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Name of the course— B.Sc. (H) Physics

Semester- IV

Name of the paper—Electrical circuits and Network Skills

Paper code-32223903

Lecture timings: 10:40 to 12:40 AM

Topics to be covered:

Name of the unit: Electrical wiring

- *Conductor and its types*
- *Classification of cables*
- *Voltage drop and power loss across conductors*
- *Power loss and drop across cables*
- *Instrument to measure voltage, current and power in AC and DC circuits*

Conductor and its types

The conductor is the type of metal which allows the electrical current to flow through it. The electrical conductor is generally made up of metals like copper, aluminium and their alloys. In an electrical conductor, the electrical charges moves from atom to atom when the potential difference is applied across them. The electrical conductors are used in the form of the wire. The choice of the conductor can be taken into account by considering the various factors like tensile strength, fatigue strength, corona loss, local conditions and cost.

The electrical conductor which is used for power transmission is usually stranded. Stranded conductors have great flexibility and mechanical strength as compared to a single wire of the same cross-section area. In stranded conductor usually, the centre wire is surrounded by the successive layers of wires containing 6, 12, 18, 24,… wires.

The size of the conductor is determined by its equivalent copper cross section area and the number of strands with the diameter of each strand. The equivalence cross section of a stranded conductor is the area of a cross section of the solid conductor of the same material and length as the stranded conductor. And also the conductor having the same resistance at the same temperature.

Types of Electrical Conductors

Hard-drawn copper, hard-drawn aluminium conductors and steel-cored aluminium conductors are most commonly used in a power. Some of the important types of conductors are explained below in details.

Hard Drawn Copper Conductor

Such type of conductors gives high tensile strength. It has high electrical conductivity, long life, and high scrap value. It is most suitable for distribution work where spans and tapping are more.

Cadmium Copper Conductor

The tensile strength of the copper is increased by approximately 50 percent by adding about 0.7 to 1.0 percent cadmium to it, but their conductivity is reduced by about 15 to 17 percent. The property of higher tensile strength enables the conductor to be erected on longer spans with the same sag. This conductor possesses the advantages of easy joining, more resistance to atmospheric condition, better resistance to wear, easy machinability, etc.

The temperature at which copper anneals and softens is also increased, and temperature effects on stresses are less. The variation in sag due to changes in load and temperature is minimised.

Steel-Cored Copper Conductor (SCC)

In steel cored copper conductor one or two layers of copper strands surround a steel cored copper conductors. The steel core adds the tensile strength to the conductor.

Copper Welded Conductor

In such type of conductors, the uniform layers of copper are welded onto a steel wire. The conductivity of the copper welded conductor varies from 30 to 60 percent to that a solid copper

conductor with the same diameter. Such types of conductors may be used for longer span such as a river crossing.

Hard-Drawn Aluminium Conductor or All-Aluminum Conductor

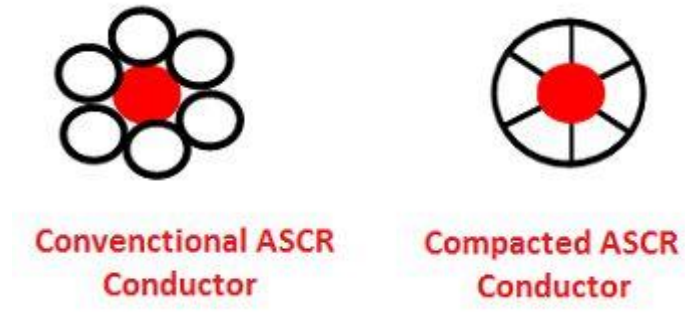
the cost of the copper conductor is very high, and hence it is replaced by the aluminium conductor. The handling, transportation and erection of the aluminium wires become very economical. It is used in distribution lines in the urban area and short transmission line with the lower voltages.

Aluminium Conductor Steel Reinforced

All aluminium conductors are not sufficiently strong mechanically for the construction of long span lines. This deficiency in strength can be compensated by adding a steel core to the conductor. Such a conductor is called steel-cored aluminium conductor (SCA) or aluminium conductor steel reinforced (ACSR).

Smooth Body ACSR Conductor

Such type of conductor is also called Compacted ACSR. The conventional ACSR conductor is pressed through dies to flatten the aluminium strands into segmental shape. The interstrand space is filled, and the diameter of the conductor reduces without affecting its electrical and mechanical properties. This conductor can be made with different ratios of aluminium to steel. The figure shows below the conductor having ratio 6 Al/1 St.



Expanded ACSR Conductor

For reducing the corona loss and radio interference at a high voltage a fibrous or plastic material is filled between the strands. The diameter of the conductor expands due to the filling material and hence, it is called an expanded conductor. These conductors consist paper material which separates the inner aluminium strands from the outer steel strands.

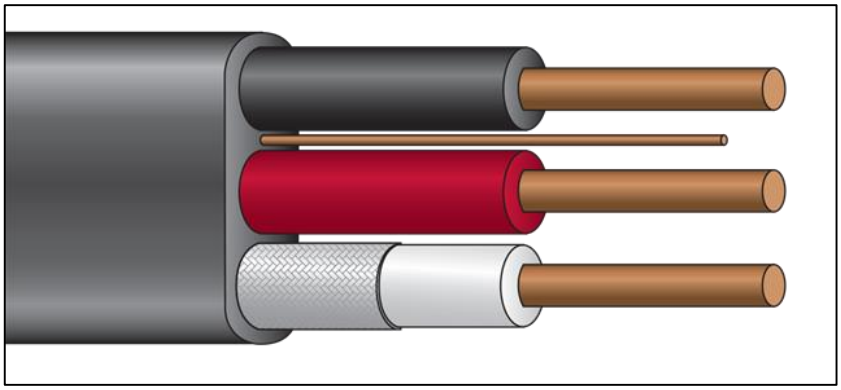
Cables and its types

An electrical cable also has different types, color and application as its determining factors. Here's a brief about cables that you need to understand to determine the correct cable for your home.

1. Types of Electrical Cables – There are more than 20 different types of cables available today, designed for applications ranging from transmission to heavy industrial use. Some of the most commonly-used ones include:

- **Non-Metallic Sheathed Cable:** These cables are also known as non-metallic building wire or NM cables. They feature a flexible plastic jacket with two to four wires (TECK cables are covered with thermoplastic insulation) and a bare wire for grounding. Special varieties of this cable are used for underground or outdoor use, but NM-B and NM-C non-metallic sheathed cables are the most common form of indoor residential cabling.

- **Underground Feeder Cable:** These cables are quite similar to NM cables, but instead of each wire being individually wrapped in thermoplastic, wires are grouped together and embedded in the flexible material. Available in a variety of gauge sizes, UF cables are often used for outdoor lighting and in-ground applications. Their high water-resistance makes them ideal for damp areas like gardens as well as open-to-air lamps, pumps, etc.



- **Metallic Sheathed Cable:** Also known as armored or BX cables, metal-sheathed cables are often used to supply mains electricity or for large appliances. They feature three plain stranded copper wires (one wire for the current, one grounding wire and one neutral wire) that are insulated with cross-linked polyethylene, PVC bedding and a black PVC sheathing. BX cables with steel wire sheathing are often used for outdoor applications and high-stress installations.
- **Multi-Conductor Cable**: This is a cable type that is commonly used in homes, since it is simple to use and well-insulated. Multi-conductor or multi-core (MC) cables feature more than one conductor, each of which is insulated individually. In addition, an outer insulation layer is added for extra security. Different varieties are used in industries, like the audio multicore ‘snake cable’ used in the music industry.

- **Coaxial Cable:** A coaxial (sometimes heliax) cable features a tubular insulating layer that protects an inner conductor which is further surrounded by a tubular conducting shield, and might also feature an outer sheath for extra insulation. Called ‘coaxial’ since the two inner shields share the same geometric axis, these cables are normally used for carrying television signals and connecting video equipment.
- **Unshielded Twisted Pair Cable:** Like the name suggests, this type consists of two wires that are twisted together. The individual wires are not insulated, which makes this cable perfect for signal transmission and video applications. Since they are more affordable than coaxial or optical fiber cables, UTP cables are often used in telephones, security cameras and data networks. For indoor use, UTP cables with copper wires or solid copper cores are a popular choice, since they are flexible and can be easily bent for in-wall installation.
- **Ribbon Cable:** Ribbon cables are often used in computers and peripherals, with various conducting wires that run parallel to each other on a flat plane, leading to a visual resemblance to flat ribbons. These cables are quite flexible and can only handle low voltage applications.
- **Direct-Buried Cable:** Also known as DBCs, these cables are specially-designed coaxial or bundled fiber-optic cables, which do not require any added sheathing, insulation or piping before being buried underground. They feature a heavy metal core with many layers of banded metal sheathing, heavy rubber coverings, shock-absorbing gel and waterproof wrapped thread-fortified tape. High tolerance to temperature changes, moisture and other environmental factors makes them a popular choice for transmission or communication requirements.
- **Twin-Lead Cable:** These are flat two-wire cables that are used for transmission between an antenna and receiver, like TV and radio.
- **Twin axial Cable:** This is a variant of coaxial cables, which features two inner conductors instead of one and is used for very-short-range high-speed signals.
- **Paired Cable:** With two individually insulated conductors, this cable is normally used in DC or low-frequency AC applications.

- **Twisted Pair:** This cable is similar to paired cables, but the inner insulated wires are twisted or intertwined.

2. Cable Color Code – Color coding of cable insulation is done to determine active, neutral and earth conductors. The NEC has not prescribed any color for phase/active conductors. Different countries/regions have different cable color coding, and it is essential to know what is applicable in your region. However, active conductors cannot be green/yellow, green, yellow, light blue or black..

Cable Size – Cable size is the gauge of individual wires within the cable, such as 14, 12, 10 etc. – again, the bigger the number, the smaller the size. The number of wires follows the wire-gauge on a cable. So, 10/3 would indicate the presence of 3 wires of 10-gauge within the cable. Ground wire, if present, is not indicated by this number, and is represented by the letter 'G'.

Safety is very important, and if your installation of wires and cables is not proper, it could lead to accidents. Before you start any electrical project that includes wiring and cabling, you need to obtain permission from your local building inspector. Once the job is done, get the installation inspected for compliance with local codes and regulations.

Voltage drop across conductors

Conductor allows the flow of electrical energy to move in one and other directions. The pressure or electrical force that helps the current to flow in a conductor is voltage. Sometimes the pressure of voltage fails to provide the desired flow of current due to impedance. This situation causes voltage drop.

It is not affected by the equal number of electrons before or after entering the conductors. The fluctuation in the speed too, does not hurt it. It is only affected by the pressure or release of energy in the conductors. Voltage drop usually lasts for few seconds.

Causes

Resistance in the conductor causes voltage drop. There are many factors responsible for the change in the resistance. The use of aluminium in wires causes voltage drop. It is less powerful and does not have much ability to bear the high pressure of electrical force. The use of small wire sizes (diameters) cause voltage drop as well.

It is important to inspect the flow of current. The rate of voltage drop increases with the increase in the flow of current. It is also caused by the loose and intermittent connections in the circuit. If the wire fails to meet the code standards, voltage drop is occurred.

Poor splices in the conductor and insufficient seating of wire in the slot cause voltage problem too. Sluggish and lazy electrical devices, high computer voltages, repeated cable failures and hard starts bring about voltage drops as well.

Consequences of voltage drop

Excess voltage drop proves dangerous. It can result into harmful consequences.

- Low voltage causes no operation in the equipment. The equipment in turn stops working. Sometimes the fault can be repaired, at times the device becomes completely useless.

- Energy is wasted. It greatly affects the efficiency of the equipment.
- Low voltage and high resistance may result in fire. Fire causes destruction which may prove fatal.
- It can cause lights to flicker dimly. This condition forces the device to work harder with less voltage.
- The houses with bad and old wiring face voltage drop very often.
- If the transformer is far away from the wiring system, the resistance increases and voltage drop occurs.
- The above mentioned consequences must be carefully observed. If the voltage drop occurs very much, adequate measures must be taken immediately to avoid the unwanted situation.

Voltage drop across cables

Cable power losses or power drop are due to the conductor resistance heating that occurs when current flows. These cable losses are more often called KW losses or I^2R losses. This is expressed by the following formula:

Power losses = $3 \times (I^2R) /1000$

Where: Power losses in kW units, I is the current (in amps) and R (in ohms) is the average conductor resistance.

How to lower the resistance in the cable?

Power lost in a cable depends on the cable length, cable size and the current through the cable. Therefore, there are three ways to lower the resistance in the cable:

- Shorten the length of the cable,
- Increase the size of the conductor,
- Decrease the current through the cable.

Minimizing cable length:

Minimizing cable length reduces significantly the cost factor when purchasing the cable and has a long-term effect on KW losses in the ESP system.

Conductor size selection:

The higher the conductor size, the higher the initial capital cost of the cable. Therefore, there are many factors to be considered when purchasing the cable:

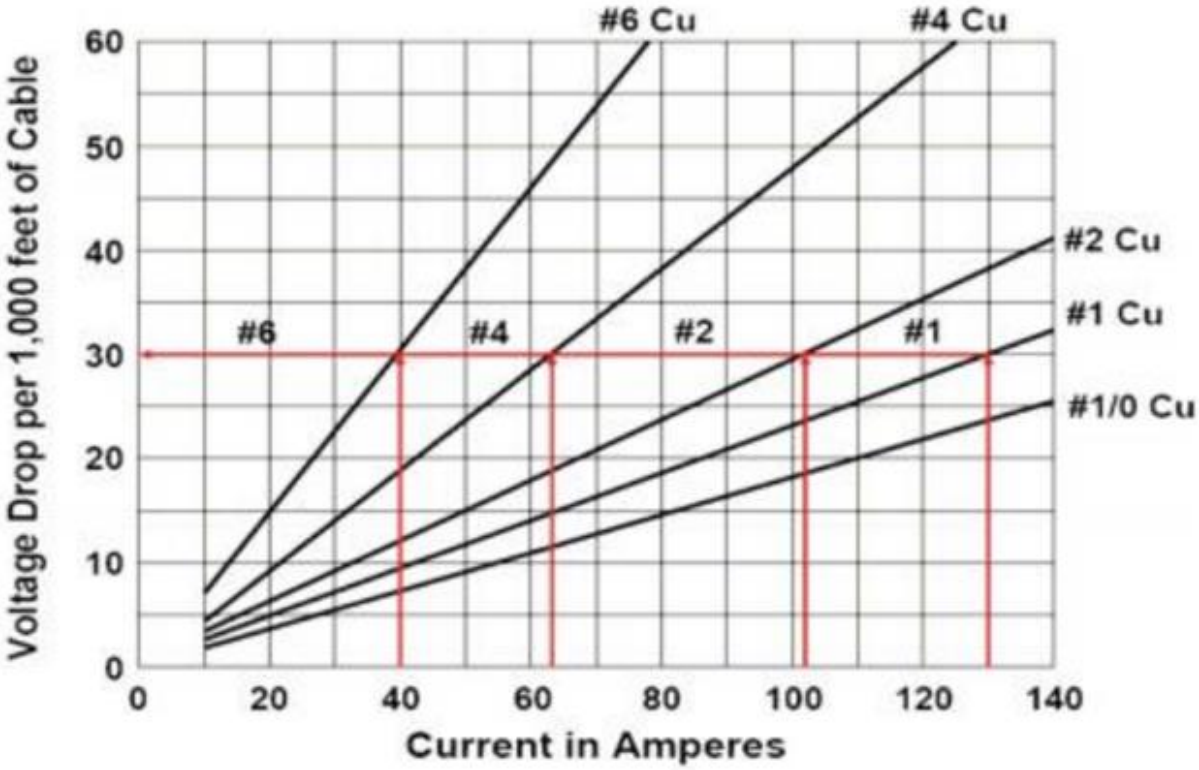
- What’s the current (amps) load expected today?
- What will be the current load in the future if the water cut increases to +90%?
- What will you pay for KW losses today and tomorrow to handle future well fluid rates?

Increasing the size of the conductor lowers the resistance in the cable and therefore reduces power losses. In the other hand, as mentioned above the higher the conductor size, the higher the initial capital cost of the cable. Nevertheless, power cost saving can generally pay for the increase cost of the cable in 2 years.

Voltage drop

Voltage drop is determined from the size and length of the conductor at the bottom hole temperature. In order to select the proper surface voltage, the cable voltage drop has to be added to the motor's nameplate voltage. Further, the main cause of the voltage drop is resistance of the cable. The resistance arises due to the length and size of the cable. Also, the voltage drop can be calculated by using ohm's law but first you need to calculate the resistance of the cable.

The following graph shows an example of Cable Voltage drop plot to determine the voltage drop in cable. At the selected motor amperage and the given down hole temperature, the selection of a cable size that will give a voltage drop of less than 30 volts per 1000 feet is recommended. This curve will also enable you to determine the necessary surface voltage (motor voltage plus voltage drop in cable) required to operate the motor.



TYPES OF MEASURING INSTRUMENTS

Some of the instruments are used for dc measurements only and some are used for ac measurements only. Some are used for dc as well as ac measurements. In this article we will be discussing about types of measuring instruments.

DC MEASURING INSTRUMENTS

The instruments, whose deflections are proportional to the current or voltage under measurement are used for dc measurements only. If such an instrument is connected in an ac circuit. The the pointer will deflect up-scale for one half cycle of the input waveform and down-scale for the next half cycle.

At lower frequencies of 50 Hz, the pointer will not be able to follow the variations in direction. And the pointer will pulsate slightly around the zero mark, seeking the average value of ac, i.e., zero. The permanent magnet moving coil (PMMC) instruments fall under the category of dc instruments.

AC MEASURING INSTRUMENTS

These types of measuring instruments utilizes the electromagnetic induced currents for their operation are used for ac measurements only. These instruments cannot be used for dc measurements because the electromagnetic induced currents are not generally available in dc circuits.The induction instruments fall under the category of ac instruments.

DC/AC MEASURING INSTRUMENTS

These types of measuring instruments having deflection proportional to the square of the current or voltage under measurement can be used for dc as well as ac measurements. Moving iron, dynamo-meter type moving coil, hot-wire, electrostatic instruments fall under this category.

The various types of measuring instruments used for measurement of current, voltage, power, and energy along with suitability for the type of measurements, type of control, type of damping, special features and applications are given below in tabular form.

AMMETERS AND VOLTMETERS

Ammeters and voltmeters, except electrostatic voltmeter, operates on the same principle. The ammeter carries the current to be measured or a definite fraction of it and this current produces the deflecting torque. On the other hand voltmeter carries the current proportional to the voltage to be measured which produces the deflecting torque.

Essential requirements of a measuring instruments are:

- Its introduction into the circuit, where measurements are to be made, does not alter the circuit condition.
- The power consumed by them for their operation is small.

Ammeters

It is connected in series with the circuit carrying the current under measurement. It must be very low resistance because the voltage drop across the ammeter and power absorbed from the circuit should be as low as possible.

S.No.	TYPE OF INSTRUMENT	SUITABILITY FOR TYPE OF MEASUREMENT	TYPE OF CONTROL	TYPE OF DAMPING
1.	MOVING IRON	DC OR AC (current and voltage)	SPRING OR GRAVITY CONTROL	AIR FRICTION
2.	MOVING COIL: 1. PERMANENT MAGNET TYPE 2. DYNAMOMETER TYPE	DC (current and voltage) DC OR AC (current and voltage)	SPRING DO	EDDY CURRENT AIR FRICTION
3.	THERMAL 1. HOT WIRE 2. THERMOCOUPLE	DC OR AC (current and voltage) DC OR AC (current and voltage)	SPRING DO	EDDY CURRENT DO
4.	ELECTROSTATIC	DC OR AC (VOLTAGE ONLY)	GRAVITY OR SPRING	AIR FRICTION
5.	INDUCTION	AC (current, voltage AND POWER)	SPRING	EDDY CURRENT
6.	RECTIFIER	DC OR AC (current and voltage)	DO	DO

Voltmeter

It is connected in parallel with the circuit across which the voltage is to be measured and must be very high resistance.

It is because the current flowing through the voltmeter and the power absorbed from the circuit should be as minimum as possible.

Ohmmeter

These are used for measurements of resistance. They incorporate a source of emf and a current measuring device.

Power loss in measuring instruments

Let $\mathbf{R_a}$ be the resistance of the ammeter and **I** be the current being measured.

Power loss in ammeter $\mathbf{P_a = I^2R_a}$ watt

If **R** be the resistance of voltmeter and **V** be the voltage being measured,

Power loss in voltmeter = $\mathbf{V^2/R}$ watt.

Thus, in order that the power loss in instruments is small, so resistance of ammeters should be small and that of voltmeter should be large.

Types of Measuring Instruments

The main type of instruments used as ammeters and voltmeter are:

- Moving iron
- Moving coil
- Electrodynamometer
- Hot wire
- Thermocouple
- Induction

- Electrostatic
- Rectifier

Of these the moving coil type can be used for direct current measurements only, and the induction type for ac measurements only. The other type can be used with either dc or ac.

Power measurements

Power measurement option is provided with the voltage and current measuring multimeters. But on the other hand, it can be measured indirectly by measuring the voltage, current and resistance. For voltage or current and resistance, power can be calculated.