Module 5

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Electricity Bill

5.1. Power rating of household appliances

You can usually find the wattage of most appliances stamped on the bottom or back of the appliance, or on its "nameplate." The wattage listed is the maximum power drawn by the appliance. Since many appliances have a range of settings (for example, the volume on a radio), the actual amount of power consumed depends on the setting used at any one time.

A refrigerator, although turned "on" all the time, actually cycles on and off at a rate that depends on a number of factors. These factors include how well it is insulated, room temperature, freezer temperature, how often the door is opened, if the coils are clean, if it is defrosted regularly, and the condition of the door seals.

To get an approximate figure for the number of hours that a refrigerator actually operates at its maximum wattage, divide the total time the refrigerator is plugged in by three.

The table below shows wattage of some typical household appliances.

Appliances	Wattage (range)
Clock Radio	10
Coffee Maker	900 - 1200
Clothes Washer	350 - 500
Clothes Dryer	1800-5000
Dishwasher	1200-2400
Hair Dryer	1200-1875
Microwave Oven	750-1100
Laptop	50
Refrigerator	725
36" Television	133
Toaster	800-1400
Water Heater	4500-5500

5.2. Definition of 'Unit' used for consumption of electrical energy

1 Unit Electricity is the amount of electrical energy consumed by a load of *1 kW power rating in 1 hour*. It is basically measurement unit of electrical energy consumption in *Joule*. 1 kWh (kilo watt hour) and 1 Unit are same. 1 kWh is the amount of energy consumption by 1 kW load in one hour. Therefore, **1 Unit = 1 kWh**.

Since,

1 Unit Electricity = 1 kWh

= 1 kW x 1 Hour

= 1000 W x 3600 seconds

= 3.6×10^6 Joule

Therefore, 1 Unit Electricity is equal to 3.6×10^6 Joule of electrical energy consumption

5.3. Two Part Tariff

The rate at which electrical energy is supplied to a consumer is known as tariff. • Although tariff should include the total cost of producing and supplying electrical energy plus the profit , yet it cannot be the same for all types of consumer.

When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the units consumed, it is called a two-part tariff.

In two-part tariff, the total charge to be made from the consumer is split into two components viz., fixed charges and running charges. The fixed charges depend upon the maximum demand of the consumer while the running charges depend upon the number of units consumed by the consumer. Thus, the consumer is charged at a certain amount per kW of maximum demand plus a certain amount per kWh of energy consumed.

i.e. Total charges = Rs (b × kW + c × kWh)

where, b = charge per kW of maximum demand

c = charge per kWh of energy consumed

This type of tariff is mostly applicable to industrial consumers who have appreciable maximum demand.

Advantages of two part Tariff:

- It is easily understood by the consumers.
- It recovers the fixed charges which depend upon the maximum demand of the consumer.
- It is independent of the units consumed.

Disadvantages two part Tariff:

- The consumer has to pay the fixed charges irrespective of energy consumed
- There is always error in assessing the maximum demand of the consumer.

Calculation of electricity bill for domestic consumers

The cost is composed of,

a) Fixed charges which are independent of the output and

b) running or operating charges which are proportional to the output.

Average power demand of an installation during a specific period can be obtained by dividing the energy consumption of the installation in kWh by the number of hours in the period.

Average power = (kWh consumed in the period) / (hours in the period)

Example1.

A consumer has the following connected load: 10 lamps of 60W each and two heaters of 1000W each. His maximum demand is 1500 W. On the average, he uses 8 lamps for 5 hours a day and each heater for 3 hours a day. Each unit is 5 INR. Find his total load, monthly energy consumption and amount of bill.

Solution.

Total connected load = 10 x 60+ 2 x 1000 = 2600W

Daily energy consumption = (8 x 60 x 5) + (2 x 1000 x 3) = 8400 Wh = 8.4kWh

Monthly energy consumption = 8.4 x 30 = 252 kWh

Electricity Bill: 1kWh = 1 unit, therefore 252 kWh = 252 unit.

Each unit cost is 5 INR, total 252 x 5 = 1260 /- INR

Example2:

A consumer has the following load schedule for a day:

From midnight (12pm) to 6 am = 200W; From 6am to 12 noon = 3000W, From 12 noon to 1 pm = 100W; From 1 pm to 4 pm = 4000W, From 4pm to 9 pm = 2000W; From 9pm to mid night (12pm) = 1000W. Find the load factor. If the tariff is Rs.10 per KW of max demand plus Rs.2/- per kWh, find the daily bill the consumer has to pay.

Solution:

Energy consumed per day i.e. in 24 hours = (200 x 6) + (3000 x 6) + (100 x 1) + (4000 x 3) + (2000 x 5) + (1000 x 3) = 44,300Wh

Average Power = 44,300 / 24 = 1846 W = 1.846 kW

Daily load factor = Average power / max power demand = 1846 / 4000 = 0.461 or 46.1%

Since max demand = 4kW M.D charge = 4* 10 = Rs.40/-

Energy consumed = 44.3kWh; Energy charge = 44.3 x 2 = Rs. 88.6/-

Daily bill of the consumer = Rs40 + Rs. 88.6 = Rs. 128.6/-

Equipment Safety measures:

5.4. Working principle of Fuse and MCB

Protective devices: Fuse and MCB

Electric circuits are vulnerable to various kinds of faults and short circuits are the highly harmful ones. This is where MCBs and fuses do their job. Both do the same thing: interrupt the current flow to the circuit or equipment and safeguard the circuit from electrical hazards. But their principle of operation and capabilities are different.

Fuse: Fuse is an electrical device that self-destructs and stops the current flow in a circuit whenever the current exceeds the predefined value.

A fuse works based on the thermal property of materials conducting electric current. It consists of a metal wire or conductor material which can conduct a predefined amount of current through it. Whenever excessive current flows through the fuse, the conducting material inside it melts down and therefore the current flow through it is interrupted.

MCB(Miniature Circuit Breaker): MCBs are resettable circuit protection device that, on the occurrence of faults, stops the current flow in a circuit. They trip during short circuits, overloads and rarely during ground faults.

It is an electromechanical device that works based on the electromagnetic as well as the thermal properties of the electric current. An electromagnetic mechanism present inside the MCB helps it to instantaneously interrupt the current flow during short circuits and the bimetallic strip present in it helps it to interrupt the current flow during overloads.

Comparison of fuse and MCB

Electric fuse	Miniature circuit breaker – MCB
Whenever excessive current flows through the fuse, the conducting material inside it melts down thereby interrupting the current flow.	An electromagnetic mechanism present inside the MCB helps it to instantaneously interrupt the current flow during faults.
Fuses other than rewireable fuses cannot be reused.	Miniature circuit breakers can be reused after the clearance of faults.
Fuses acts faster than MCB. Typical tripping time 2ms.	Tripping time for MCB is 20ms.
Can protect against short circuit and overloads.	Can protect against short circuit and overloads.
Cheaper than MCB.	MCB costlier than fuses.

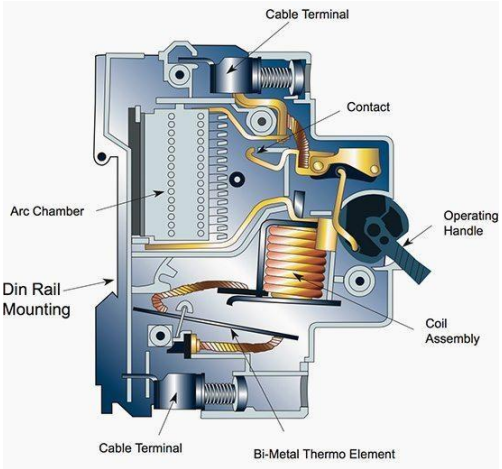


Fig: MCB cut-section view and Outer view

Fig: Fuse

Merits and Demerits

FUSE:

Advantages:

- Fuse is cheapest type of protection in an electrical circuit.
- Fuse needs zero maintenance.
- Operation of fuse is simple and no complexity is involved.
- Fuse has the ability to interrupt enormous short circuit current without producing noise, flame, gas or smoke.
- The operation time of fuse can be made much smaller than operation of circuit breaker. It is the primary protection device against short circuits.
- It affords current limiting effect under short-circuit conditions.
- Fuse inverse time current characteristic has the ability to use for over-load protection.

Disadvantage:

- During short circuit or overload once fuse blows off replacing of fuse takes time. During this period the circuit lost power.
- When fuses are connected in series it is difficult to discriminate the fuse unless the fuse has significant size difference.

MCB

Advantages of MCBs:

- MCBs have more sensitive to current then fuse.
- It has quick work against short circuits.
- It works quickly on overloading and under voltage.
- It is reusable hence less maintenance cost and less replacement cost.
- It is very simple to resume the supply.
- It can be easily used circuit control switch when needed.
- Handling MCB is electricity safer than handling fuse, in case of MCB.
- MCB performance immediate indication of faculty circuit.

- The performance of MCB is good in case of earth leakage.
- In the case of surge current, The MCB has time delay characteristics, therefore, it works properly.
- Shorter tripping time under moderate over current than with fuses.
- When the use of MCB, the faulty zone of the electrical circuit can be easily identified.

Disadvantages of MCBs:

- The cost of the MCB is greater than the fuse.
- The cost of the MCB distribution board is greater than the rewireable fuse board.
- The risk of overloading of the circuit due to unqualified of the person operating than completing removed.

Personal safety measures:

5.5. Electric Shock

A sudden agitation of the nervous system of a body, due to the passage of an electric current is called as electric shock.

Factors affecting the severity of shock:

- Magnitude of current through the body
- Path of current through the body
- Time for which the current passed through the body
- Frequency of the current
- Physical and psychological condition of the person.

Safety precautions to be taken against electric shock

1) Make sure that all metallic parts of the electrical equipment's are effectively earthed.
2) Broken switches, plugs, etc., should be replaced immediately.
3) Before replacing a broken switch, plug or blown fuse, always switch off the main supply.
4) Never use equipment's and appliances with damaged or frayed lead wires.

5) Never insert bare wires in the holes of a socket, for taking a connection. Always use a proper plug.

6) Always use well insulated tools.

7) Use correct rating of fuse wire.

8) Never try to connect machines or equipment to a voltage supply other than the rated one.

9) While working on an electric pole or tower, use safety-belt and a rubber padded ladder.

10) Strictly follow all the precautions and instructions given on the 'name plate' of the machine you are working.

11) Be careful that your body does not touch the wall or any other metallic frame having contact with earth.

5.6. Earthing

The connection of electrical machinery to the general mass of earth, with a conducting material of very low resistance is called earthing.

The earthing of electrical equipment brings the equipment to zero potential and avoid the shock to the operator, under any fault conditions.

Necessity of Earthing:

1. To protect the operating personnel from danger of shock in case they come in contact with the charged frame due to defective insulation.
2. To maintain the line voltage constant under unbalanced load condition.
3. Protection of the equipments.
4. Protection of large buildings and all machines fed from overhead lines against lightning.

Methods of Earthing:

The important methods of earthing are the **plate earthing** and the **pipe earthing**. The earth resistance for copper wire is 1 ohm and that of G I wire less than 3 ohms. The earth resistance should be kept as low as possible so that the neutral of any electrical system, which is earthed, is maintained almost at the earth potential. The typical value of the earth resistance at powerhouse is 0. 5 ohm and that at substation is 1 ohm.

Plate Earthing:

In this method a copper plate of 60cm x 60cm x 3.18cm or a GI plate of the size 60cm x 60cm x 6.35cm is used for earthing. The plate is placed vertically down inside the ground at a depth of 3m and is embedded in alternate layers of coal and salt for a thickness of 15 cm. In addition, water is poured for keeping the earth electrode resistance value well below a maximum of 5 ohms.

The earth wire is securely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance.

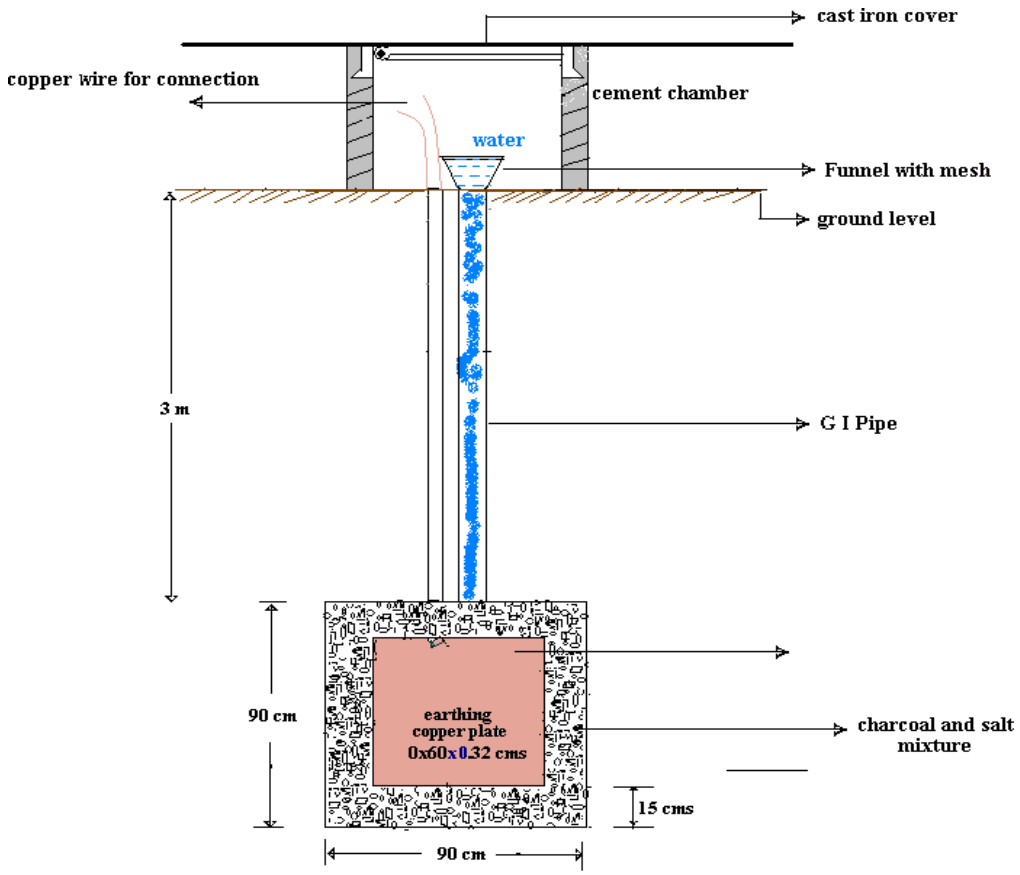
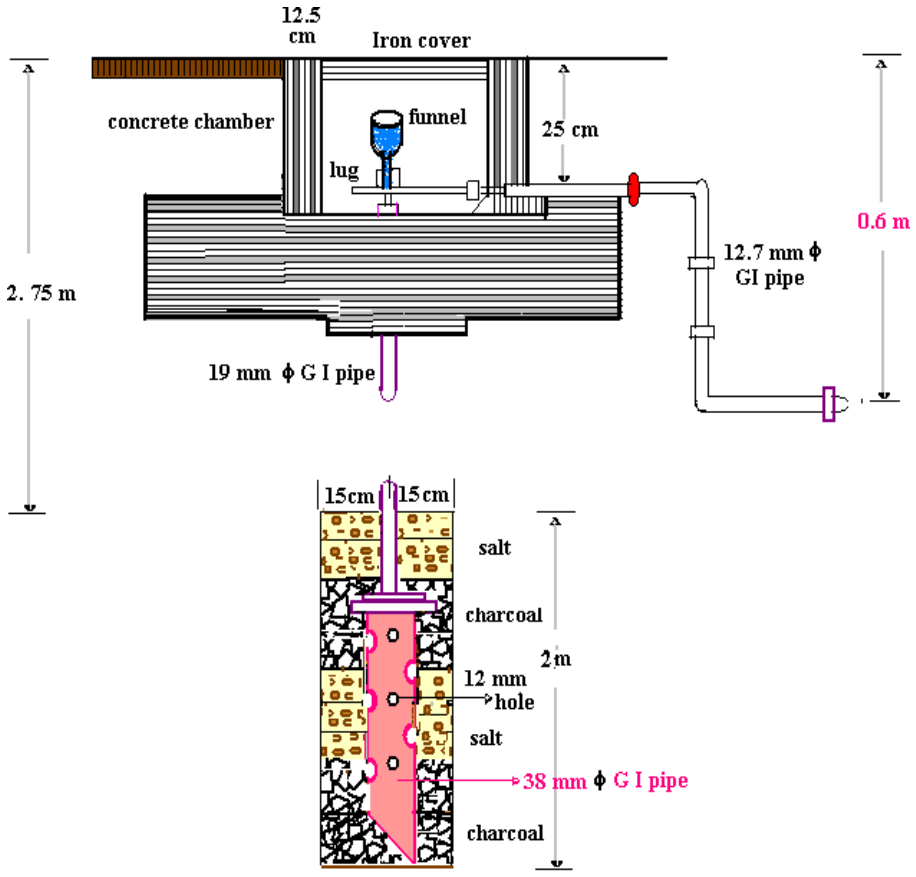


PLATE EARTHING

Pipe Earthing:

Earth electrode made of a GI (galvanized) iron pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75m in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15cms) surrounding the GI pipe is filled with a mixture of salt and coal.. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross- sectional area are

run through a 12.7mm diameter pipe (at 60cms below) from the 19mm diameter pipe and secured tightly at the top as shown in the following figure.



PIPE EARTHING

When compared to the plate earth system the pipe earth system can carry larger leakage currents as a much larger surface area is in contact with the soil for a given electrode size. The system also enables easy maintenance as the earth wire connection is housed at the ground level.

5.7. Residual Current Circuit Breaker

RCCB (**Residual Current Circuit Breaker**) falls under the category of wide range of circuit breakers. As we know there are several types of miniature circuit breakers like MCCB which works on different operational principle and has different safety purposes.

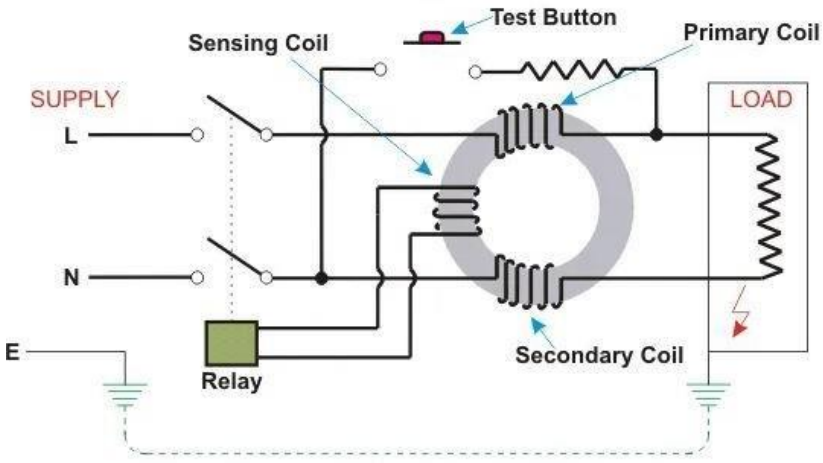
Function: Residual Current Circuit Breaker is essentially a device which senses current and disconnects any low voltage (unbalanced current) circuit whenever there is any fault occurs.

Purpose: Residual Current Circuit Breaker basically is installed to prevent human from shocks or death caused by shocks. It prevents accidents by disconnecting the main circuit within fraction of seconds.

How Residual Current Circuit Breaker Works?

It has very simple working based on Kirchhoff's Current Law i.e, the incoming current in a circuit must be equal to the outgoing current from that circuit. This circuit breaker is made such that whenever a fault occurs the current balance of line and neutral did not matches (imbalance occurs, as the fault current finds another earthing path of current). Its circuit is made such that an every instance it compares the value of incoming and outgoing circuit current. Whenever it is not equal, the residual current which is basically the difference between the two currents actuates the circuit to trip/switch off.

Working Principle of Residual Current Circuit Breaker:



Working Principle of Residual Current Circuit Breaker

The basic operating principle lies in the Toroidal Transformer shown in the diagram containing three coils. There are two coils say Primary (containing line current) and Secondary (containing neutral current) which produces equal and opposite fluxes if both currents are equal. Whenever in the case there is a fault and both the currents changes, it creates out of balance flux, which in-turn produces the differential current which flows through the third coil (sensing coil shown in the figure) which is connected to relay.

The Toroidal transformer, sensing coil and relay together is known as RCD – Residual Current Device.

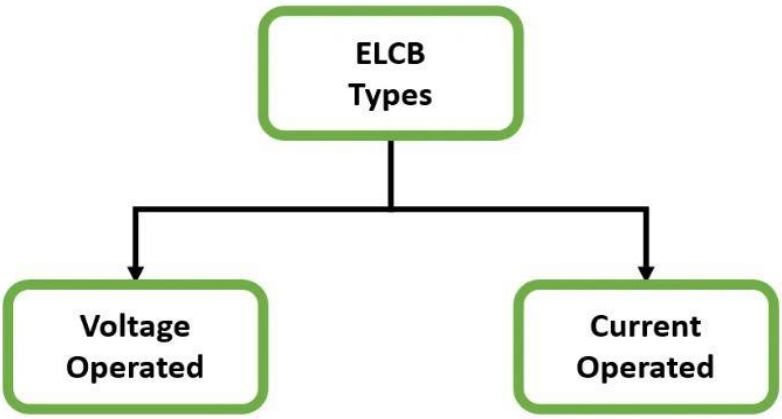
Test Circuit:

The test circuit is always included with the RCD which basically connects between the line conductor on the load side and the supply neutral. It helps to test the circuit when it is on or off the live supply. Whenever the test button is pushed current starts flowing through the test circuit depending upon the resistance provided in this circuit. This current passes through the RCD line side coil along with load current. But as this circuit bypasses neutral side coil of RCD, there will be an unbalance between the line side and neutral side coil of the device and consequently, the RCCB trips to disconnect the supply even in normal condition. This is how the test circuit tests the reliability of **RCCB**.

Earth Leakage Circuit Breaker:

ELCB is an Earth Leakage Protective device that detects current leakage that might be there in one's premise, and automatically trips and disconnects the electricity supply to the premise/equipment. As per the mandate by CEA and DERC, ELCB has to be installed at customer's electrical circuit along with MCB's. The electrical installations at homes, factories or workplaces have relatively high earth impedance. If ELCB is not installed in the premises, then there is a very high chance for Earth Leakage to occur due to intermixing of wiring or faulty wiring. In the absence of ELCB one has to constantly keep checking the Earth leakage LED indicator on the meter to check for Earth Leakage In case the ELT LED is found to be "ON" or "GLOWING" position or the meter display this sign then it signifies current leakage within the internal wiring of customer's premise. This is an unsafe condition, and can damage not only to the equipment's available in the premise but also pose danger to life and property at large, which can cause inconvenience to the customer.

ELCBs are two types.



Voltage Earth Leakage Circuit Breaker

Voltage ELCB is a voltage-operated Circuit breaker. The device will function when the current passes across the ELCB.

Voltage ELCB contains a relay coil which is connected to the metal body at one and connected to the ground on the other end.

Principle of Operation

If the voltage of the equipment body rises either by the failure of insulation of the equipment or by touching phase to metal parts, which could cause the difference between earth and body load voltage, the danger of electric shock will occur. This voltage difference will generate an electric current from the load metal framework that flows through the relay loop and to earth.

When the voltage on the appliance or equipment metallic body increase to the danger level which exceeds 50 V, the flowing current through the relay loop could move the relay contact by disconnecting the supply current to avoid any dangerous electric shock.

The ELCB detects fault currents from phase to the earth (ground) wire around an installation it protects. If sufficient voltage appears across the sense coil of the ELCB, power will get turned off, and remain in the same state till the circuit breaker is manually reset.

A voltage sensing ELCB does not sense fault currents from phase to any other earthed body. These ELCBs monitor the voltage on the earth wire and disconnect the supply if the earth wire voltage is more than 50 volts. The earth electrode must be placed outside the resistance area of any other parallel piles of earth in the surrounding area.

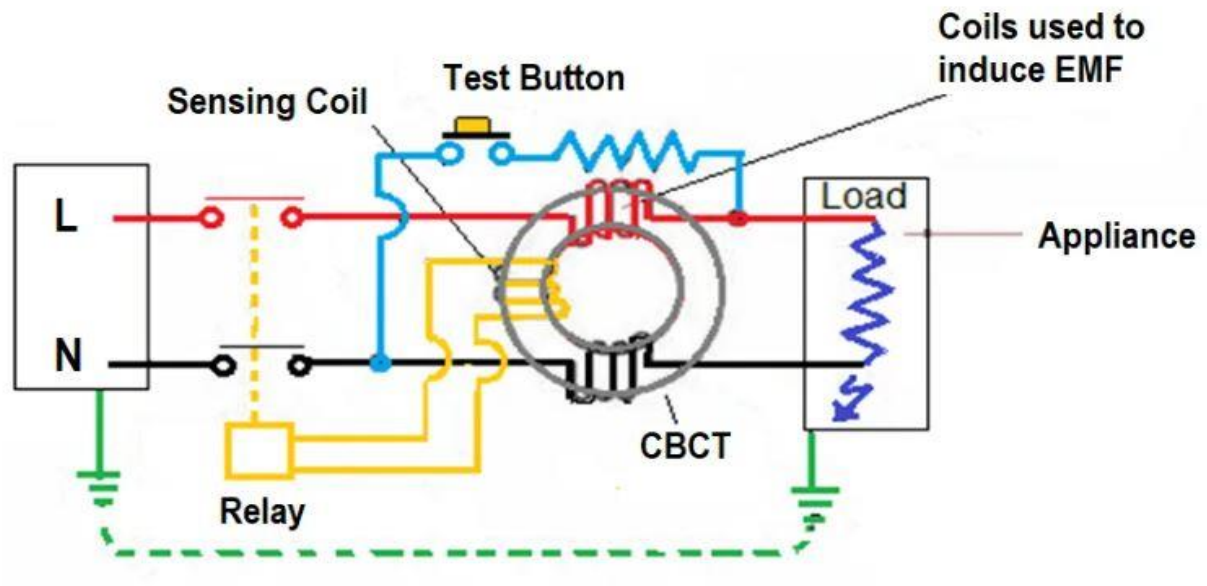
Current Earth Leakage Circuit Breaker

The current ELCB is a circuit breaker that is commonly used. It is also called RCCB (Residual Current Circuit Breaker).

Principle of Operation

The Current ELCB (or RCCB) consists of a three winding transformer, which has two primary windings and one secondary winding. It is called the Core Balance Current Transformer (CBCT).

Phase and neutral wires act as the two primary windings. A wire-wound coil is the Secondary winding.



At the balanced condition, the current through the secondary winding is zero. For example, if the phase wire carries 5A means same 5 A current will be returned to the neutral wire also. The sum of the current is zero. It is the normal state, in which the current ELCB doesn't get operated. Now consider a human touching a phase wire, it causes current to pass from phase to earth. Now phase carries 5A (normal load) plus 30 mA of fault current. But our neutral wire carries a 5A current. There is a difference of 30mA of current. It is sensed by the CBCT (Core Balanced Current Transformer and send to the relay operating coils.

When a fault occurs, a small amount of current will flow to the ground also. This makes an unbalance between phase and neutral currents and creates an unbalanced magnetic field. This induces a current across the secondary winding, which is connected to the sensing circuit. This will detect fault currents and send a signal to the tripping system and trips the contact.

Advantages

- Voltage-operated ELCB is less sensitive to fault conditions, therefore has fewer nuisance trips.
- They do not detect faults that are don't pass current through the circuit protective conductor (CPC) to the earth rod.
- Current operated ELCB is not affected by parallel earth.

Disadvantages

- Voltage-based ELCB devices are not used in the present days due to their drawbacks as if the fault is between phase and circuit earth, they will isolate the supply.

- Voltage ELCBs are not recommended over current ELCB (RCCB) and no longer available because of old technology.
- Voltage ELCBs detect faults that flow back through the main earth line.

Applications

- The voltage-operated E.L.C.B. is generally used where there are poor earthing conditions (for example, rocky or dry sub-soil).
- Current operated ELCB is a popular circuit breaker used in industrial, commercial, and household applications.