of lithium battery used in consumer applications uses manganese dioxide as cathode and metallic lithium as anode.

Application: It is used in portable consumer instruments like calculator, digital diaries, toys, mobiles.

#### **5.4.2 IMPORTANT CHARACTERISTIC OF BATTERY:**

- (A) Voltage: Average emf of cell is approximately 2.0 volts. The value of emf of a cell does not remain constant but varies with the change in specific gravity of electrolyte, temperature and the length of time since it was last charged.
- (B) Capacity: The total no of ampere hour or watt hours that can be withdrawn from a fully charged cell or battery under specific conditions of discharge is termed as capacity of battery. It is defined in term of Ampere hour (AH).
- (C) Efficiency: The efficiency of the battery can be given in two ways.

- (i) Ampere Hour efficiency: It is defined as the ratio of Ampere Hour of discharge and Ampere Hour of charge.

$$\eta_{AH} = \frac{\text{Ampere hours of discharge}}{\text{Ampere hours of charge}} = \frac{I_d T_d}{I_c T_c} \times 100$$

- (ii) Energy or Watt Hour efficiency: It is defined as the ratio of energy delivered in Watt Hour by the cell during discharge and the energy drawn by the cell in Watt Hour during charge.

$$\eta_{WH} = \frac{\text{Output in Watt hour}}{\text{Input in Watt hour}} = \frac{V_d I_d T_d}{V_c I_c T_c} \times 100 = \eta_{AH} \frac{V_d}{V_c}$$

### 5.4.3 CALCULATION:

- (1) Electricity consumption per day: To calculate the daily consumption, the difference between the meter reading is divided by the number of days in the period covered.
- (2) Electricity consumption per year: To calculate the electricity consumption for one year, the electricity consumption per day can be multiply with 365 days.
- (3) Energy saving: The difference between the electricity consumption in the previous year and the monitoring period is the energy saving for the monitoring period.
- (4) Battery backup: Time taken to discharge the battery is known as battery backup.

**Q.1** A house hold has the following meter reading: 12300 (1 December 2016); 13200 (28 February 2017). The previous energy bill was: 3960 KWh (from 10 November 2015 to 5 November 2016). Calculate daily electricity consumption, energy consumption extrapolated to 1 year and energy saving.

**Sol.** The daily electricity consumption during the monitoring period =  $\frac{13200-12300}{90 \text{ days}} = 10 \frac{\text{KWh}}{\text{day}}$

The electricity consumption extrapolated to 1 year = 10 kWh/day × 365 days/year = 3650 kWh/year

Energy saving      Energy consumption in last year 3960 in 360 days

Energy consumption in last year per day =  $\frac{3960 \text{ KWh}}{360} = 11 \text{ kWh/day}$

Energy consumption in last year in 365 days = 11 kWh/day × 365 days/year = 4015 kWh/year

Energy saving = Energy consumption in last year – Energy consumption in monitoring year

= 4015 KWh/year – 3650 kWh/year = 365 KWh/year **Ans.**

**Q.2** If no of bulb = 2 and no. of ceiling fan = 1 Rating of each bulb = 15 Watt Rating of each fan = 100 Watt Rating of battery is 12 V, 150 Ah, Calculate the battery backup.

**Sol.** Total load = load of bulb + load of fan = 2×15 + 1×100 = 130 Watt

Watt hour rating of battery = voltage rating of battery × Ah rating of battery = 12 × 150 = 1800 Wh

$$\text{Backup time} = \frac{\text{Watt hour rating of battery}}{\text{Total load}} = \frac{1800 \text{ Wh}}{130 \text{ Watt}} = 13.84 \text{ hour Ans.}$$

**Q.3** A battery has taken a charging current of 5.2 Amp. for 24 hours at a voltage of 2.25 V, while discharging it gives of 4.5 A for 24 hours at an average voltage 1.85 V. Calculate the quantity efficiency and the energy efficiency of the battery.

**Sol.** Given  $I_c = 5.2 \text{ A}$ ,  $T_c = 24 \text{ H}$ ,  $V_c = 2.25 \text{ V}$ ,  $I_d = 4.5 \text{ A}$ ,  $T_d = 24 \text{ H}$ ,  $V_d = 1.85 \text{ V}$

$$\eta_{AH} = \frac{I_d T_d}{I_c T_c} \times 100 = \frac{4.5 \times 24}{5.2 \times 24} \times 100 = 86.54 \% \text{ Ans.}$$

$$\eta_{WH} = \frac{V_d I_d T_d}{V_c I_c T_c} \times 100 = \frac{1.85 \times 4.5 \times 24}{2.25 \times 5.2 \times 24} \times 100 = 71.15 \% \text{ Ans.}$$

**Q.4** A cell is discharged at a steady current of 4 A for 12 hours, the average terminal voltage being 1.2 V. To restore it to original state of voltage, a steady current of 3 A for 20 hours is required, the average terminal voltage being 1.44 V. calculate the ampere hour and watt hour efficiency.

**Sol.** Given  $I_d = 4 \text{ A}$ ,  $T_d = 12 \text{ H}$ ,  $V_d = 1.2 \text{ V}$ ,  $I_c = 3 \text{ A}$ ,  $T_c = 20 \text{ H}$ ,  $V_c = 1.44 \text{ V}$

$$\eta_{AH} = \frac{I_d T_d}{I_c T_c} \times 100 = \frac{4 \times 12}{3 \times 20} \times 100 = 80.00 \% \text{ Ans.}$$

$$\eta_{WH} = \frac{V_d I_d T_d}{V_c I_c T_c} \times 100 = \frac{1.2 \times 4 \times 12}{1.44 \times 3 \times 20} \times 100 = 66.7 \% \text{ Ans.}$$

**Q.5** Thirty five lead acid secondary cells each of discharge capacity 120 Ah at 12 hours rate are to be fully charges at constant current for 10 hours. The DC supply is 125 volts, the ampere hour efficiency is 80 % and the emf of each cell at start and at the end of the charge is 1.9 volts and 2.6 volts respectively. Calculate the maximum and minimum of external resistance necessary. Neglect the internal resistance of the cell.

**Sol.** Given  $I_d T_d = 120 \text{ Ah}$ ,  $T_d = 12 \text{ H}$ ,  $T_c = 10 \text{ H}$ ,  $\eta_{AH} = 80\%$ ,  $V = 125 \text{ V}$ ,  $V_d = 1.9 \text{ V}$ ,  $V_c = 2.6 \text{ V}$

$$I_c T_c = \frac{I_d T_d}{\eta_{AH}} \times 100 = \frac{120}{80} \times 100 = 150 \text{ Ah}$$

$$I_c = \frac{I_c T_c}{T_c} = \frac{150}{10} = 15 \text{ A}$$

Combined emf of 35 cells connected in series at the start of charge (fully discharge)  $E_1 = 35 \times 1.9 = 66.5 \text{ V}$

Combined emf of 35 cells connected in series at the end of charge (fully charged)  $E_2 = 35 \times 2.6 = 91 \text{ V}$

The resistance will be maximum at the start of charge because emf is minimum so

$$R_{\max} = \frac{V - E_1}{I_c} = \frac{125 - 66.5}{15} = 3.9 \Omega \text{ Ans.}$$

The resistance will be minimum at the end of charge because emf is maximum so

$$R_{\min} = \frac{V - E_2}{I_c} = \frac{125 - 91}{15} = 2.267 \Omega \text{ Ans.}$$

**Q.6** A discharged battery is put on charge at 5 A for 3.5 hours at a mean charging voltage of 13.5 V. It is then discharged in 6 hours at a constant terminal voltage of 12 V through a resistance of R ohms. Determine (i) value of R for an ampere hour efficiency of 85% (ii) Watt hour efficiency of the battery

**Sol.** Given  $I_c = 5 \text{ A}$ ,  $T_c = 3.5 \text{ H}$ ,  $V_c = 13.5 \text{ V}$ ,  $T_d = 6 \text{ H}$ ,  $V_d = 12 \text{ V}$ ,  $\eta_{\text{AH}} = 85\%$

$$(i) I_d = \frac{\eta_{\text{AH}} I_c T_c}{T_d} = \frac{0.85 \times 5 \times 3.5}{6} = 2.48 \text{ hours}$$

$$R = \frac{V_d}{I_d} = \frac{12}{2.48} = 4.84 \Omega \text{ Ans.}$$

$$(ii) \eta_{\text{WH}} = \eta_{\text{AH}} \frac{V_d}{V_c} = 85 \frac{12}{13.5} = 75.55\% \text{ Ans.}$$