ELECTRICAL EQUIPMENT IN MINES

Semester: 4TH

STUDY MATERIAL

ELECTRICAL EQUIPMENT IN MINES

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Underground Cables

An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

Construction of Cables:-

The main parts of underground cables are :

Cores or Conductors: The conductor of cable could be of aluminum or copper,cable may have one or more than one core depending upon the type of services for application .

It may be:

a- Single Core.
b- Two Core.
c- Three Core
d- Four Core.

(2) Insulation*:* Each core or conductor is provided with a suitable thickness of insulation, the thickness of layer depending upon the voltage to be withstood by the cable. The commonly used materials for insulation are impregnated paper, varnishedcambric or rubber mineral.

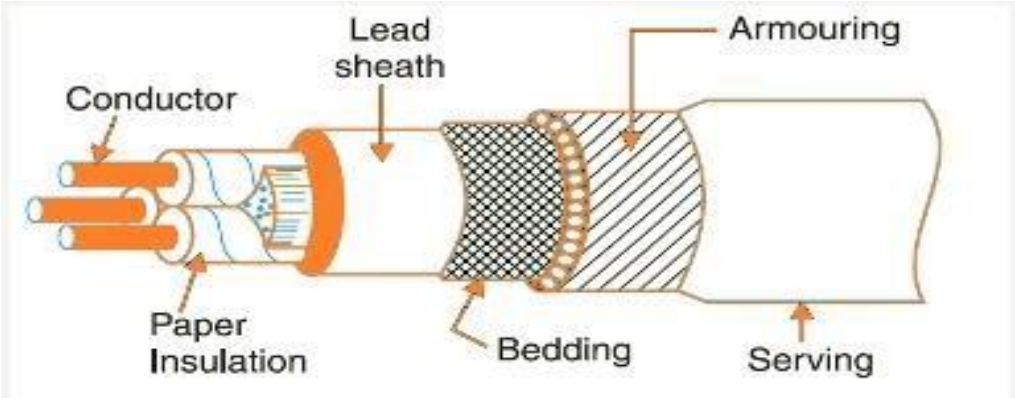
(3) ***Metallic sheath:*** In order to protect the cable from moisture, gases or other damaging liquids in the soil and atmosphere, a metallic sheath of lead or aluminum is provided over the insulation as shown.

(4) ***Bedding:*** Over the metallic sheath is applied a layer of bedding which consists of a fibrous material,the purpose of bedding is to protect the metallic sheath against corrosion and from mechanical damage.

(5) ***Armouring:*** Over the bedding, armouring is provided which consists of one or two layers of galvanized steel wire or steel tape. Its purpose is to protect the cable from mechanical injury while laying it and during the course of handling. Armouring may not be done in the case of some cables.

(6) ***Serving:*** In order to protect armouring from atmospheric conditions, a layer of fibrous material (like jute) similar to bedding is provided over the armouring. This is known as *serving.*

2.



Classification of underground cables:-

The underground cable are classified according to voltage capacity and the construction of cable.

(A) Voltage Capacity

- LT Cables :Low tension cables with maximum capacity of 1000 V.
- HT Cables :High tension cables with maximum capacity of 11KV.
- ST Cables :Super tension cables with rating capacity of 22KV- 33KV.
- EHT Cables :Extra High tension cables with rating capacity of 33KV- 66KV.
- Extra Super voltage cables: with maximum voltage rating beyond 132KV.

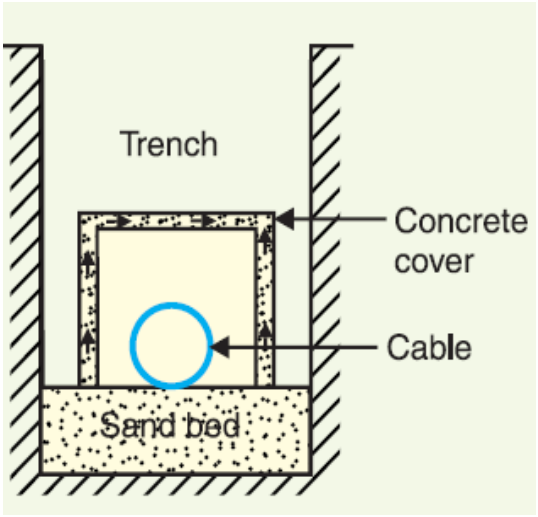
(B) Construction of cable

- Belted Cables : Maximum voltage of 11KV.
- Screened Cables : Maximum voltage of 66KV.
- Pressure Cables : Maximum voltage of more than 66KV.

Laying of underground cables:-

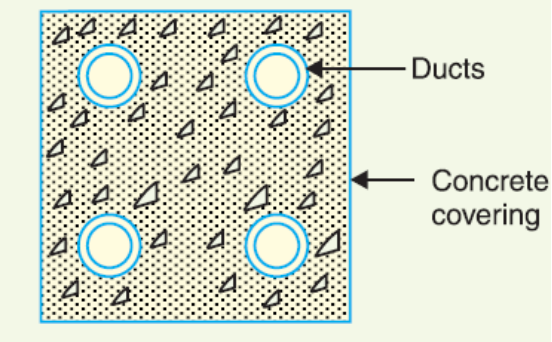
1. Direct laying:-

- This method of laying underground cables is simple and cheap and is muchfavored in modern practice.
- In this method, a trench of about 1·5 meters deep and 45 cm wide is dug.The trench is covered with a layer of fine sand .
- the cable has been laid in the trench, it is covered with another layer of sandof about 10 cm thickness. The trench is then covered with bricks and other materials in order to protect the cable from mechanical injury.
- When more than one cable is to be laid in the same trench, a horizontal or vertical inter axial spacing of at least 30 cm s provided in order to reduce the effect of mutual heating and also to ensure that a fault occurring on one cable does not damage the adjacent cable.



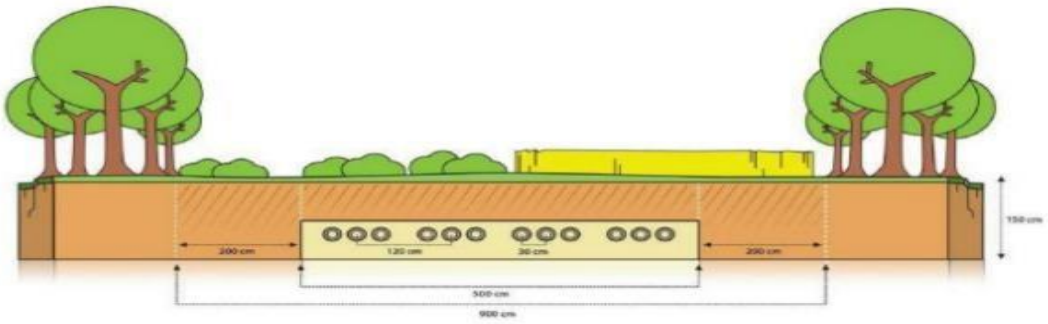
2. Draw in System:-

- In this method, conduit or duct of glazed stone or cast iron or concrete arelaid in the ground with manholes at suitable positions along the cable route.
- The cables are then pulled into position from manholes. Fig. 5-5 showssection through four-way underground duct line.
- This method is generally used for short length cable routes such as inworkshops and road crossings .



3.Solid System:-

- In this method of laying, the cable is laid in open pipes or troughs dug out in earth along the cable route. The troughing is of cast iron, stoneware, asphalt or treated wood.
- After the cable is laid in position, the troughing is filled with an asphaltic compound and covered over.
- Cables laid in this manner are usually plain lead covered because troughing affords good mechanical protection.
- This method is more expensive than direct laid system, but it provides good mechanical strength.



A comparison between underground cables and overhead T.L

1. Construction

Underground cables are more expensive , Construction of the cables is more complicated compared to the overhead cables which are simple to construct, and do not require insulation and sheathing. The overhead cables have lesser requirements andcheaper to construct.

2. Size of Conductors

Underground cables have larger conductor sizes compared to overhead lines for the same amount of power. This is due to the fact that the overhead lines have a naturalcooling and hence the ability to carry more power without heating up.

3. Voltage carrying capacity

The overhead lines are better suited to carry higher voltages compared to the underground cables, which are limited by the expensive construction and limited heat dissipation. For these reasons, the underground cables are mostly used for transmitting up to 33KV.

4. Fault detection and repair

It is easier to detect and repair faults in overhead cables. It is more complicated and takes more time to locate and repair the underground systems.

5. Public safety

Underground cables are safer to the public, animals and environment compared to the overhead lines i.e. there are no issues such as people getting in contact with fallen lines.

6. Interference

Overhead lines interfere with communication lines that are in close proximity, have corona discharge, radio and TV interference which does not happen with the underground lines.

7. Voltage drop

There is more voltage drop in the overheads due to the fact that their cables are of much smaller diameter than underground cables for the same power delivery.

Electric Braking

Sometimes it is desirable to stop a d.c. motor very quickly. This may be necessary in case of emergency or to save time if the motor is being used for frequently repeated operations.

-In Electric braking, the kinetic energy of the moving parts (i.e motor) is converted into electrical energy which is dissipated in a resistance as heat or alternatively it is returned to the supply source.

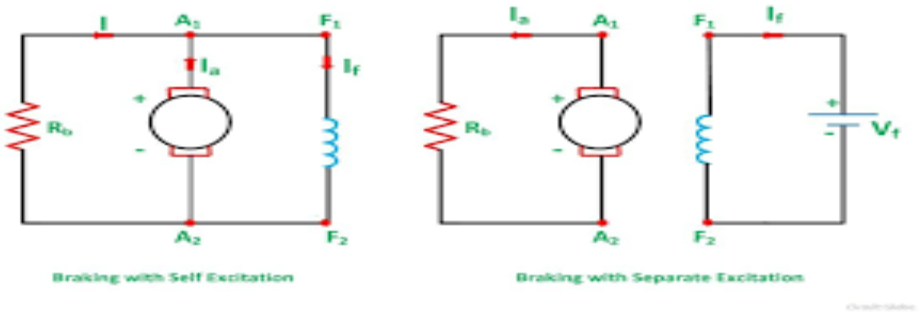
Regenerative Braking:-

-In the regenerative braking, the motor is run as a generator.As a result, the kinetic energy of the motor is converted into electrical energy and returned to the supply.

There are two methods of regenerative braking for a shunt motor.

(a)In one method, field excitation is disconnected from the supply and field current is increased by exciting it from another source.As a result, induced e.m.f E exceeds the supply voltage V and the machine feeds energy into the supply. Thus braking torque is provided upto the speed at which induced e.m.f. and supply voltage are equal.

-As the machine slows down, it is not possible to maintain induced e.m.f at a higher value than the supply voltage.Therefore,this method is possible only for a limited range of speed.



(b)In a Second method, the field excitation does not change but the load changes the motor to run above the normal speed. As a result, the induced emf E becomes greater than the supply voltage V.The direction of armature current I, therefore reverses but the shunt field current I_f remains unaltered. Hence the torque is reversed and the speed falls until E becomes less than V.

Magnetic Braking:-

Electromagnetic braking means applying brakes using electronic and magnetic power. Here we use the principle of electromagnetism to achieve friction less braking. This tends to increase the life span and reliability of brakes since no friction leads to less wearing out of brakes. Also it requires less maintenance and oiling. The main purpose behind the proposed use of these brakes in vehicles is that it is frictionless. This leads to a sizably less maintenance cost due to no friction and no oiling. Also traditional braking systems are prone to slipping while this one is guaranteed to apply brakes to the vehicle. So without friction or need of lubrication this technology is a preferred replacement for traditional braking. Also it is quite smaller in size compared to the traditional braking systems. To make electromagnetic brakes work, a magnetic flux when passed in a direction perpendicular to the rotating direction of the wheel, we see eddy current flowing in a direction opposite to the rotation of the wheel. This creates an opposing force to the wheel rotation and in turn slows down the wheel.

Eddy Current Brake:-

An eddy current brake, also known as an induction brake, electric brake or electric retarder, is a device used to slow or stop a moving object by generating eddy currents and thus dissipating its kinetic energy as heat. Unlike friction brakes, where the drag force that stops the moving object is provided by friction between two surfaces pressed together, the drag force in an eddy current brake is an electromagnetic force between a magnet and a nearby conductive object in relative motion, due to eddy currents induced in the conductor through electromagnetic induction.

Protective System

Classification and construction of relay

Electromechanical relays

These relays are constructed with electrical, magnetic & mechanical components & have an operating coil & various contacts,& are very robust & reliable. Based on the construction, characteristics, these are classified in three groups.

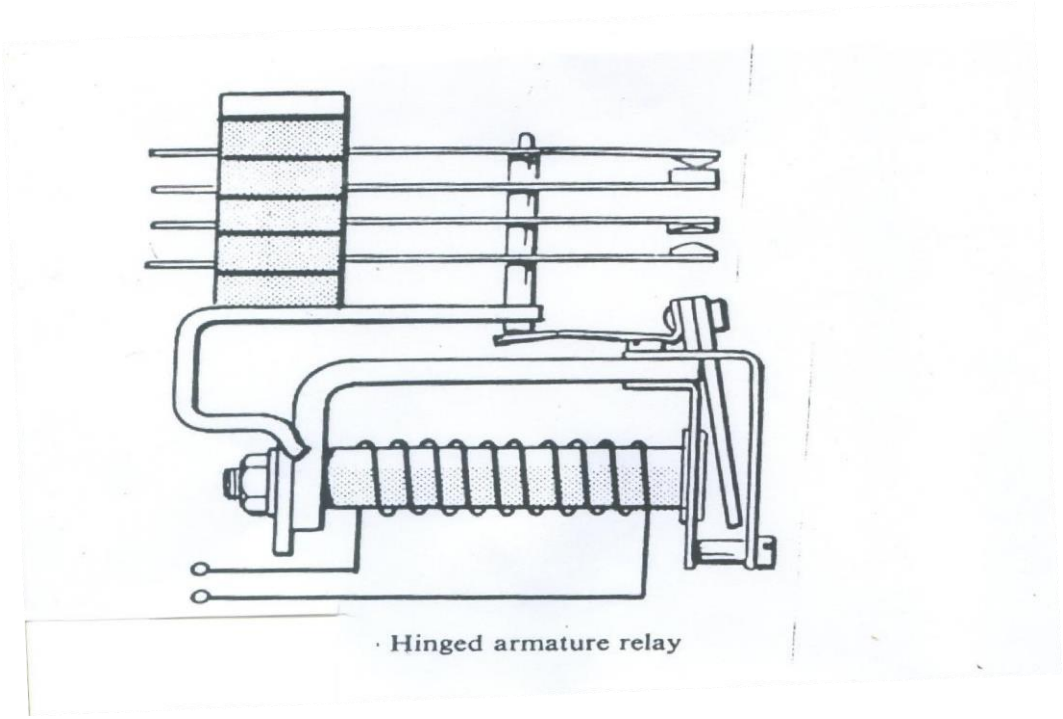
Attraction relays

Attraction relays can be AC & DC and operate by the movement of a piece of iron when it is attracted by the magnetic field produced by a coil. There are two main types of relays:

1. The attracted armature type
2. Solenoid type relay

Attracted armature relays

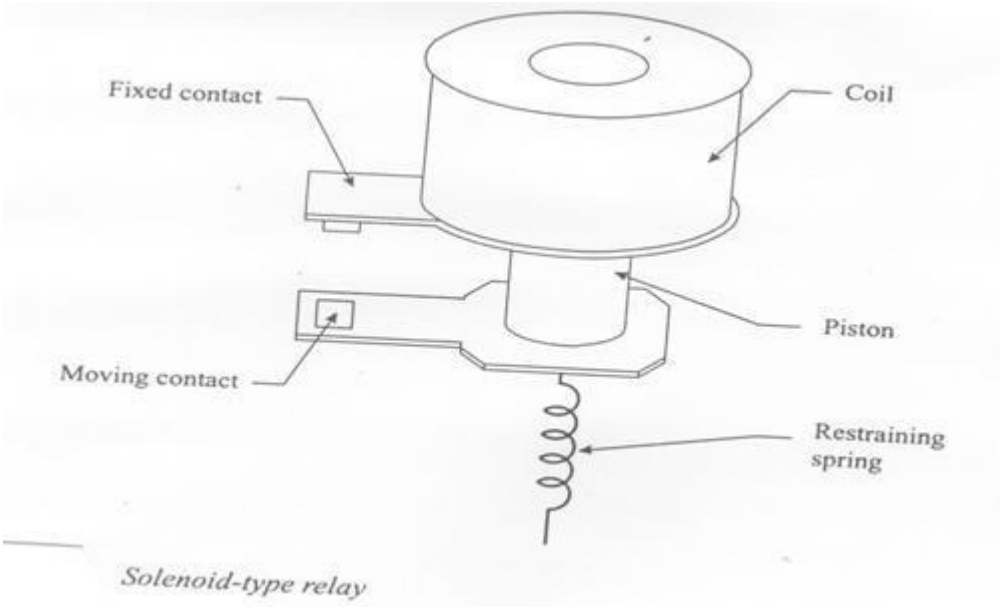
- Consists of a bar or plate (made of iron) that pivots when it is attracted towards the coil.
- The armature carries the moving part of the contact ,which is closed or opened, accordingto the design, when the armature is attracted to the coil.



Hinged armature relay

Solenoid type relays

In this a plunger or a piston is attracted axially within the field of the solenoid. In this case, thepiston carries the moving contacts.



Solenoid-type relay

The force of attraction = $KI^2 - K$

Where, K depends on

- The number of turns of the coil

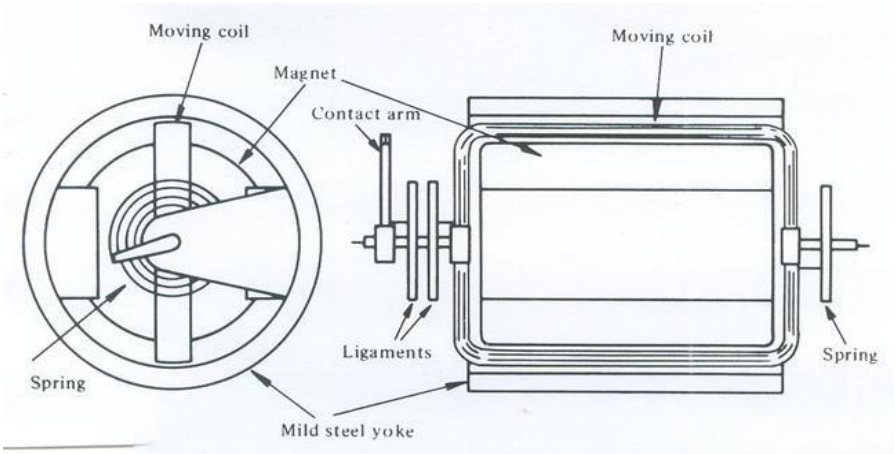
- The air gap
- The effective area
- The reluctance of the magnetic circuit

$$K_1 I^2 = K_2 \qquad I = \sqrt{\left(\frac{K_1}{K_2}\right)}$$

In order to control the value of current at which relay operates, the parameters K_1 and K_2 may adjusted. Attraction relays effectively have no time delay and are widely used when instantaneous operation is required.

Relays with movable coils

This type of relay consists of a rotating movement with a small coil suspended or pivoted with the freedom to rotate between the poles of a permanent magnet. The coil is restrained by two special springs which also



Moving-coil relay for protection schemes

serve as connections to carry the current to the coil.

The torque produced in the coil is

$$T = BlaNi$$

Induction relays:-

- An induction relay works only with AC
- It consists of an electromagnetic system Which operates on a moving conductor,generally in the form of a DISC or CUP

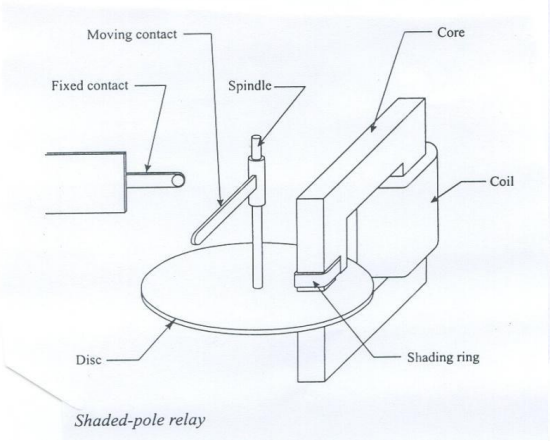
Classification of induction relays

1. Shaded pole relay
2. Watt hour- meter type relay
3. Cup type relay

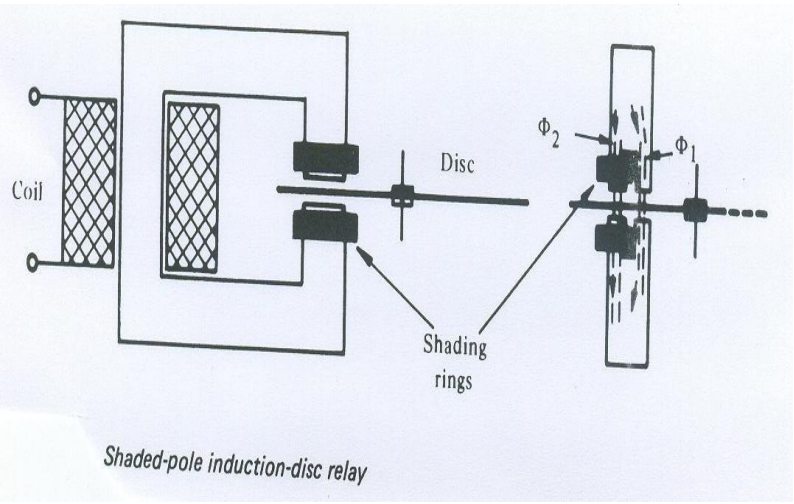
Shaded pole relay:-

The air gap flux produced by the current flowing in a single coil is split into two out ofphase components by a so called „Shading Ring“ generally of copper, that encircles part of the pole face of each pole at the air gap.

- The shading ring may be replaced by coils if control of operation of the shaded pole relayis desired.
- The inertia of the disc provides the time delay characteristics.



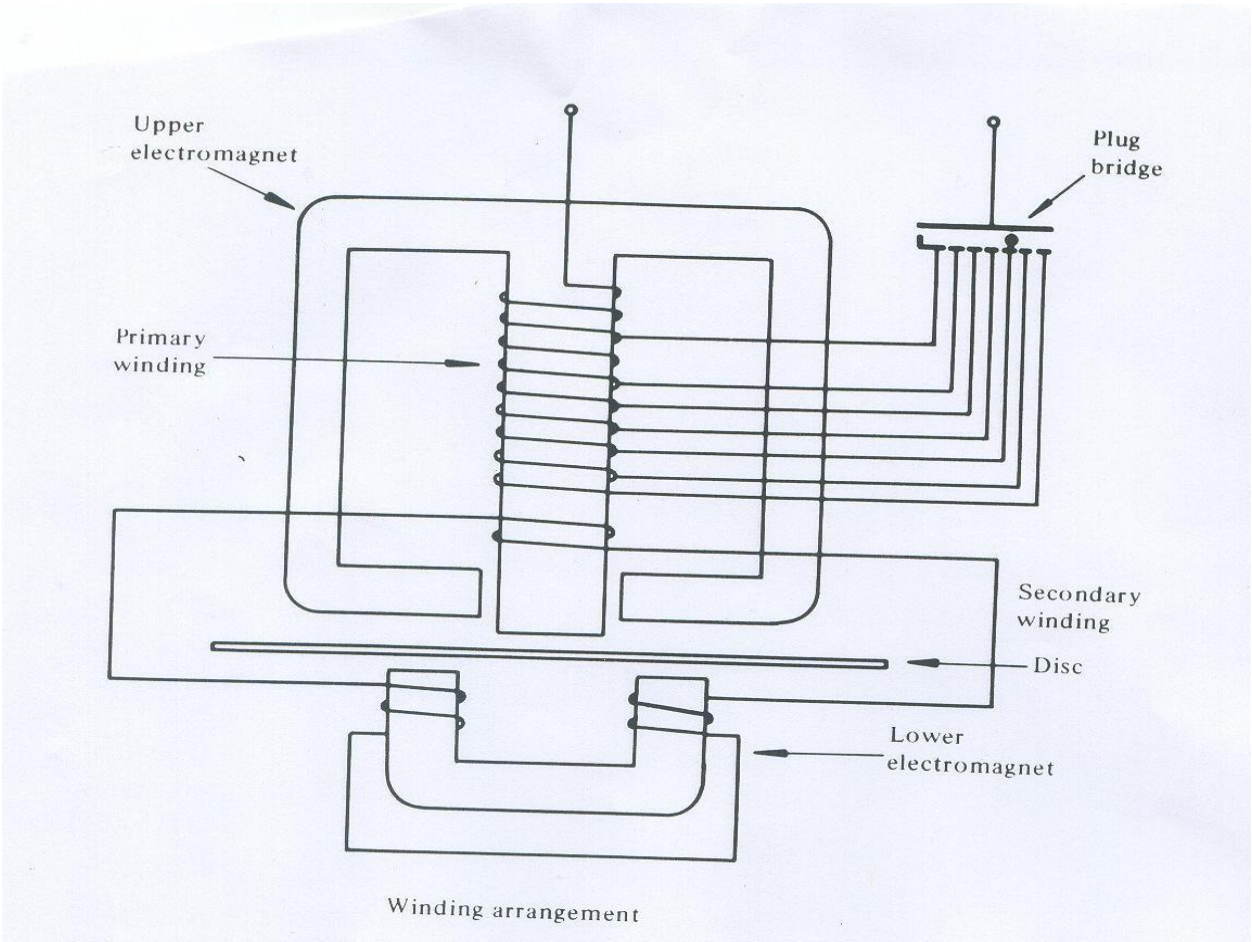
Shaded-pole relay



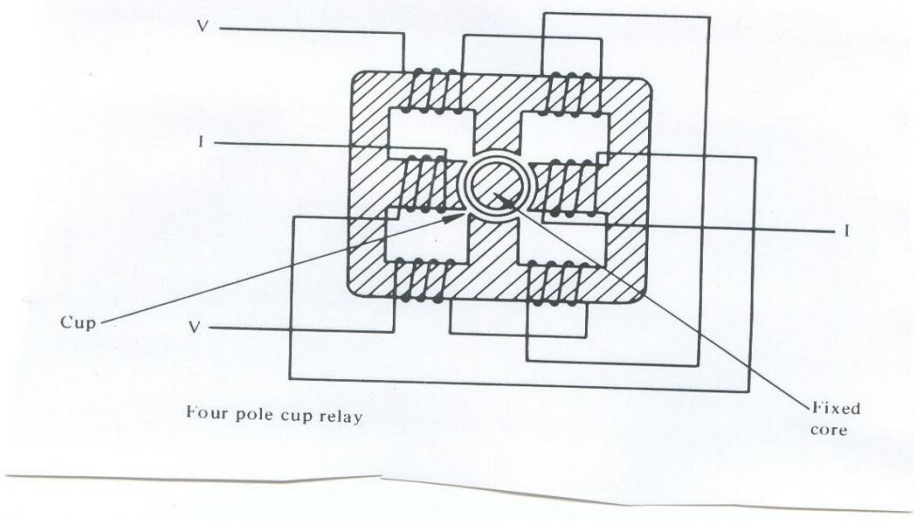
Shaded-pole induction-disc relay

Watt hour –meter structure:-

- This structure gets its name from the fact that it is used in watt hour meters.
- As shown in the top figure below, it contains two separate coils on two different magneticcircuit, each of which produces one of two necessary fluxes for driving the rotor, which is also a disc



Winding arrangement



Four pole cup relay

Sensors:-

A Sensor is a device that detects a physical parameter(heat,light,sound)and convert into electrical signal that can be measured and used by an electrical or electronic system.

Types of sensors:-

There are many sensors commonly used in various applications . All these sensors are categorized as per their physical properties like temperature, résistance, pressure, heat flow etc. The following are different types of sensors.

1) Temperature sensors:-

A temperature sensor is used to measure the amount of energy in the form of heat and cold produced by an object and system. It allows one to sense or detect any physical change to that energy and gives the output as analog or digital.Temperature sensors are used in various applications such as notification of environmental temperature, medical instruments, automobiles etc. According to application and its characteristics, many different types of temperature sensors are available. There are basically two types of temperature sensors, contact temperature sensor and non-contact temperature sensor. In contact temperature sensor, there is physical contact with the object being sensed and to monitor the change in temperature, conduction is used. It is used to sense solids, liquids or gases over a wide range of temperatures. In a non-contact temperature sensor, we use convection and radiation properties to measure the changes in temperature. It uses radiant energy in the form of heat and cold.

• Thermostat: The thermostat is a kind of contact temperature sensor employing an electro-mechanical component and using two thermally different kinds of metals, nickel, copper, tungsten or aluminum etc, which are stuck together to form a Bi-metallic strip. When it is cold, one of the strips is contracted and its contacts are closed and current passes through the thermostat. When it is hot, one metal strip is expanded and opens the contacts to stop the flow of current.

• Thermistor: The thermistor is another type of temperature sensitive device or resistance whose electrical resistance changes as the object temperature changes. This is made up of semiconductor materials. When temperature of the object or surroundings increases or decreases, resistance will also increase or decrease. How much the resistance will increase or decrease depends on the properties of the semiconductor material. The thermistor is of two types: positive temperature coefficient, (PTC) and negative temperature coefficient,(NTC). In PTC, resistance value increases with an increase in the temperature and in NTC, its resistance value goes down with an increase in the temperature. Thermistors are used for precise temperature measurement, control and compensation. Thermistors are highly sensitive and exhibit non-linear characteristics of resistance versus temperature. Generally, these are made up of manganese, nickel, cobalt, copper and iron.

• Resistive temperature detector: The resistive temperature detector (RTD) is also known as resistance thermometer, and used for measurement of temperature. It is based on the temperature coefficient of sensors and generally composed of high-purity conducting metals like platinum, copper or nickel.These materials are looped into a coil whose changes of electrical resistance depend on a temperature function. The working principle of an RTD is very similar to that of the thermistor.

• Thermocouple: The thermocouple is a device which is used for the measurement of the temperature variation in a measurement of sensors. The thermocouples are coupled with two metals joined together forming a junction. Thus, there are two junctions in the metals, one is called hot junction and other is called cold junction, also referred as measuring junction and reference junction, respectively. These junctions are kept at different temperatures due to the change of EMF (electromotive force) induced in a thermocouple and output voltage obtained with the help of the relationship between the voltage and temperature. When the two junctions are at different temperatures, a voltage is developed across the junction which is used to measure the temperature sensor. The thermocouple is based on three main effects:Thomson effect, Seebeck and Peltier effect. It has broadest range of temperatures of all the temperature sensors, covering from −200 °C to2000 °C.

2) Position sensors:-

The position sensor detects the position of an object either linearly or in rotation with respect to some fixed point or position. Position can be determined by the distance between two points moving away from some fixed points. We can measure the displacement of position in a straight line by linear sensor and angular displacement using rotational sensors. Position sensors are also known as potentiometers and used to measure the displacement of the object. A potentiometer can be an electrical or resistive type of sensor, because its working principle is based on change in

resistance of wire with its length. This converts rotary or linear displacement to electrical voltage. The resistance of wire is directly proportional to length of wire. If the length of wire changes then the resistance of wire also changes. Potentiometers are available rotary and linear potentiometers in the market, and can be used to measure the angular position and linear position, respectively;
through voltage division the changes in resistance can be used to create an output voltage that is directly proportional to the input displacement. The sensors have three terminals, where the one in the middle is known as the wiper, and the other two are known as the ends. The wiper is a movable contact where resistance is measured with respect to it and either one of the end terminals. The displacement of the moving object is measured with the help of the sliding element of the potentiometer. When position of the moving body changes then its resistance between two fixed points also changes. The result is obtained in the form of differential output voltage which varies linearly with the movement of core position. The resulting output signal has both the amplitude and polarity. Amplitude is calculated as linear function of the displacement and polarity gives the direction of movement. Major advantages of the potentiometer include user friendly operation, low cost, high amplitude output and the sensors are used for measuring even large displacement, but its operating cycles are limited.

3) Light sensors

A light sensor is a photoelectric passive sensor which changes the light energy into an electrical signal output. It measures the ambient light which is surrounding light,room light and reflected light. The major component of a light sensor is the light dependent resister (LDR) or photo resistor. It is a resistor that depends on the light
Which changes its resistance depending on the amount of light incident on it. The sensors are made up of semiconductor materials and therefore when light is incident on semiconductor material it becomes low conductive and therefore has less resistance. When we increase the light intensity, its resistance decreases and vice versa Intensity of light falling on an LDR is measured in lux. There are different kinds of light sensors such as photo resistors, photodiodes, photovoltaic cells, phototubes, photomultiplier tubes, phototransistors, charge coupled devices (CCDs) etc.

4) Sound sensor

A sound sensor is also known as auditory and used to detect the intensity of sound.It converts the acoustic wave into an electrical signal output. These sensors can also detect sound pressure waves which are not within the audible range, making them suitable for a wide range of tasks. Sound sensors are mostly used for security
Purposes.

5) Proximity sensor

A proximity sensor can be used for detecting the presence of a nearby object without any physical contact. It emits an electromagnetic field for a beam of electromagnetic radiation as infrared instances and changes in the field returning a signal. The object being sensed is often referred to as the proximity sensor's target. Depending on different types of proximity sensors, different targets are used. For example, an inductive proximity sensor needs a metal object, whereas a capacitive photoelectric sensor is suitable for a plastic target. A proximity sensor has high reliability due to the absence of mechanical parts and lack of physical contact between the sensor and target. It has very short range when used as a touch switch. It is commonly used in industrial applications, manufacturing of food production, mobile phones etc.

6) Accelerometer

This sensor is used to detect the acceleration of an object, and operates by sensing the acceleration of gravity, and the direction of the object is calculated.
This sensor is a kind of microelectromechanical system (MEMS), which uses a silicon integrated circuit. These sensors convert the mechanical motion caused in an accelerometer into an electrical signal by using the piezoelectric, piezo-resistive and capacitive components.

7) Infrared sensor

An infrared (IR) sensor consists of two packs, one is Rx (receiver) and the other is Tx(transmitter). Transmitters are used in transmitting the rays in the infrared spectrum and the receiver receives the IR spectrum range. In the IR spectrum, the voltage is given between its terminals and then it emits rays. The main principle of working of an IR sensor is reflectivity by an object. When an object is placed in front of the transmitter it tends to reflect the rays that are coming from the IR sensor back to the IR sensor. Whenever a ray that is reflected by an object is received by the receiver it generates a voltage level across the terminal. This voltage level depends upon the intensity of light that is

reflected by the object. Transmitter and receiver are placed side by side, and the IR transmitter transmits a signal within a limited range and going to a certain distance. When IR rays hit the surface, some rays are reflected depending upon the colour of the surface. The brighter the colour the more IR rays are reflected; similarly, the darker the surface the more IR rays are absorbed by the surface and fewer IR rays are reflected back.

8) Pressure sensor

Pressure is an external force exerted on a surface in unidirectional areas. We commonly measure the pressure of liquid, air and other gases. A pressure sensor monitors this pressure and is sometimes called a pressure transmitter as it converts pressure into an electrical signal. The most common type of pressure sensor is the
strain gauge-based pressure sensor. Conversion of pressure into electrical signal is achieved through the physical deformation of strain gauge which is bound into the diaphragm of the pressure sensor. The strain will produce a change in electrical resistance which is proportional to the pressure. Change in voltage is the result of ambient pressure. A pressure sensor can also be used to measure other variables such as fluid or gas flow, speed, water level, and altitude.

9) Ultrasonic sensors

An ultrasonic sensor uses ultrasonic waves for the purpose of sensing and measuring the distance of a particular object. Ultrasonic waves are very high frequency waves.The sensors have two main transducers, namely transmitter and receiver. A transmitter uses 40 KHz of frequency wave transmitted in the air and when it is blocked by an object then its gets reflected and bounced back to the sensor. These reflected waves are absorbed by the receiver of the sensor. So, the total time taken by the ultrasonic waves to travel from the transmitter to the object and again from the object to the receiver of the sensor is given by the output of the sensor. Ultrasonic sensors are used in many applications such as robotics, driverless cars, for measuring distance, and also in radar systems etc.

10) Touch sensor

Touch sensors are sensitive to touch, pressure and force. The sensors operate as switches and when the surface of the sensor is touched the current starts to flow in `the circuit just like current flowing in a closed circuit. When there is no contact, it performs like an open circuit and no flow of current is reported. There are two types of touch sensors, capacitive and resistive. The touch sensors are used popularly in modern gadgets such as smartphones, and other handy devices.

• Capacitive sensor: The capacitive sensor has an important element as a capacitor. Parallel capacitors are generally placed like top and bottom platesat some certain distance and between these parallel capacitor plates there is a dielectric medium. The main principle of change in capacitance is used such that it may be caused by change in overlapping area, change in distance between two plates and change in dielectric constant. Changes of these parameters can be made by the physical variables like displacement, force, pressure and flow of liquid. Capacitance and output impedance are measured with a bridge circuit. An extremely small force is needed to operate them and hence they are very useful for a small system. The sensors are highly sensitive with good frequency response and high output. As force requirement is small, thus the power requirement is also less to operate the sensors. The metallic parts of the sensor must be insulated from each other in order to reduce the
effect of stray capacitance.

• Resistive sensor: The resistive sensor is based on the change in resistance of the material and is used to measure temperature, displacement, moisture etc.A slider is free to move between two points and at a certain point we get the zero output and at some other point we get the maximum output. The output voltage is obtained between these two points and it is directly proportional to displacement. So, the change in length of the wire causes the change in the value of the resistance. This property is utilized to measure the changes in displacement using resistivity and resistance. When the fixed voltage is applied across end terminals of the sensor, a proportional voltage is generated across the slider and this voltage can be calculated using voltage divider rule. As distance increases, the output voltage will also increase. The resistive technique used in this sensor can be used to sense or measure linear displacement.

11) Humidity sensor

Humidity is the amount of water present in the surrounding air and a hygrometer is the device which measures humidity directly. Humidity is a non-electrical quantity that is converted into electrical quantity by using resistance, capacitance and impedance properties. There are various parameters that change due to humidity. There are five

basic types of humidity sensor: resistive hygrometer, capacitive hygrometer, microwave refractometer, aluminum oxide hygrometer and crystal hygrometer.

• Resistive hygrometer: In a resistive hygrometer, the main element is a material whose resistance changes with the change in humidity or relative humidity. A wire or electrode coated with hydroscopic salt (lithium chloride) can be used for measurement of the humidity. Resistance of salt changes with humidity because hydroscopic salt absorbs moisture and its resistance decreases.

• Capacitive hygrometer: In a capacitive hygrometer, the changes in humidity are caused by the changes in the capacitance. Dielectric medium is used in the capacitor and the capacitor consists of two electrodes or plates and a dielectric medium is there between the plates. There is also some hydroscopic material which exhibits the change in dielectric constant with the change in the humidity. Therefore, such hydroscopic material or salt can also be used for construction of a capacitive hygrometer. If the change is very small, then the capacitor includes a frequency determining element in the oscillator and another frequency is produced by the beat frequency oscillator. This frequency is heterodyned and the difference in frequency is a measure of
relative humidity.

• Microwave refractometer: A microwave refractometer consists of two cavities,each coupled with Klystron. Klystron is a material which produces microwaves in which one cavity is filled with dry air and another cavity is filled with a mixture whose humidity is measured. In the mixture, water vapour will be present and due to the presence of water vapour, there will be a change in dielectric constant, and frequency of one of the oscillators changes consequently. If there is no change in dielectric constant, its frequency is going to be constant, whereas in the mixture water vapours are present, and there is change in dielectric constant which results in change in its frequency. Frequency changes are measured as the measure of humidity.

• Aluminum oxide hygrometer: In an aluminum oxide hygrometer, aluminum oxide is coated on anodized aluminum and this aluminum oxide exhibits a change in the dielectric constant with respect to changes in humidity. There are two electrodes in which one is the inner electrode and the other is the outer electrode made from a very thin layer of material like gold. Some pores are presents in the inner layer. Due to the change in humidity, dielectric constant changes and this change can be measured to measure the humidity by bridge or electric method. The errors are much reduced and the response time is small and therefore the response is very fast.
• Crystal Hygrometer: In a crystal hygrometer, crystals are coated with hydroscopic materials (hydroscopic polymers). These crystals are used as frequency determination elements in the oscillator, and therefore just like
with the capacitive hygrometer, if there is change in humidity then frequency also changes. Frequency changes due to the humidity as the mass of the crystal changes with amount of water absorbed by the coating.

This change in frequency is measured. Humidity sensors are used in industry, agriculture, the medical field, environment monitoring etc.

12) Colour sensor

A colour sensor is used to detect and identify various colour patterns and convert them into desired frequency as output. It consists of four photodiodes of red, green, blue and clear (no colour). All these photodiodes are connected in parallel and work as filters. For example, if we have to detect red colour, we use red colour filter for this purpose. Colour light signals are sensed by the photodiodes and we get the square wave signals with the frequency directly proportional to light intensity and that is transferred to the microcontroller and we get the result of colour.

13) Chemical sensor

A chemical sensor is a device which transmits chemical information from a chemical reaction. The chemical information may be of composition, concentration and chemical activity which originates from a chemical reaction or from physical activities. It has different applications such as for home appliances and the chemical
industries. The chemical sensor usually contains two basic components, which are a chemical resonance system known as the receptor and a physical chemical transducer. The receptor interacts with analytic molecules and the transducer sends the electric signal. A test sample is given to the receptor which checks composition connected with the transducer. The transducer collects the information from the receptor and sends it to the signal amplifier. This amplifies the signal from the transducer and sends it as output signals. There are two types of chemical sensors used to detect the composition: optical sensor and electro chemical sensor.

• Optical sensor: In the optical sensor, there are an emitter and a detector as the main elements. The emitter senses the light to the optical sensor and the light rays fall on the analyte and these rays may be reflected or refracted. These reflectedor refracted lights are passed through the detector. Now the detector receives these lights and according to their intensity, the chemical compound present is analysed. Operation of an optical sensor is very simple and it uses absorption coefficient characteristics of the medium and path length travelled by the rays.

• Electrochemical sensor: The electrochemical sensor operates by acting on gas molecules of interest and produces an electric signal proportional to the compound present in the gas. It consists of sensing modules and electrodes, separated by a thin layer of electrolyte. There are two plates and the centre is filled by electrolytes. One plate is the cathode and the other plate is the anode. An external membrane is introduced in solution and it is absorbed by certain ions from the solution. Therefore, chemical properties of the solution change and the electromagnetic field will also change; and consequently change in the electromagnetic field ensures that the chemical composition is present in the gas.

14) Seismic sensor

A seismic sensor measures small movements of the ground and also amplifies and records these small movements. It is also known as a seismometer, and is mostly used in measuring the details of earthquakes, volcanic eruptions and other vibrations. There are two types of seismic sensor, inertial seismometer and strain
meter or extensometer seismic sensor.

• Inertial Seismometer: The inertial seismometer consists of a weight suspended from a frame by a spring. The frame moves due to the vibration being measured but the mass is held stationary due to the spring. It is used to measure a large-scale vibration such as an earthquake. Now the movement of mass is converted for output as a digital electric signal. Since both types of seismic sensors most commonly output an electric signal, calibration is necessary to derive a relationship between the input and output.

• Strain meter or extensometer seismic sensor: In a strain meter seismic sensor, astrain gauge is used to measure the motion relative to the various points. It generally is used for smaller scale measurement and movement of mass is converted for output as a digital electric signal.

15) Magnetic sensor

Magnetics sensors respond to the presence or interruption of a magnetic field like flux, strength and direction by producing a proportional output. It converts magnetic information into an electrical signal for processing by the electronic circuit. A magnetic sensor is used in different types of application such as sensing position, velocity and movement of an object. There are different kinds of technology used to design a magnetic sensor. Fluxgate, Hall effect, resistive, inductive, proton processing etc, have a dissimilar approach of using magnetic sensors. A resistive magnetic sensor keeps the electrical resistance of the magnetic field and an inductive magnetic sensor uses coils surrounding its magnetic material, which have the ability to detect changes within the Earth's magnetic field. A fluxgate magnetic sensor uses the approach of changing flux parameters. Each type of technology focuses on a specific area for identifying measurements to be detected. Sensitivity of the magnet is increased by combining layers of magnetic alloys and the magnetic field is surrounded by an electric current, and variation within the field is detected. The output of a magnetic sensor increases with a strong magnetic field and decreases with a weak magnetic field.