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DIRECTORATE OF TECHNICAL EDUCATION
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Diploma in Electrical and Electronics Engineering

Course Code: 1030
M – Scheme

e-TEXTBOOK
on

OPERATION AND MAINTENANCE OF ELECTRICAL EQUIPMENT

for

VI Semester DEEE

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DIPLOMA IN ELECTRICAL AND ELECTRONICS ENGINEERING

M - SCHEME

Course Name: Diploma in Electrical and Electronics Engineering

Subject Code: 1030 **Semester: VI**

Subject Title: OPERATION AND MAINTENANCE OF ELECTRICAL EQUIPMENT

RATIONALE

- Electricity is safe to use but may become dangerous in careless hands and may cause fire ,damage and fatal or non fatal accidents to personnel, unless appropriate elementary precautions are taken.
- The various activities concerning operation and maintenance of electrical equipments are dealt in this subject.

OBJECTIVE

- Understand building electrical installation and electrical safety.
- Understand operation and maintenance of transformer.
- Understand operation and maintenance of Generators, substations and circuit breakers.
- Understand operation and maintenance of AC motors and Starters.
- Understand operation and maintenance of Lighting transmission and distributions.

DETAILED SYLLABUS

1030 - OPERATION AND MAINTENANCE OF ELECTRICAL EQUIPMENT (M - SCHEME)

Unit-1 EARTHING ARRANGEMENTS, SAFE WORKING ON ELECTRICAL EQUIPMENT, BUILDING ELECTRICAL INSTALLATIONS Page No: (5-26)

Earthing Arrangements- Points to be earthed, Earthing Procedure, Earth resistance measurement, Action to be taken to reduce earthing resistance, Earth Leakage Protection (ELCB) Safe Working on Electrical Equipment- Authorized Person, Procedure for Shutdown, and testing device for Electricity, Special shutdown precautions in substations and Power House.

Building Electrical Installations- Points to be inspected, Insulation Resistance Measurement Procedure, Points to be checked in switches and fuses, Points to be inspected in Potable equipment, Action to be taken if electrical equipment catches fire, Different types of Fire extinguishers & its applications

Unit -2 OPERATION & MAINTENANCE OF TRANSFORMER Page No: (27-43)

Forces generated in transformer during short circuit - Noise in operation – Reason for temperature rise- -insulation resistance-Drying out- precaution for paralleling transformer-inrush current and remedy- insulation co-ordination-effect on insulation during star point earthing – transformer maintenance schedule – action to be taken while transformer oil, temperature rises unduly – points to be checked by oil level tends to fall down – attention required for bushing and insulator.

Unit -3 OPERATION & MAINTENANCE OF GENERATORS, SUBSTATIONS AND CIRCUIT BREAKER Page No: (44-66)

Generators- Parallel operation of Alternators, Real power and Reactive power adjustment between alternator running in parallel, AVR role, Causes for Alternator fails to buildup, Instability in Alternator, Cyclic speed irregularity, Protective & Indicative equipments for Alternator, Causes for overheating of armature &field winding of Alternators, Causes for circulating current between Alternators running in parallel, Causes for pitting of Alternator bearings, Reverse current protection & its necessity. Sub-stations and Circuit Breaker- Difference between Isolator & Circuit breaker, Rupturing capacity of Circuit breaker, Short-circuit calculations, Conditions can a circuit breaker arranged to trip, Auto reclose breaker, Fault clearance time, Inverse time overload relay, Procedure to ensure proper operation of Circuit breaker in the event of a fault, Maintenance requirement for Oil Circuit Breakers, Attention required for the contacts of Contactors, Maintenance requirement of SF6 Circuit breakers.

Unit -4 OPERATION & MAINTENANCE AC MOTORS AND STARTERS Page No: (67-88)

Change the direction of Rotation, Role of Single phase preventer, Types of enclosures, Permissible overload, effect of ambient temperature, Insulation classification, Indicating & Protecting devices for Large Size Motors, If overload mechanism trips frequently what action to be taken, Control devices for motors, role of relays in motor, Points to be attended during periodical maintenance, Air gap measurement, Ball & Roller bearing usage, precautions in fitting bearings, bearing problems, Alignment of directly coupled motors, Static and Dynamic balancing of rotor, Causes of low insulation resistance, rectification of low insulation resistance problem, drying out of motors, Step to be taken if a motor is unduly hot, Vacuum impregnation, Selection of starters for High/Low starting torque applications.

Unit-5 OPERATION & MAINTENANCE OF LIGHTING, TRANSMISSION AND DISTRIBUTION LIGHTING Page No: (89-115)

Glare reduction, Stroboscopic Effect and methods to reduce, Steps in Designing Lighting Installation, Troubleshooting in Fluorescent Lamp and Discharge Lighting, Street Light Control Methods, Fluorescent Lamp Disposal, precautions in Erecting Lighting Installations. Symptoms to identify the end of the useful life of Lamp, Causes for lowering of Illumination level Transmission and Distribution permissible limit for variation of voltage/frequency as per IS Standard, Factor of Safety, Safety devices for overhead Transmission lines, Minimum clearance of between conductors & building, Advantages & Limitations of Steel Cored Aluminium Conductors (ACSR), Purpose of continuous earth wire, Points to be checked when carrying out inspection in overhead transmission line, Prevent rusting of Steel post, Protection requirements for Transmission line, Insulation level & Co-ordination, Precautions in erecting UG Cable, Causes for failure of UG Cable, Cable fault locations, Fall of potential method, Murray loop test method, Locating cable discontinuity.

UNIT I

EARTHING ARRANGEMENTS, SAFE WORKING ON ELECTRICAL EQUIPMENT, BUILDING ELECTRICAL INSTALLATION

1. Earthing:

Earthing means connecting any non current carrying conductor part of an electrical equipment/appliance with the general mass of earth (considered to be at zero potential) for the safety of the human body from shocks.

1.2 NECESSITY OF EARTHING

All metallic covers of machines, starters or sheathing of wiring etc are generally deada non current carrying parts but can become alive due to failure of insulation or bad workmanship. When a person touches such parts of machine or installation, gets a serious shock. To avoid from severe shocks, all the metallic covers and frames of machines are need to be earthed. A good earthing should have very low resistance and easily allow the leakage current through it.

1.3 METHODS OF EARTHING

There are two methods of earthing

1) Pipe/Rod earthing
2) Plate earthing

1.3.1 Components of Earthing System

A complete electrical earthing system consists on the following basic components.

- ***Earth Continuity Conductor***
- ***Earthing Lead***
- ***Earth Electrode***

1.3.1.1 Earth Continuity Conductor or Earth Wire

That part of the earthing system which interconnects the overall metallic parts of electrical installation e.g. conduit, ducts, boxes, metallic shells of the switches, distribution boards, Switches, fuses, Regulating and controlling devices, metallic parts of electrical machines such as, motors, generators, transformers and the metallic framework where electrical devices and components are installed is known as earth wire or earth continuity conductor.

The resistance of the earth continuity conductor is very low. According to IE rules, resistance between consumer earth terminal and earth Continuity conductor (at the end) should not be increased than 1Ω. In simple words, **resistance of earth wire should be less than 1Ω**.

Size of the Earth Continuity Conductor or Earth Wire depends on the **cable size** used in the **wiring circuit**.

1) Plate Earthing:

In plate earthing system, a plate made up of either copper with dimensions 60cm x 60cm x 3.18mm (i.e. 2ft x 2ft x 1/8 in) or galvanized iron (GI) of dimensions 60cm x 60cm x 6.35 mm (2ft x 2ft x ¼ in) is buried vertical in the earth (earth pit) which should not be less than 3m (10ft) from the ground level are shown in figure 1.1.

For proper earthing system, follow the above mentioned steps in the (Earth Plate introduction) to maintain the moisture condition around the earth electrode or earth plate.

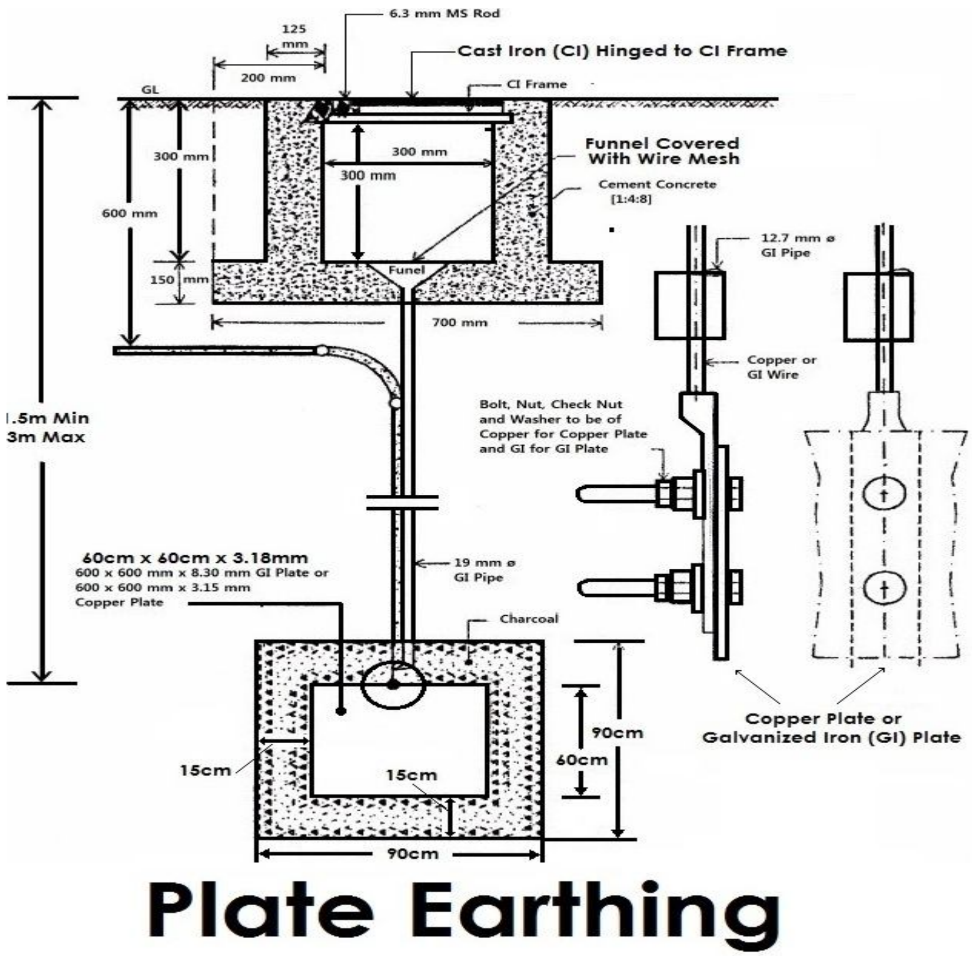

Fig1.1 Plate Earthing

2) Pipe Earthing:

A galvanized steel and a perforated pipe of approved length and diameter is placed vertically in a wet soil in this kind of system of earthing. It is the most common system of earthing are shown in figure 1.2.

The size of pipe to use depends on the magnitude of current and the type of soil. The dimension of the pipe is usually 40mm (1.5in) in diameter and 2.75m (9ft) in length for ordinary soil or greater for dry and rocky soil. The moisture of the soil will determine the length of the pipe to be buried but usually it should be 4.75m (15.5ft).

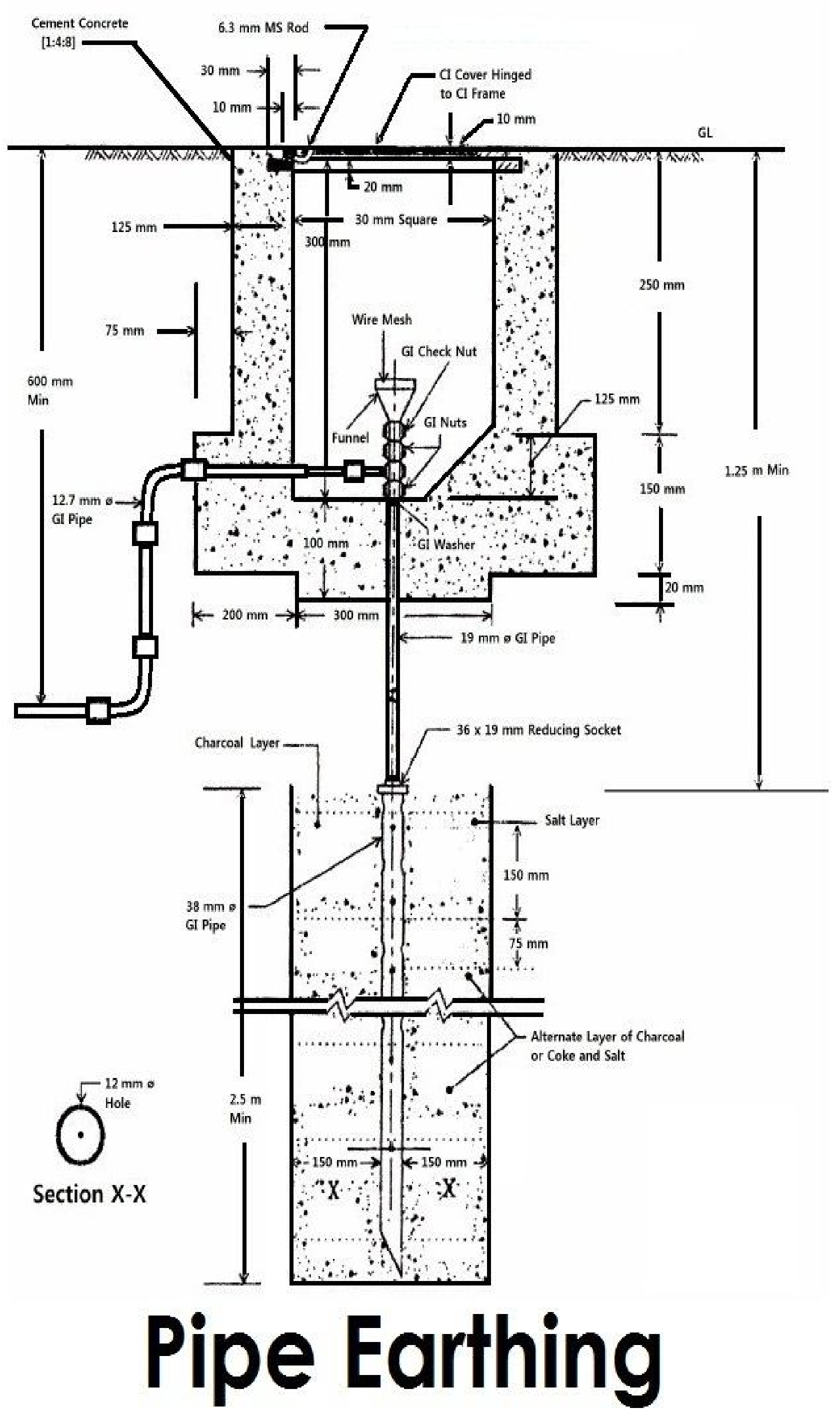

Fig1.2. Pipe Earthing

Points to be earthed:

As per Indian Electricity Rules, the Earthing is required in the following cases:

1. The metallic frame of every heavy power equipment such as generator, electric motor, starter, iron clad board, transformer and structural steel work at substations, etc ., should be earthed by two independent earth conductors.
2. Fabricated steel transmission line towers, tubular steel or rail posts which carry overhead conductors. The individual post may be earthed by connecting them suitably to the overhead earth wire. In addition, independent earths should be provided at least 4 per mile and the steel structure and the earth wire connected to it solidly. This will ensure that the overall earth resistance is low since several earths will be in parallel.
3. Stay wire provided for over Head lines should be earthed by connecting at least one strand to the earth wire on top.
4. The metal casing of portable apparatus should be earthed. This covers electric drills, soldering irons, heaters, refrigerators, boilers and similar electrically operated equipment. If any of them are installed in a fixed position, a separate direct connection to the earth should be provided in addition to the earth wire in the connecting cable.
5. The metal body of iron clad switches, G.I pipes and conduit pipes enclosing V.I.R or P.V.C cables, iron clad fuse boards the down rod of electric fans, and if possible the metallic type reflectors of fluorescent lamps.
6. Earth pin of 3- pin lighting plug sockets and 4-pin power plug sockets.

The resistance to earth of each of the above should be checked at least once a year. It should not be more than one ohm from any point on the system to the earth electrode provided for installation.

1.4 EARTHING PROCEDURE:-

A conductor or group of conductor in intimate contact with and providing an electrical connection to earth will be known as earth electrode. For efficient earthing, the resistance offered by the earth electrode, contact resistance between the electrode and soil and soil resistance all the above should be very low. So that there earthing arrangement/system will provide beard apportion to current flowing through it, such a way that the faulty circuits fuse, blows off immediately.

1.4.1 Earth resistance measurement:

By earthing system we mean all the conduits metallic parts, loop earth wire etc. connected to earth electrode for the purpose of earthing and also includes the earth terminal provided at the supply company’s meter board.

The test is carried out for the earth continuity of all metal parts because if there is any break in the wire, or discontinuity between earth electrode and the metallic parts then there is always a danger of shock or death of human life in case of any leakage in the circuit/appliance. If the earthing system is effective then the leakage current of the appliances/circuit flows immediately to earth and disconnected the supply by blowing off the respective circuits fuse in the cut-out sub main board.

The reason for earth test is the measurement of the value of the resistance offered by the earthing system to the flow of leakage current. In case the resistance offered is high then only a very small part of the leakage current flow to the earth electrode does not blow of the fuse, and the metallic part/conduit/appliance remains charged at all times of leakage, if any one touching or coming in contact with it will get a shock.

The ohmic value of earthing system between the earth (soil) and the farthest point of the earthing system should not be more then two ohm including the value of earth electrode (i.e. plate/pipe) used.

The earthing system is tested with the help of a "earth tester" pitch is a special form of ohm meter and supply source is available through inside hand driven generator.

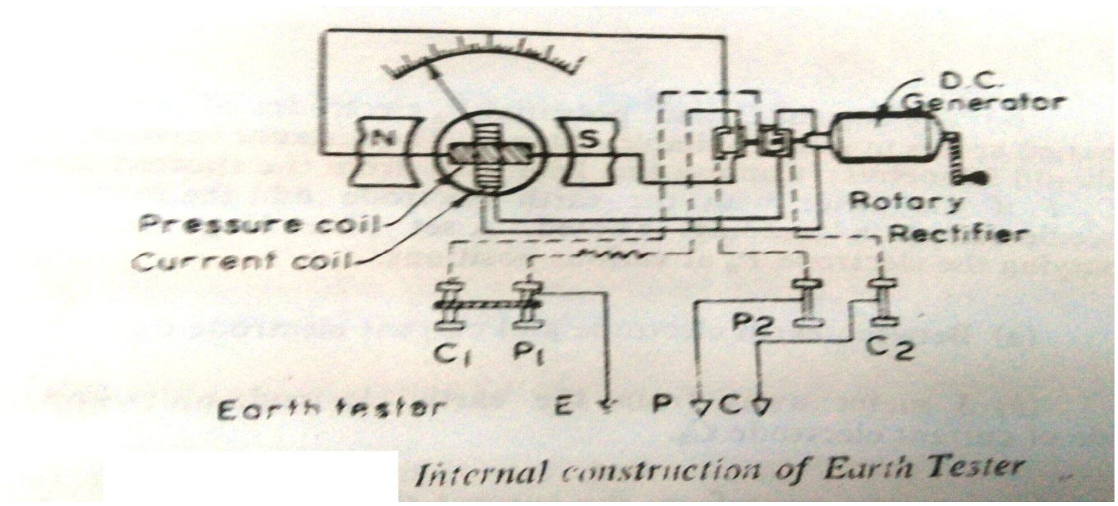

Fig1.3. Internal Construction of Earth Tester

Procedure:

1. Connect together the terminals P1 and C1 as given in circuit diagram and connect them to the electrode or metal structure to be tested.
2. Keep the lead used for this connection as short as possible, as its resistance is included in the measurement.
3. Connect the terminal, marked as P2 and C2 with two temporary earth spikes driven into the ground.

4. Rotate the handle provided in the earth tested at the required speed.
5. Measure the resistance of the electrodes under the test.
6. Repeat the test by placing the spike corresponding to the terminal P2 at different spacing.

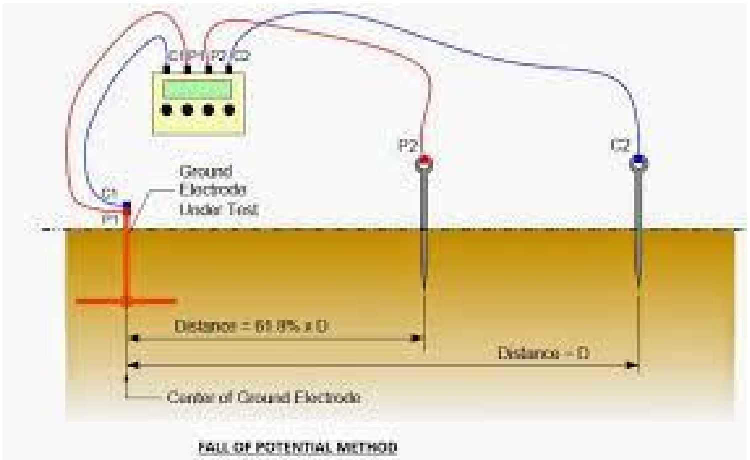

Fig1.4.Potential Method

1.5 ACTION TO BE TAKEN TO REDUCE EARTHING RESISTANCE:

To lower than the resistivity of soil for good earthing, the methods generally used are very simple in nature and execution. This method consists of embedding the electrode at a depth two of to three meter (7to 8 feet) and the area surrounding the plate or pipe (i.e. electrode) is filled with charcoal salt mixture. The soil resistivity decreases as the contact area of plate and area covered by soil mixture increases.

The dampness of the soil and coal salt mixture depends upon the atmospheric condition. In summer season fresh salt fresh water should be poured through the pipe over the coal bed. In case of copper plate earthing, copper sulphate solution should be used as a copper is affected i.e.(undergoes chemical reaction by the salt).

The soil resistance can be lowered only to a certain limit by the above methods, and in order to lower it further, followings are the additional steps to be taken up;

1. Increase in electrode area
2. Increase in pit depth
3. Electrodes in parallel, i.e(increase in the number of electrodes.)

1. Increase in plate area :

In case of increase in plate/electrode area, the increases of resistance value is not in direct proportion with the area. It is found that to reduce the resistance value by one-sixth the increase in area is 36 times more for the same soil condition and depth of the electrode.

These enormous increases in plate area leads to increases of the material cost, hence it limits the plate area increase value.

2. **Increase in pit depth :**

The increase of depth below the ground level for the same plate reduces the resistivity of the earthing system. It is found that plate area reduces to 50% when the depth is doubled for the soil resistance. With this method also the soil resistance value cannot be lowered as much as desired, on account of excavation worth, however, it helps to a create extent.

3. **Electrode in parallel :**

   In this system of lowering a soil resistance the soil resistance reduces considerabily as the number of electrodes interconnected in parallel are increased for the same depth.

   This method is suitable only where greater area of a free soil is available for earthing.

   The plate (i.e. electrodes) should be so spaced in parallel so as no one to over lap the earthing region covered by the individual electrode.

   The total resistance is given be the equation for resistance in parallel as,

   $$1/R=1/R1 + 1/R2 + 1/R3 + 1/R4 + \ldots\ldots\ldots\ldots =$$

   Where R1, R2, etc., are the earth resistance of each electrode and ‘R’ is the total earth resistance of the system.

1.6 Earth Leakage Circuit Breaker (ELCB):

An Earth Leakage Circuit Breaker (ELCB) is a safely device used to detect the earth leakage current from an installation and makes the power supply off by opening the associated circuit breaker.

There are two types of ELCBs:

1. Voltage operated Earth Leakage Circuit Breaker(voltage-ELCB)
2. Current operated Earth Leakage (Current-ELCB).

Voltage-ELCBs were first introduced about sixty years ago and Current-ELCB was first introduced about forty years ago. For many years, the voltage operated ELCB and the differential current operated ELCB were both referred to as ELCBs because it was a simpler name to remember. But the use of a common name for two different devices gave rise to considerable confusion in the electrical industry.

If the wrong type was used on an installation, the level of protection given could be substantially less than that intended.

To overcome this confusion, IEC decided to apply the term Residual Current Device (RCD) or differential current operated ELCBs. Residual current refers to any current over and above the load current.

Voltage operated ELCB

- It is a voltage sensitive device. Voltage-ELCB contains a relay Coil which it being connected to the metallic load body at one end and the other end is connected to ground directly.
- If the voltage of the Equipment body is rise (by touching phase to metal part or failure of insulation of equipment) which could cause the difference between earth and load body voltage, the danger of electric shock will occur. This voltage difference will produce an electric current from the load metallic body through the relay loop and to earth. When voltage on the equipment metallic body rose to the danger level which exceeds to 50Volt, the flowing current through relay loop could move the relay contact by disconnecting the supply current to avoid from any danger electric shock.
- The ELCB detects fault currents from live to the earth (ground) wire within the installation for which it is connect. If sufficient voltage appears across the ELCB's sense coil, it will switch off the power, and remain off until manually reset. A voltage-sensing ELCB does not sense fault currents from live to any other earthed body.

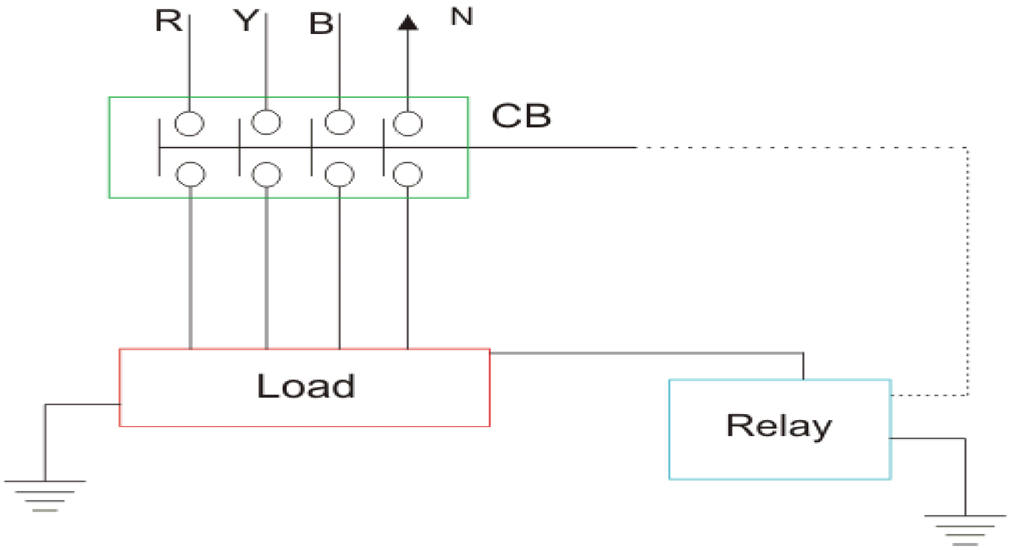

Fig1.5.Voltage ELCB

- These ELCBs monitored the voltage on the earth wire, and disconnected the supply if the earth wirevoltagewasover50volts.

- These devices are no longer used due to its drawbacks like if the fault is between live and a circuit earth, they will disconnect the supply. However, if the fault is between live and some other earth (such as a person or a metal water pipe), they will NOT disconnect, as the voltage on the circuit earth will not change. Even if the fault is between live and a circuit earth, parallel earth paths created via gas or water pipes can result in the ELCB being bypassed. Most of the fault current will flow via the gas or water pipes, since a single earth stake will inevitably have a much higher impedance than hundreds of meters of metal service pipes buried in the ground.

Advantages

- ELCBs have one advantage over RCDs: they are less sensitive to fault conditions, and therefore have fewer nuisance trips.
- When an installation has two connections to earth, a nearby high current lightning strike will cause a voltage gradient in the soil, presenting the ELCB sense coil with enough voltage to cause into trip.

- If the installation's earth rod is placed close to the earth rod of a neighboring building, a high earth leakage current in the other building can raise the local ground potential and cause a voltage difference across the two earths, again tripping the ELCB.

Current-operated ELCB (RCB /RCCB)

- Current-operated ELCBs are generally known as Residual-Current Devices (RCD). These also protect against earth leakage. Both circuit conductors (supply and return) are run through a sensing coil; any imbalance of the currents means the magnetic field does not perfectly cancel. The device detects the imbalance and trips the contact.

  When the term ELCB is used it usually means a voltage-operated device. Similar devices that are current operated are called residual-current devices. However, some companies use the term ELCB to distinguish high sensitivity current operated 3 phase devices that trip in the milliamp range from traditional 3 phase ground fault devices that operate at much higher currents.

  Typical RCD circuit:

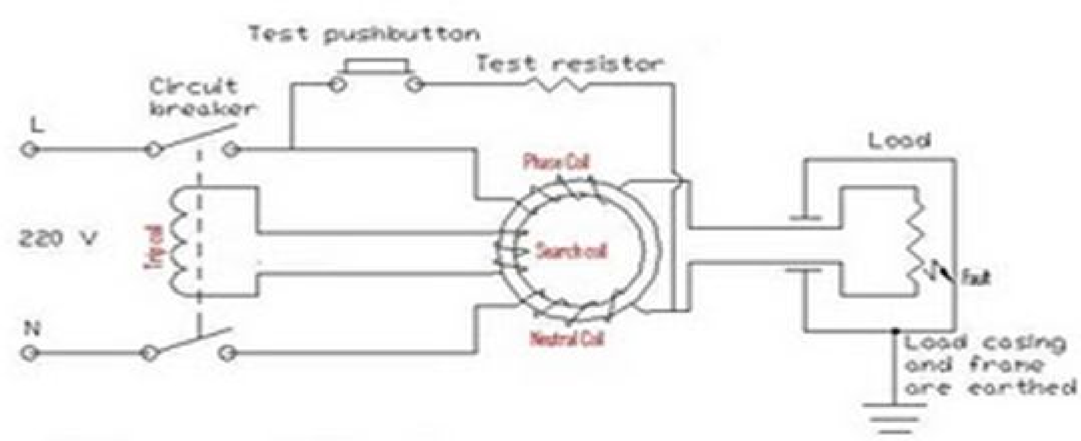

Fig1.6.RCD Circuit

- The supply coil, the neutral coil and the search coil all wound on a common transformer core.

- On a healthy circuit the same current passes through the phase coil, the load and return back through the neutral coil. Both the phase and the neutral coils are wound in such a way that they will produce an opposing magnetic flux. With the same current passing through both coils, their magnetic effect will cancel out under a healthy circuit condition.

- In a situation when there is fault or a leakage to earth in the load circuit, or anywhere between the load circuit and the output connection of the RCB circuit, the current returning through the neutral coil has been reduced. Then the magnetic flux inside the transformer core is not balanced anymore. The total sum of the opposing magnetic flux is no longer zero. This net remaining flux is what we call a residual flux.

- The periodically changing residual flux inside the transformer core crosses path with the winding of the search coil. This action produces an electromotive force (e.m.f.) across the search coil. An electromotive force is actually an alternating voltage. The induced voltage across the search coil produces a current inside the wiring of the trip circuit. It is this current that operates the trip coil of the circuit breaker. Since the trip current is driven by the residual magnetic flux (the resulting flux, the net effect between both fluxes) between the phase and the neutral coils***, it is called the*** residual current device.

- With a circuit breaker incorporated as part of the circuit, the assembled system is called Residual Current Circuit Breaker (RCCB) or Residual Current Devise (RCD). The incoming current has to pass through the circuit breaker first before going to the phase coil. The return neutral path passes through the second circuit breaker pole. During tripping when a fault is detected, both the phase and neutral connection is isolated.

1.7 SAFE WORKING ON ELECTRICAL EQIUPMENT:

Authorized person:

An authorized person is one who is specifically empowered by the administration to carry out a specified task or duty. This authority is usually given in the form of a 'Certificate of Competence' which clearly defines the responsibility resting on each person, by virtue of his holding any particular category of post. The following are some example of competency certificates:

Unskilled labourer:

Authorized to carry out external cleaning of electrical equipment, renew lamps and fuses, and assist electric fitters to carry out work on electrical equipments. He shall not work on any aerial line or internal parts of electrical equipment unless they have been made dead and earthed by the electric fitter or chargeman.

Skilled electric fitter or electrician:

Authorized to affect shutdown, test, earth and issue line-clear certificates on low and medium tension lines and circuits, directly under his charge: supervise the work of khallasis and labourers; render artificial respiration. He shall not test or earth high tension lines or circuits except under the direct supervision of an electrical foreman or electrical chargeman. He shall not bring into commission any new electrical installation.

High tension linesman:

Authorized to test and earth H.T lines, provided that he has received a 'permit-to-work' from competent authority after the supply to the lines have been cut off. He is also authority to give line-clear certificate after work is completed and staff is withdrawn from the work.

Substation operator:

Authorized to effect shutdown on any feeder, on receipt of requisition and issue 'permit-to-work' and to energies the feeder after receiving the line –clear certificate, from the party concerned.

Electric foreman, electric chargeman:

Authorized to effect shutdown, test and earth H.T lines under his charge and issue 'permit-to-work'; supervise the work of subordinate staff; commission new low and medium tension equipment and installation after ensuring that they comply with the rules. He is not authorized to commission any new H.T installation or do any modification to an existing installation; un till it has been inspected and passed by competent authority.

It should be noted that a competency certificate is a personal document of the person concerned and his work cannot, therefore, be delegated to someone else. A register of authorized persons should be maintained in every office.

1.8 PROCEDURE FOR SHUTDOWN:

Before starting the shutdown process, it is important to get the ‘Permission for shutdown and ‘Permit to work’.

The following are the essential steps to be taken:

Step 1: study the circuit and identify the circuit – breakers or control switches to be opened.

Step 2: open and lock the circuit-breaker or switch in the ‘off’ position and keep the key in your Personal custody. If the switch cannot be locked out, remove the fuses and keep them under lock and key. Disconnect neutral link if any.

Step3: Hang or tie a ‘men-at-work’ notice board on the circuit breaker or switch handle.

Step4: Test for supply after making sure that the testing device itself is ok.

Step5: Earth the equipment.

1.9 TESTING DEVICE FOR ELECTRICITY:

In low voltage circuit where the supply voltage is below 250 volts, one 250volts lamp could be used as a test lamp. In the case of medium tension installations, two 250 volts lamps in series would be satisfactory. Alternatively, a voltmeter could be used. For higher voltages of the order of 2.2 to 11 kv, one type of tester is the ‘spark’ tester, where a sharply pointed metal cone fixed at the end of an insulated handle draws sparks when the pointed end is brought very close (about ¼ in.) to the live conductor. The spark is faint and therefore, liable to be erroneously judged. There is also ‘neon testers’ specially designed for testing live circuits. These give a much better indication. Another way is to make use of a potential transformer with a voltmeter connected to the secondary circuit. Care should, however, be taken to use fully insulated handles when making the contact with the live wire. Another convenient device is the electrostatic voltmeter.

For higher voltages, above 11KV it will be necessary to rely entirely upon the correct switching operations being carried out at the substations, and a foolproof system of exchange of the necessary shutdown messages. However , a very interesting development in this field is the ‘metric live –line indicator’ which does not require any contact to be made with the live line but is designed to detect the electrostatic field set up in the vicinity of a conductor energized by an a.c. voltage. It is made in two models: 33 to 275 kV and 22 to 66 kV by Messrs. Everett Edgcumbe. It has been specially developed for verifying the isolation of the higher voltage apparatus before working on it. It gives a clear reading on an illuminated scale in the presence of an energized conductor. It weighs less than 2 lb including self-contained batteries and is a very convenient one-hand instrument.

1.10 SPECIAL SHUTDOWN PRECAUTIONS IN SUBSTATIONS AND POWER HOUSE:

The **following** points require attention:

1. In substation and power houses, where several supervisory staff are on duty at the same time, it is important that the responsibility for effecting shutdown and resuming supply should devolve only on one ‘authorized person’ at any time, who will be in overall control of the switching operations, and no operation should be carried out without his personal knowledge. This is particularly important in times of trouble or failure of supply when different officials present are like to give conflicting orders.
2. In addition to switching off the circuit-breaker, the corresponding isolating switch should also be opened. Even where the isolating switch is provided with an earthing device in its ‘off’ position independent earthing of the lines should be done at the work spot.
3. The authorized official in charge must be thoroughly familiar with the circuit layout and inter-connections. For instance, it is not enough to switch off the H.T circuit breaker for isolating a transformer. The transformer terminals may continue to be alive through the L.T side. Similarly ring mains or bus-couplers may feed currents into equipment, even though the direct link has been cut off.

1.11 BUILDING ELECTRICAL INSTALLATION:

Points to be inspected:

Every part of the installation should be checked by a responsible official and preferably recorded in a register or entered in a tabulated form. In brief, this consists of the following inspections:

1. Service connection
2. Main switchboard.
3. Internal wiring and its insulation.
4. Earth tests and bonding.
5. Switches and fuses.
6. Portable apparatus.
7. Fire precautions.

If the annual inspections are carried out conscientiously, most of the defects come to light and could be corrected before they result in a serious breakdown or accident. Some of these defects would perhaps be installation defects and a few even due to faulty design. Both these aspects will, therefore, have to be borne in mind, when carrying out inspections.

1.12 INSULATION RESISTANCE MEASUREMENT PROCEDURE:

Insulation test of the internal wiring is carried out most conveniently by a 500 volts megger and comprises mainly two parts, viz., line to earth test and line to line test. Before starting the tests, switch off the supply, remove the main fuses and disconnect the neutral link. Then proceed as follows:

Line to earth test:

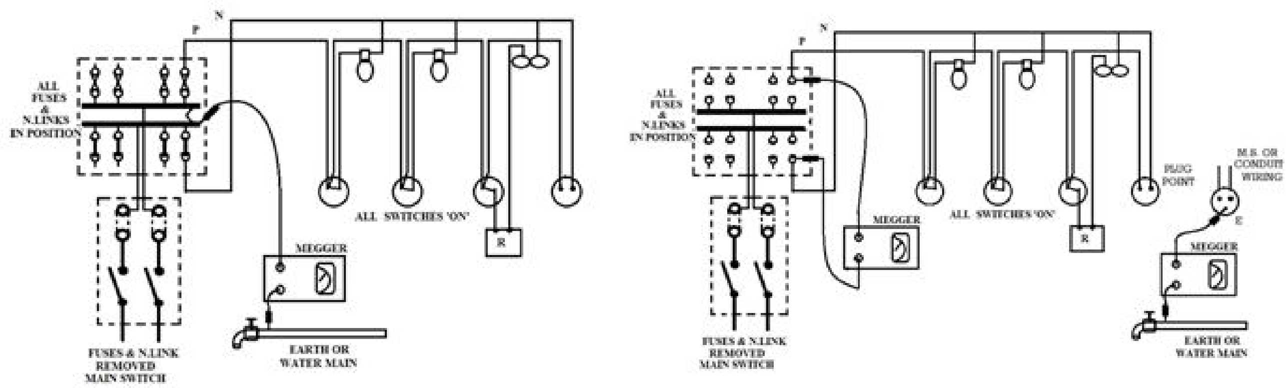

Fig1.7.Line to Earth Test

- Insert all fuses at the fuse board; insert all lamps close all single pole tumbler switches; where fans are provided, close the fan switches and put the regulators in the 'on' position.

- Temporarily short the phase and neutral terminals on the dead side of the main switch and connect them to one terminal of the megger. The other terminal is connected to the earth, or the conduit in which the wiring is run, or if the wiring is in lead covered cables, to the lead sheathing.
- Note and record the megger reading.

  (N.B where 2-way staircase type switches are provided, reading should be taken in both positions of the switch)

This gives the total combined insulation resistance to earth of both the phase and the neutral conductors (I.E.E Rule no.1103),

The minimum permissible resistance should be not less than 50**/ no. Of outlets**

For instance, if there are 20 wiring points, the insulation resistance should not be less than 50/20 i.e. 2 ½ megohms. If the resistance is below this value, it cannot be considered as satisfactory. The insulation resistance of each sub-circuit should than be taken individually and the faulty section located and attended to each final sub-circuit should have a resistance of at least .5 megohms, under the worst conditions, i.e. during the rainy season when wiring is damp.

Line to line insulation test:

- Remove or disconnect all consuming devices such as lamps, fans, or portable apparatus plugged on to 2-pin or 3-pin sockets,etc.
- Keep all single pole tumbler switches in the 'on' position.
- Remove all fuses in the fuse boards, and open the neutral link.
- Take the insulation resistance between the phase and neutral lines of each final sub-circuit for simplicity, a single circuit alone is shown.

The insulation resistance between lines of each final sub-circuit should be not less than 5 megohms for 10 wiring points. If the readings are lower, the cause must be located and rectified.

I.E rule No.48 states that the maximum permissible leakage on the consumers' premises is $1/5000^{th}$ part of the maximum current supplied to the consumer. Thus, if the maximum load on the premises is say, 5 amps. On a 230 volts system (1150 watts), the maximum permissible leakage is 5/5000=1 milliampere. On a 230 volts circuit, the minimum insulation resistance should, therefore, be 2,30,000 ohms or .23 megohms.

The above tests would reveal nearly all insulation defects in a wiring installation. Insulation resistance of all portable apparatus such as electric irons, heaters, etc. should, however, is taken separately.

1.13 POINTS TO BE CHECKED IN SWITCHES AND FUSES:

The following points should be checked:

1. Every fuse should be of the correct size. The correct size should be indicated on the fuse board or the main board as the case may be. Examine the fuse wire; if it shows any signs of overheating or sulphation, renew it.
2. The main contact jaws of all switches should be cleaned and lightly vase lined.
3. The inlet and outlet holes in iron clad switchgear, fuse boards, etc. should be properly protected by means of suitable insulated bushes. The leads themselves should be taped up, protected with insulating varnish and sealed with compound to prevent moisture or water from getting into the equipment.
4. All switches, fuses, etc. should be properly numbered to facilitate identification of circuits. The main switch should also be prominently marked to facilitate quick identification and to comply with the I.E rules.
5. The V.I.R. connection inside wooden distribution boards should be rearranged and taped up. Renew them if necessary.
6. Every single pole tumbler switch should be tested for its being correctly connected in the phase line. It shall under no circumstances be connected in the neutral line. This can be checked by a test lamp, connected between the earth and the switch terminal, with the switch in the closed position. If the lamp burns, it proves that the switch is in the phase line. It is, however, very important to remember, when conducting this test that the tumbler switch should be kept closed. If this precaution is not taken, the results will be misleading. The switch connected in the neutral line is incorrect.

   yet the test the test lamp will light up since the test lamp and the main lamp are in series across the supply. Both of them will light up but they will be dim. Since the test lamp lights up one is likely to conclude erroneously that the switch is in the phase line even though it is not.

   The correct method of conducting this test is to keep the switch closed the test lamp will then not light up unless the switch is in the phase line.

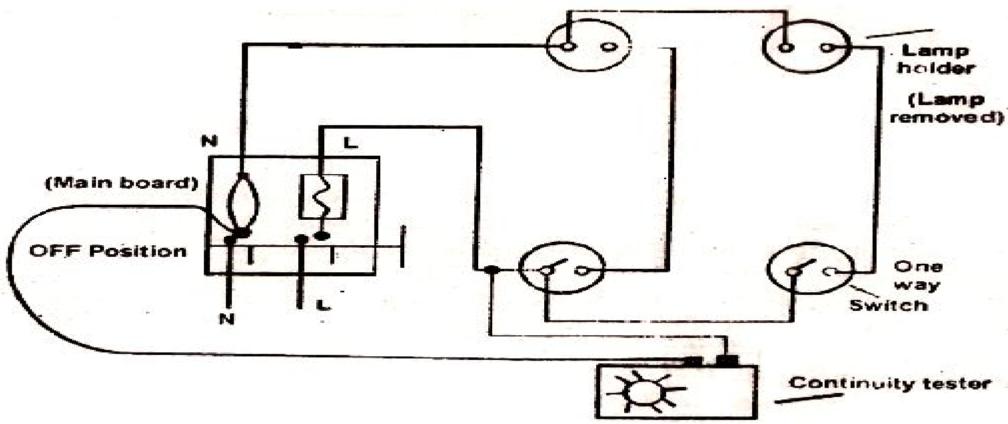

Fig1.8.Switches and Fuses

1.14 POINTS TO BE INSPECTED IN PORTABLE EQUIPMENTS:

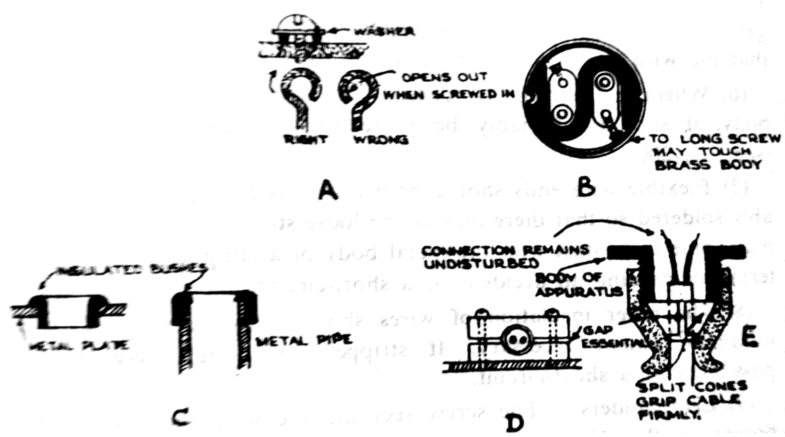

Fig1.9.Portable Equipments

1. The insulation resistance of the conductors should be checked by a megger.

If the reading is low, the cause must be investigated and rectified. Frequently the cause is perished lead-in connections due to chafing of the leads.

2.On effective cable grip should invariably be provide on every portable apparatus and also at the plug end, where flexible cable connections are made (figure D&E) the effectiveness of the cable grip should be checked periodically, the internal connections should not get disturbed when the cable is pulled, jerked or twisted,

But the grip pressure itself should not pinch the insulation unduly. It is a good practice to re-do the connections periodically after cutting off the exposed ends of the cable. in the absence of a cable grip of good design , the cable may be looped and bound to the handle by whip-cord as a temporary expedient.

3. Where interlocked switch plugs are provided, check if the interlocking action is effective, i.e. it should not be possible to close the switch without the plug in position, nor to withdraw the plug when the switch is in the closed position.

4. In the case of heavy equipment like a refrigerator, heater or boiler which remains more or less in a fixed position, an independent permanent earth connection should be made to the metal casing of the equipment by a copper wire of sufficient section (8S.W.G), in addition to the usual earth connection derived from the plug socket through the connecting cable, as a further measure of safety.

5. When making cable connections take care to see that the wire ends are twisted and bend into a neat eyelet, to take in the screw securing it. The wire end should always be placed clockwise below the screw head so that the end may tend to close inside inwards when the screw is tightened; if placed anticlockwise, it will tend to open out and get loose. Use a washer immediately below the screw head to ensure that the wire is firmly gripped (See. Fig. C)

6. Whenever wiring is passed through a hole in a metal body, it should invariably be protected and insulated by a bush (See. Fig. C).

7. Flexible wire ends should be neatly twisted together and preferably soldered so that there may be no loose strands; Such loose strands may come in contact with the metal body of a lamp holder or adjacent terminals causing as accident or short circuit.

8. The outer insulation of wires should only be stripped to the minimum extent necessary. If stripped too long, there is every possibility of a short circuit.

9. Lamp holders: The screw securing the wire end should be of proper length. If too long, it may touch the body of the lamp holder (See. Fig. B). If the porcelain interior is wrongly assembled the locking nick in the outer brass. Ring may touch the live terminals. For Hand Lamps, Porcelain or Bakelite lamp holder should be used as far as possible as brass lamp holders are not so safe.

Action To Be Taken If Electrical Equipment Catches with Fire:-

The following are the steps:

- ✓ Switch off the main supply.

- ✓ Use fire extinguishers recommended for the electrical fires.
- ✓ Water should not be used.
- ✓ Sand should not be used on electrical machines/equipment; this may be used for other purposes.
- ✓ There should be provision for fire extinguishers and buckets filled with sand on every large installation or industry.

1.17 DIFFERENT TYPES OF FIRE EXTINGUISHER ANT IT'S APPLICATION:-

All fire extinguishers depends upon two main principles

1. Cooling the fire so that it's temperature falls below the ignition point and
2. Cutting off the access to air

The main types of extinguishers in common use are

1. *Soda acid type:* It is inexpensive and very commonly used. The chemicals employed are concentrated sulphuric acid kept in a sealed glass bottle and a solution of bicarbonate of soda. When required for the use, hit the handle on the top of the extinguishers sharply; this breaks the glass bottle inside and the liberated acid mixes with the solution, generating carbon dioxide. Owing to the gas pressure inside the container, the effervescing liquid comes out as a jet or spray which is directed the against the fire. The solution should be renewed at least once every year.

2. Chemical foam type: This is especially suitable for putting out oil fires (transformers, oil switches). The chemicals used are aluminium sulphate and bicarbonate of soda and some special chemicals, kept in separate compartments as solutions. The dry chemicals are supplied in tins by the markers of the equipment. By inverting the extinguisher, the two solutions get mixed up and carbon dioxide is generated. The liquid issues forth under pressure as foam, i.e. tenacious bubbles containing CO_2 carbon dioxide, which can be directed as far as 15 or 20 ft. away. The fire gets quickly extinguished by the blanket of foam, because of the combined cooling action and air supply being cut off. It is thus very effective.

Never throw water on hot oil. The steam generated will burst with explosive violence, Dispersing the hot oil over a wide area and causing further damage.

3. *Carbon-tetra-chloride:* This is the most effective and cleanest form of putting out electrical fires. Since carbon-tetra-chloride is an insulator, it may be used on live equipment without any danger of shock. The extinguisher contains a sealed cartridge containing CO_2 liquid under great pressure. By striking a piston the gas cartridge is punctured and a considerable pressure is build-up in the extinguisher, which squirts a jet of carbon-tetra-chloride liquid as far as 15 or 20 ft. Carbon-tetra-chloride evaporates quickly and smothers the flame effectively. It will not damage any electrical equipment and may be used with complete safety.

   It is of course important that the extinguisher itself is of an approved make. Periodical checks and inspections must be carried out to ensure that are perfectly serviceable at all times. Gas-tightness should be ensured. Gaskets should be renewed if required. The chemical charge should be replaced if too old. Staff should be trained in the correct method of using the equipment, and fire-drills should be held at regular intervals so that the effectiveness of the fire-fighting scheme is fully tested. Keep ready at hand or display prominently on the wall the telephone number of the fire-fighting station.

Classes of fire extinguisher

- Class A - fires involving solid materials such as wood, paper or textiles.
- Class B - fires involving flammable liquids such as petrol, diesel or oils.
- Class C - fires involving gases.
- Class D - fires involving metals.
- Class E - fires involving live electrical apparatus. (Technically ‘Class E’ doesn’t exists however this is used for convenience here)
- Class F - fires involving cooking oils such as in deep-fat fryers.

Review questions

Part A& Part B

1. What is earthing?
2. What are the methods of earthing?
3. What is ELCB and mention its types?
4. What is the procedure for shutdown?
5. What are points considered in building electrical installations?
6. What is Action to Be Taken If an Electrical Equipment Catches with Fire.
7. Mention the different types of fire extinguisher ant it’s application.
8. Mention points to be inspected in portable equipments.
9. Mention the points to be checked in switches and fuses.
10. Write about Line to line insulation test.
11. What do you mean by residual flux?

Part C

1. Explain the procedure for insulation resistance measurement.
2. Explain about safe working on electrical equipment.
3. Explain about ELCB.
4. Write about the procedure of earthing.
5. Explain about building electrical installation.
6. Explain about different types of fire extinguisher ant it’s application.
7. Explain the points to be inspected in portable equipments

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Unit –II

OPERATION AND MAINTENANCE OF TRANSFORMER

2.1 FORCES GENERATES IN TRANSFORMER DURING SHORT CIRCUIT:

Transformer coils are subject to tremendous forces under short circuit conditions, because currents may be of the order of hundreds or thousands of amperes. Moreover force is proportional to the square of the current. The force exerted on each conductor is given by the well-known formula:

$$F=Bi=Ki^2$$

Where F=force on conductor in dynes per cm of length

B=flux density through conductor in gauss=Ki

I=current in conductor in absolute amperes

K=constant

Since the core flux passing through the secondary winding is destroyed by the short circuit current, the flux created by the primary current appears as leakage flux passing through between the primary and secondary coils.

In concentric windings, this creates radial forces acting outwards on the outer coil subjecting the conductors in it to tensile stress shown in figure. As the primary and secondary conductors carry currents in opposite directions, they repel each other. The entire outer winding may be imagined as a cylinder subject to internal hydraulic pressure and it therefore tends to burst outwards, the maximum force occurring on the outermost layer. The mechanical force are tremendous in large transformers-they may even amount to a few tons-such as to stress the outer turns of copper beyond the elastic limit and therefore the turns on the outer layers are liable to be broken by tensile failure. To guard against this, it is necessary to put in special re-enforcement above the outermost layer to hold the coils in place. The inner coil, on the other hand, is subjected to compressive forces. Fortunately, in this case the coil is well supported on the core and there is very little possibility of any damage.

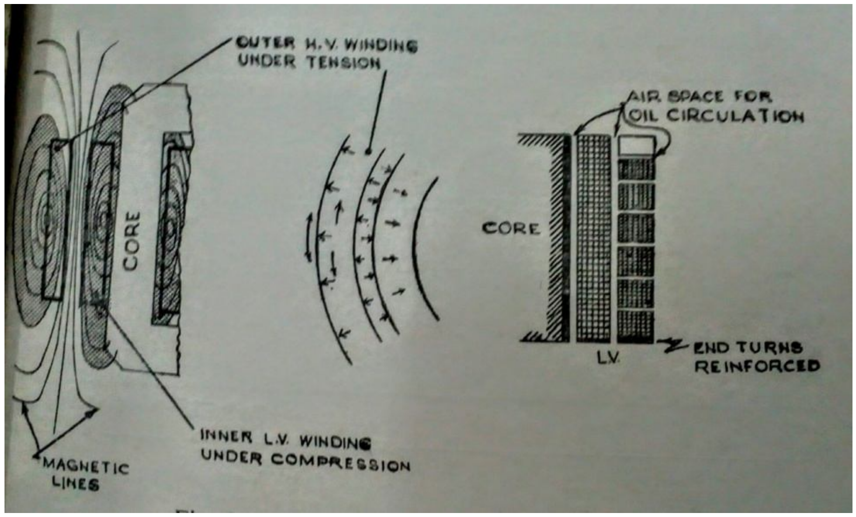


Fig 2.1 Transformers in Short Circuit

Another force which occurs is axial. The inner and outer windings are subject to axial forces if they are unbalance magnetically i.e. they will be displaced from each other axially. As a safeguard, the end insulation next to the core is made very strong and suitable wedges are driven between the ends coils and the surface of the core and its supports so that the whole coil assembly is rigidly held in position axially. In large transformers, the windings are specially seasoned by several cycles of drying-out in a hot chamber, and compression under hydraulic pressure, so that all slackness is taken up and the windings are fully shrunk. Special tie road and pressure screws are provided on large transformers to take up the shrinkage and settlement of winding which occurs in service especially during short circuits.

In order to prevent any magnetic unbalance which may occur when different voltage taps in the are selected, it is common practice to place the voltage taps in the are selected, it is common practice to place to voltage taps in the centre part of the coil assembly and not at the ends as may usually be supposed shown in figure.IS:2026 specifies that a transformer having 4 per cent impedance voltage i.e. with a short-circuit current of 25 times the normal value, should be able to withstand a short-circuit for at least 2 seconds, the maximum current not exceeding 93 A/sq. mm. For impedance voltages of 7 per cent or above, the transformer should withstand a short circuit of 14 times or less the normal current for 5 seconds, at 62A/mm^2

2.2 NOISE IN OPERATION:

Every transformer does make some noise, but it becomes conspicuous when the size is large. The noise are hum is due to the fact that the core, which is made up of thin laminations, vibrates because of the alternating magnetic flux, and therefore expands or contracts ever so slightly with each cycle magnetization this causes the audible hum. The contraction caused due to magnetization is called Magnetostriction.

To reduce the hum the core must be tightly clamped together. The flux density should also be reduced as much s possible, but there is a practical limit to this. Sometimes, under unfavorable conditions of poor design or construction, the hum gets multiplied 100's of times due to resonance. This should not be permitted.

The noise and hum reduced by large transformers in urban areas often reached such high values has to be a source of disturbance and annoyance to the people living nearby. The noise level decreases quickly with distance. i.e. By some 6 dB for every doubling of the distance, so that at about 200 feet the reduction could be about 26dB. Transformer should therefore be located as far away from residential areas as possible.

Where they have to be located in heavily populated places, one method adopted to reduce the noise is to install the transformer inside an enclosure which is made sound proof. Brick walls lined with acoustics material are quite effective and all connections should be by underground cables. When the size is large and the voltage is high, the radiators could be mounted outside the enclosure and connected to the transformer by flexible pipe connections. The transformer itself is mounted on resilient pads. Air inlet and outlet ducts are lined with sound absorbing material to deaden the noise of ventilating fans which should admit sufficient quantity of air to take away the heat produced by the transformer.

It is not possible to build conventional enclosures around the large transformer, because of the high voltage bushings and clearances required. This difficulties has been solved by M/S AEI for a 180 MVA outdoor transformer by building an acoustic enclosure comprising a double wallet sheet shell, filled with viscous compound, round the transformer tank leaving out the bushings and the radiators. Sufficient space is left inside to permit normal maintenance. The transformer is mounted on one $1\frac{1}{2}$ inch thick cross ribbed neoprene rubber mats to limit the ground borne noise.

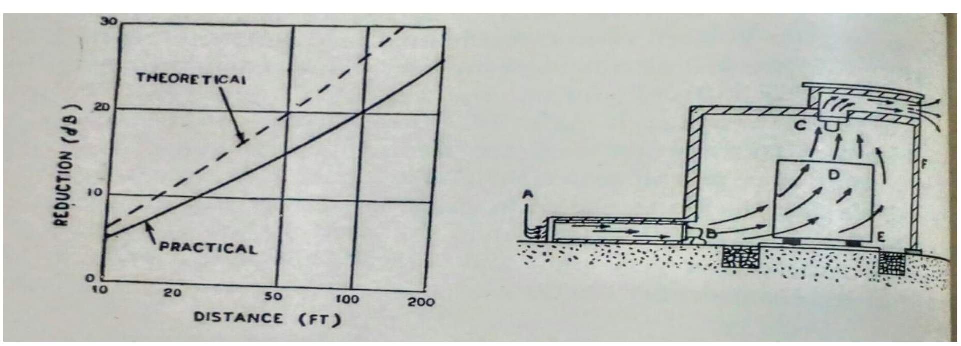


Fig 2.2 Noise Operation

2.3 REASON FOR TEMPERATURE RISE:

Copper losses in both primary and secondary windings and core losses are converted into heat in a transformer. These losses are all measured in watts. This heat must be conducted out of the windings and core and dissipated to the surrounding, or ambient air. There's a time delay involved in getting this heat out; as a result, the transformer temperature increases. This temperature will continue to increase until a condition of equilibrium is reached, one where the amount of heat generated in the transformer equals the amount of heat being dissipated.

The difference in temperature between a non operating transformer ("cold" condition) and one at full load equilibrium point ("hot" condition) is called temperature rise. It usually is measured in degrees Centigrade.

Measuring temperature rise

The core temperature is measured with a thermometer, with readings taken with the transformer "cold" and "hot." With these two readings, the temperature rise is calculated. For example, if we have a reading of 25 [degrees] C "cold" and 75 [degrees] C "hot," then the temperature rise is 50 [degrees] C. The average winding temperature rise is determined by measuring the resistance of a winding when it's "cold" and again when the winding temperature has stabilized under full load. From the difference in the resistance readings, the average temperature is calculated for each winding.

2.4 INSULATION RESISTANCE (IR):

The alternating current resistance between two electrical conductors or two system of conductor separated by an insulating material.

Insulation resistance tests are made to determine insulation resistance from individual windings to ground or between individual windings. Insulation resistance tests are commonly measured directly in megohms or may be calculated from measurements of applied voltage and leakage current.

The recommended practice in measuring insulation resistance is to always ground the tank (and the core). Short circuit each winding of the transformer at the bushing terminals. Resistance measurements are then made between each winding and all other windings grounded.

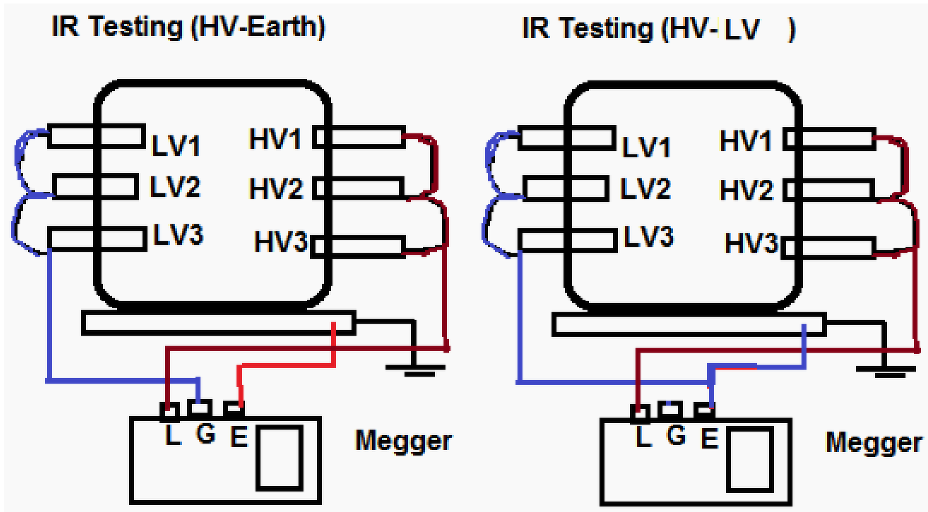


Fig 2.3 IR Testing

Insulation resistance testing: HV – Earth and HV – LV Transformer windings are never left floating for insulation resistance measurements. Solidly grounded winding must have the ground removed in order to measure the insulation resistance of the winding grounded. If the ground cannot be removed, as in the case of some windings with solidly grounded neutrals, the insulation resistance of the winding cannot be measured. Treat it as part of the grounded section of the circuit.

We need to test winding to winding and winding to ground (E).For three phase transformers, We need to test winding (L1,L2,L3) with substitute Earthing for Delta transformer or winding (L1,L2,L3) with earthing (E) and neutral (N) for wye transformers.

IR Value for Transformer	
Transformer	Formula
1 Phase Transformer	**IR Value (MΩ) = C X E / (√KVA)**
3 Phase Transformer (Star)	**IR Value (MΩ) = C X E (P-n) / (√KVA)**
3 Phase Transformer (Delta)	**IR Value (MΩ) = C X E (P-P) / (√KVA)**
Where C= 1.5 for Oil filled T/C with Oil Tank, 30 for Oil filled T/C without Oil Tank or Dry Type T/C.	

Example: For 1600KVA, 20KV/400V,Three Phase Transformer

- IR Value at HV Side= (1.5 x 20000) / v 1600 =16000 / 40 = 750 MΩ at 20^0C
- IR Value at LV Side = (1.5 x 400) / v 1600= 320 / 40 = 15 MΩ at 20^0C
- IR Value at 30^0C =15X1.98= 29.7 MΩ

Transformer Coil Voltage	Megger Size	Min.IR Value Liquid Filled T/C	Min.IR Value Dry Type T/C
0 – 600 V	1KV	100 MΩ	500 MΩ
600 V To 5KV	2.5KV	1,000 MΩ	5,000 MΩ
5KV To 15KV	5KV	5,000 MΩ	25,000 MΩ
15KV To 69KV	5KV	10,000 MΩ	50,000 MΩ

IR Value of Transformers

Voltage	Test Voltage (DC) LV side	Test Voltage (DC) HV side	Min IR Value
415V	500V	2.5KV	100MΩ
Up to 6.6KV	500V	2.5KV	200MΩ
6.6KV to 11KV	500V	2.5KV	400MΩ
11KV to 33KV	1000V	5KV	500MΩ
33KV to 66KV	1000V	5KV	600MΩ
66KV to 132KV	1000V	5KV	600MΩ
132KV to 220KV	1000V	5KV	650MΩ

Steps for measuring the IR of Transformer:

- Shut down the transformer and disconnect the jumpers and lightning arrestors.
- Discharge the winding capacitance.
- Thoroughly clean all bushings
- Short circuit the windings.
- Guard the terminals to eliminate surface leakage over terminal bushings.
- Record the temperature.
- Connect the test leads (avoid joints).
- Apply the test voltage and note the reading. The IR. Value at 60 seconds after application of the test voltage is referred to as the Insulation Resistance of the transformer at the test temperature.
- The transformer Neutral bushing is to be disconnected from earth during the test.
- All LV surge diverter earth connections are to be disconnected during the test.
- Due to the inductive characteristics of transformers, the insulation resistance reading shall not be taken until the test current stabilizes.
- Avoid meggering when the transformer is under vacuum.

2.5 DRYING OUT

New transformers are almost invariable sent fully dried out, filled with oil and fitted with a breather. Sometimes large transformers are sent out without oil, with the cooling coils separately packed, to reduce weight and facilitate handling. The cooling tube outlets are the sent blanked off sealed, the tank itself being filled with dry gas, either air or nitrogen under pressure, so that the windings may be perfectly dry when received; it will then be necessary only to mount the cooling tube and fill the tank with good transformer oil, preferably by the vacuum suction process. Drying out period in the field will then be greatly reduced.

The main problem in drying out a transformer is not so much drying the oil-this is quite easily done by passing it twice or thrice through a suitable filter-as the removal of moisture the windings. This is quite a time consuming process in a new transformer to be commissioned to 3 or 4 weeks for a large unit. And throughout this period the temperature has to be maintained between 80^0

to 85^0 C irrespective of ambient air temperature variations. A vital condition to be ensured throughout the period is that the oil temperature never exceeds the limit of 90^0 C, as it may seriously damage the insulation. The amount of heat radiated from a transformer tank is quite appreciable especially in cold cover round the transformer if it is installed outdoors and also to lag the sides and the cooling tubes to reduce the radiation losses. In substation having a large number of transformers which have to be periodically dried out, it is worthwhile installing a purifier in the substation premises and providing a piping system permanently so that purification of the oil could be carried out on any transformer at any time desired, from the central plant, by making just a few flexible pipe connection. Incidentally purification of the oil may proceed while the transformer is in service on light load. Coming to the methods of drying out, there are basically two i.e. with the tank dry or with the tank filled with oil.

(a) With the tank dry i.e. with the core and winding in position but without oil, the heat required for drying may be produced in two ways:

(i) By blowing in hot air through the transformer tank.

The air is blown into the tank through a suitable opening at the bottom of the tank such as the drain pipe or radiator pipe outlet. An air outlet should be left at the top by removing the explosion vent or manhole cover. The inlet air should be at a temperature not less than 85^0 nor more than 100^0 C. Some manufactures offer special driers comprising a centrifugal type air blower with built in air filters and heating elements of 15 KW capacity, which will be sufficient for a tank capacity of 10 m^3 (350CU.FT.). The outlet air temperature should be not less than 65^0 to 75^0 (140^0 to167^0F). This method is quite reliable and the drying time with reasonably dry air and ambient temperature, is about 4 days for an 11kV unit and 15 days for large 220 kV unit. This advantage of this method is that the oil is not subjected to high temperatures for long period as in other methods. Moisture in the windings is quickly removed because of low humidity of hot air.

(ii) By short circuiting the secondary windings and applying a reduced voltage on the primary, as in the heat run test. The top cover should be kept open for free ventilation. This is not entirely a satisfactory method because the temperature distribution in the windings will be uneven due to absence of oil, and is not recommended except for small transformer and when there is no other means available for drying. However, this method may be adopted in conjunction

With method (i) above to reduce the burden on the air heaters. The winding temperature, by the resistance method should never be permitted to exceed 90^0 C.

(b) With the tank filled with oil, heat could be produced in three different ways:

(i) By short circuit method outlined above.

(ii) By circulating oil through a suitable purifying plant.

(iii) By connecting several immersion type heaters and letting them into the transformer tank.

N.B. Application of vacuum may be applied directly into the transformer tank by connecting a vacuum pump production at least 28 in. of vacuum, through a suitable outlet, provided that the tank is specially designed to withstand the full air pressure (15 lbs/sq.in.) on the exposed surfaces of the tank. Alternatively vacuum type purifiers should be used.

2.6 PRECAUTION FOR PARALLING TRANSFORMER

The following precaution should be taken:

(i) Study the name plate particulars, voltage ratio, percentage impedance, vector diagram and group number, terminal marking etc. and make sure that all conditions for parallel operation are fulfilled. If the name plate or terminal marking is missing a much more elaborate procedure is required i.e. the transformer windings have to be lifted out and the external connections traced and identified, if necessary.

(ii) Even when everything seems right, it is still advisable to observe a definite testing procedure as any erroneous connection may result in a short circuit. Do not forget to connect the transformer tank body solidly to earth.

(iii) For conducting a phasing out test, it is not necessary to apply the rated voltage side. A much lower voltage is more convenient. For example, a 6.6 kV/ 400 V transformers primary cloud be connected to a 400 volt supply. The secondary voltage will be corresponding lower i.e. about 24 volts which make it much safer and easy to work with.

(iv) If full rated voltage has to be applied, it will be necessary to use potential transformers. The terminal markings and polarity of the potential transformers also will have to be checked. Remember the possibility of 180^0 phase difference if the connections are not correctly made to lie terminals.

(v) It is necessary to link up the two secondary by one common connection, so that voltmeter readings may be taken. If the secondary star connected and the neutrals are available, no neutral is available and the secondary leads of the two transformers are completely isolated, connect any terminal of one transformer of what appears as the corresponding terminal of the other transformer. Even if it is connected to the wrong terminal, no harm is done and the tests will reveal the error.

(vi) In using a voltmeter for the test, a fundamental precaution to be taken is to put its range switch to a much higher scale before carrying the test, i.e. at least twice the excepted voltage. If the secondary voltage is 400 V, the voltmeter range switch should be set to 1000 V, for the first set of measurements. After the terminals are identified and the corresponding terminals show little or no voltage, the selector switch should be put to a lower scale say 0-50 volts or less to make an accurate measurement of the voltage different between corresponding terminals. This should be negligible.

2.7 INRUSH CURRENT AND ITS REMEDY:

When a transformer is switched off the line, the primary circuits open at zero current, but the secondary current takes a sort time to decay to zero. This leaves a residual flux in the core of the transformer. It is a fundamental principle of the transformer that the voltage applied to the primary is nearly counterbalanced by the back e.m.f produced by the alternating magnetic flux in the core. At the instant of switching in a transformer the back e.m.f which develops is dependent upon the value of the residual flux which may either be in opposition to the flux produced by the impressed voltage as it should be, are it may be as assisting it. Therefore at the instant of switching in the current flow is determined by the value and direction of the back e.m.f. and, therefore, upon the residual flux in the core at the time. Under the worst condition, this current is limited only by the air core reactance of the windings since the core would be saturated and its impedance is greatly reduced. The current inrush would be as high as five times full load current and persist for as long as two seconds. Since the current flows only through the primary winding of the transformer and there is no corresponding outflow on the secondary side, it has the same effect as an internal fault as the differential relay is concerned.

This unavoidable current such at the time of switching in a transformer has always been a source of difficulty especially with high speed differential relays the inrush current is essentially a pulsating direct current which rapidly decays. It contains a large percentage of harmonic components. This fact is utilized to block the operation of the differential relay during the current inrush period by providing restraining coils (RC) and harmonic restraint, comprising series and parallel tuned filter circuits (TF). To make the differential relay inoperative during the current inrush, but leaving unimpaired its ability to act instantly for false within the transformers.

2.8 INSULATION CO-ORDINATION:-

A grid network comprising extensive overhead transmission lines, switch gear and transformer is subject to over voltages which may cause by external atmospheric sources such as lightning discharges, or internally produced surges due to switching operations or faults. When such voltage disturbances occur, it is naturally the weakest link in the system which breaks down. In the interest of continuity of supply it is obviously necessary to protect the system against such over voltages by the installation of lightning arresters or spark gaps whose characteristics should be such as to bypass the surge safely to earth. The breakdown voltage of the arrester should be carefully chosen: it should be appreciably lower than that of the overhead line insulators, switch gears or the transformers, but much higher than the normal operating voltage.

It is, therefore, necessary to co-ordinate and grade the insulation level of the various components parts of a system intelligently, the principle being that the greater the cost of an equipment and the more its vulnerability the higher should be it's insulation level to reduce the risk of failure. Thus, in a grid network, the surge diverters should have the lowest insulation level(Figure), followed by suspension insulators, isolating switches, circuit breakers and finally the transformer which should have the highest level since they are costliest. The expression 'insulation co-ordination' refers to the steps taken to correlate the insulating strength of the different electrical apparatus to prevent their being damaged by over-voltages and to localize flashovers and thereby achieving reliability of supply.

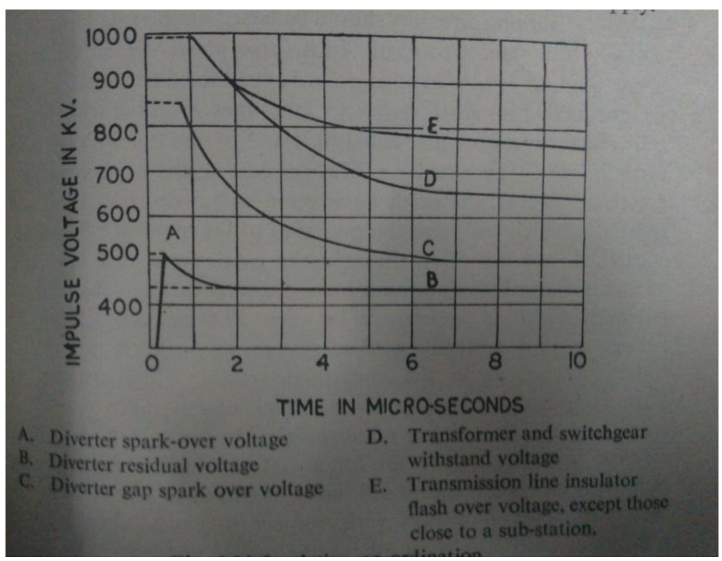


Fig 2.4 Insulation Co-Ordinanation

2.9 EFFECT ON INSULATION DURING STAR POINT EARTHING:

In the three phases UN earthed system fig. if one leg say C gets earthed, the other two lines A and B will be at a potential equal to full line voltage above the ground. Therefore the protective devices including lightning arrestors should be based on full rated line to line voltage, with respect to earth. In a three phase system containing a star winding, whose neutral point is connected to a perfect earth. One having no earth resistance, the lines A and B will theoretically remain at a potential equal to $1/\sqrt{3}$of the line voltage above earth, if line C is earthed, 57.6 percent of the normal value. In practice, however, the earth connection will necessarily have some resistance which will raise the potential of the neutral, when line c is earthed, because of IR drop in the earth resistance. The effect of this is that all insulators on the line A and B will be subjected to a potential which is somewhere between 57.6 percent of full line voltage as in a perfectly earthed system. And a maximum of line-to-line voltage as in the unearthed system. Thus earthing has a direct bearing on the insulation level, and is taken care of by what is called ‘co-efficient of earthing’. The system which is considered as effectively earthed if the co-efficient of earthing is 80 percent. The insulation level is always with respect to earth, although it is indicated against the three phase line-to-line voltage.

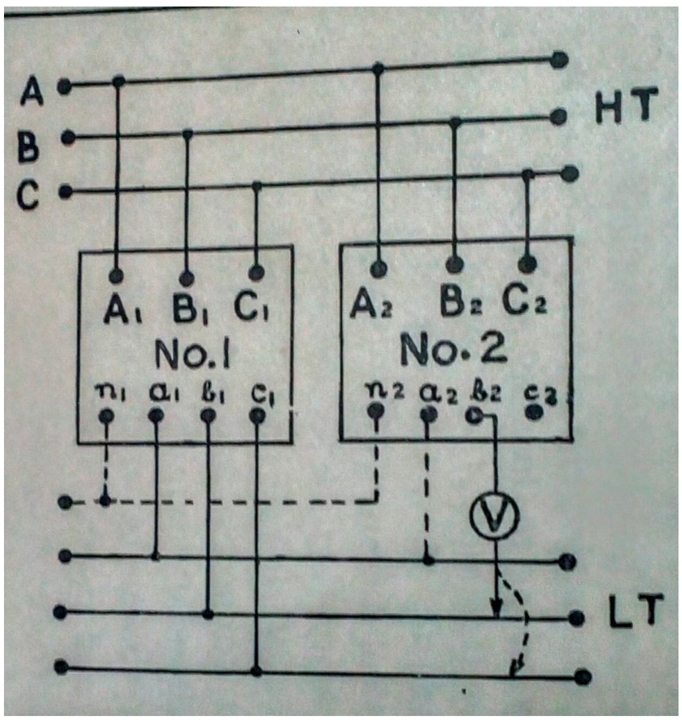


Fig 2.5 Insulation during Star Point Earthing

2.10 TRANSFORMER MAINTENANCE SCHEDULE:

The transformer is one of the most reliable items of electrical equipment, requiring relatively little attention; yet often even this minimum of attention is not given, and no wonders they do sometimes breakdown because of neglect!

The programme of inspection and maintenance is governed by the size of the transformer, where it is installed, whether indoors or outdoors, if in a substation is it manned or unattended, the operating conditions and so on. The degree of attention required depends greatly upon how heavily or lightly the transformer is loaded the maintenance schedule in table 1. Covers oil immersed, naturally-cooled transformers of three categories.

1. Major installations at large grid substations which are manned all the time, with unit size of 1000 to 10000 KVA or more. Quite often the transformer loading is quite high.
2. Medium installation in small substations with unit capacities of 250 KVA to 1000 KVA.
3. Minor installation up to 250 KVA unit capacity which are unattended and often at remote points, such as pole mounted transformers, and rural distribution transformers.

The interval of inspection are indicated as; H for hourly, D for daily, W for weekly, M for monthly, 3-M & 6-M for 3 monthly and 6 monthly, Y for yearly,

2-Y for, 5-Y for, 2yearly and 5 yearly.

In major and medium installations a stand by transformers should always be available to be switched on at a moment's notice, in place of the largest unit installed. It should be maintained to the same standards as the other units, and periodically put to use to keep it in a good and healthy condition.

In major installations, using year blast cooling or water cooling, a daily check should be made of the ancillary installations like air blowers, water pumps and the connected protective devices, on load tape changes etc.

	Major	Medium	Minor
Watch operating condition i.e. ambient temperature, oil temperature, current loading and variation of primary voltage. Check position of tape switch and re adjust if necessary	H	D	M
Inspect general condition, see if there is any unusual noise, check oil level in a tank And bushings	D	W	M
Clean transformer bushings insulator and examine for fine cracks if, any check tightness of external electrical connection	M	3M	6M
Check breather and ensure at the air passage is clear.	3M	3M	6M
Test operation of all protective alarms and relays, batteries and wiring.	3M	6M	-
Take megger readings and records	3M	6M	Y

Check ground connections and record earth resistance.	3M	6M	Y
Test oil for dielectric strength, clarity color etc. drain out samples of oil from drain plugs at bottom of tank. Examine for water, sludge and acidity. Drain out until clean samples are obtained. Replenish with good dry oil. Carry out oil filteration, if required.	3M	Y	2Y
Check tightness of all cover bolts	3M	Y	2Y
Check lightning arrestors. Check spark gaps.	6M	6M	Y
Thorough overhaul after lifting up the core repaint the tank if necessary	10Y	7Y	5Y

2.11 ACTION TO BE TAKEN WHILE TRANSFORMER OIL TEMPERATURE RISES UNDULY:

In every large well regulated system, a close watch is always maintained of the loading conditions, and the oil temperature. Excessive oil temperature is the result of overloading. This should not be permitted to occur, by taking timely action to switch on a larger unit for operation or to put another unit in parallel to share the load. Remember, excessive temperature reduces life and therefore, if oil temperature rises unduly for any reason the transformer should be put out of service immediately, but the cooling fans. If any, should continue to run until the oil temperature falls to normal.

2.12 POINTS TO BE CHECKED BY OIL LEVEL TENDS TO FALL DOWN:

Transformer oil may leak at several points, i.e. oil level gauge, cork packing below the top cover, oil conservator, connection, drain cock, gasket, bolt where a cable box is bolted in, and welded joints. Every oil leak should be traced to its source and remedial action taken to stop the leak.

If the gasket leak cannot be stopped by tightening the bolts, the gasket should be renewed. The belt material for gasket is cork, rubber sheet 5mm thick. This consists of fine granulated cork and synthetic rubber as the binding medium. The surfaces between which the gasket is provided should be quite flat and smooth without any burrs or irregularities. They should be perfectly clean and free from scale, rust, old paint, remains of glue and old gasket, grease or oil. The surface should be thoroughly cleaned and washed with trichloroethylene, alcohol or other gases solvent. If it is glossy surface such as bakelite, it should be made rough by emery cloth or sand paper. The gasket should preferably made slightly narrow than the flange width so that it may not swell beyond the edge when compressed. Though the cascade makes good oil tight a joint, it is an advantage if the gasket joint surface is coated with a thin layer of special glue obtainable from the manufacturers. Inspection covers, which may require to be opened whenever required, may be coated with ball- bearings grease over the surface which comes in contact with the gasket. The cover can then be opened without damaging the gasket. Care should be taken to tighten the bolts uniformly going from one bolt top the next, over the entire lot several times so that the surface pressure is uniform all over. The compression should be limited to 2/3 of original thickness. The retightening operation should be repeated sometimes after the transformer is put into use, as the gasket tends to settle down after sometime. This should be done, say two days after renewing the gasket, and again a week later the bolt lighteners should also rechecked during a six monthly inspection.

Sometimes slight oil leakage occurs at the welded joints the exact point of the leakage outside the tank can be discovered first by cleaning the surface thoroughly with a grease solvent or petrol or denatured alcohol, and then coating the surface with a thin layer of chalk, cement plate in water or white wash and allowing it to dry. Leakage of oil is then readily revealed by the dark patch it forms.

As for the cure much depends upon how bad the leak is. Formation of a few drops over a period of time is not of any consequence and occurs in most transformers. If it is bad, cracked or spongy well may be repaired by welding in a metal patch. A small hole in the weld can often be put right by peeping with a cold blunt chisel until the hole is closed, and then finally using a ball peen hammer to complete the seal. Special solders which have a great affinity for iron but which are unaffected by oil could also be used to stop oil leaks through porous weld threaded bolt fixtures, internal welds making use of a blow torch; take care to guard against any explosions. If a hole exists in a casting it may be drilled and a tight brass plug driven in. it is no use using shellac as a filter as shrinks considerably when it dries.

After completing the repairs, the deficiency in oil level should be made good and a careful note made of the oil level for verification at the next inspection.

2.13 ATTENTION IS REQUIRED ON BUSHINGS AND INSULATORS.

It is essential to examine porcelain bushing and other insulators, such as busbar supporting insulators and surge-diverter at frequent intervals. The porcelain surface should be thoroughly cleaned with a wet cloth and polished, after removing every trace of oil or dust. In most insulator urban areas there is heavy atmospheric pollution, and fine dust, soot, and industrial deposit settle down on the insulator skirts. If not removed at frequent intervals they tend to form a very hard curst. When dew or moisture appears on the insulator, the combinations make a conducting path which could easily result in a flashover. Very often, the heat produced by the leakage path damages the glazed surface of the insulators. The position is aggravated is coastal areas subject to salt deposition. In U.K. extensive failures have occurred when snow deposition on insulators starts melting in early spring and eases up the dirty deposit of soot, salt and dust.

Extensive research has been made as to the methods of overcoming the trouble. One of the principles employed is to apply a water repellent on the porcelain surface such as thin coat silicone grease. Dust and coil will no doubt stick to the surface and the insulator may present a very dirty appearance, but the function of the insulator remains unimpaired, as the oil or grease engulfs the contaminants and insulator one particle from the other, inhibiting and tendency of from leakage path. It is of course necessary to point is reached, and to apply a fresh coat of thin grease.

Another method employed for live-line cleaning, at substation which cannot be shut down, is to wash the insulators by directing a high-pressure finely atomized water spray, using high resistivity water and maintaining safe distances. In India, none of these procedures appear to be called for. Hand cleaning by wiping off the deposits with a wet or petrol soaked cloth will be found to be fully efficacious it the glazed surface is finally polished with a dry cloth.

When polishing, the bushing surface should be carefully examined for hair-line cracks; when the transformer is put on load, the crack may develop rapidly to dangerous dimension. At the same time it is as well to go over all current-carrying parts with a spanner gently but firmly, to ensure good contact. Remember that a poor contact will develop enormous heat when in operation, which may ultimately cause a burnout or crack the insulators.

Review questions

Part A& Part B

1. What are the loses in Transformers, Explain?
   Ans. (1) Iron loses (2) Copper loses
   Iron Loss: Iron loss occurs in the transformers Iron core due to hysteresis and eddy currents taking place. They are almost fixed irrespective of loading of transformers.
   Copper Losses: Copper losses are I2 R losses in the primary and the secondary windings of the transformer which with the loading of transformer.
2. Why a transformer requires cooling. What are the methods of cooling transformers?
   Ans. Transformers requires cooling as they get heated up due to various losses taking place in the transformer. (Like iron of copper losses)
   Following are the methods of cooling of transformer.
   a. Natural cooling by Air.
   b. Oil Natural cooling Air natural (ONAN).
   c. Forced oil air Natural Cooling (OFAN).
   d. Forced oil and forced Air cooling (OFAF).
   3. What are the schedules of maintenance done on transformers?
   Ans. Following are the schedules of maintenance on transformers**.**
   a. Daily maintenance.
   b. Monthly maintenance.
   c. Quarterly maintenance.
   d. Half yearly maintenance.
   e. Yearly maintenance.
   f. 5 Yearly maintenance.
4. What are the steps for measuring IR of transformer?
5. What are precautions on paralleling the transformer?
6. What is inrush current?
7. What is the effect on insulation during star point earthing?
8. What is the action performed in temperature rise in transformer.
9. Write short notes transformer maintenance schedule.
10. What are the reasons for temperature rise in transformer?

Part C

1. Explain the forces generates in transformer during short circuit**.**
2. Explain about insulation resistance (IR**)**.
3. Explain about drying out in transformer.
4. Write about the precaution for paralleling transformer.
5. Explain about effect on insulation during star point earthing.
6. Explain about point s to be checked by oil level tends to fall down.
7. Explain about the attention is required on bushings and insulators

UNIT-III

OPERATION AND MAINTENEANCE OF GENERATORS, SUBSTATIONS AND CIRCUIT BREAKER

3.1 Parallel Operation of Alternator

Alternator is really an AC generator. In alternator, an EMF is induced in the stator (stationary wire) with the influence of rotating magnetic field (rotor) due to Faraday's law of induction. Due to the synchronous speed of rotation of field poles, it is also known as synchronous generator. Here, we can discuss about **parallel operation of an alternator**. When the AC power systems are interconnected for efficiency, the alternators should also have to be connected in parallel. There will be more than two alternators connected in parallel in generating stations.

3.1.1 Condition for Parallel Operation of Alternator

There are some conditions to be satisfied for **parallel operation of the alternator**. Before entering into that, we should understand some terms which are as follows.

- The process of connecting two alternators or an alternator and an infinite bus bar system in parallel is known as synchronizing.
- Running machine is the machine which carries the load.
- Incoming machine is the alternator or machine which has to be connected in parallel with the system.

The conditions to be satisfied are

1. The phase sequence in both incoming machine and running machine/bus bar should be the same.
2. The RMS line voltage (terminal voltage) of the bus bar or already running machine and the incoming machine should be the same.
3. The phase angle of the two systems should be equal.
4. The frequency of both (incoming machine and the bus bar) should be identical. Large power transients will occur when frequencies are not nearly equal.
5. For satisfactory parallel operation, the characteristics of the two machines should be similar.

Departure from the above conditions will result in the formation of power surges and current. It also results in unwanted electro-mechanical oscillation of rotor which leads to the damage of equipment.

3.1.2 General Procedure for Paralleling Alternators

The figure below shows an alternator (generator 2) being paralleled with a running power system (generator 1).These two machines are about to synchronize for supplying power to a load. Generator 2 is about to parallel with the help of a switch, S1. This switch should never be closed without satisfying the above conditions.

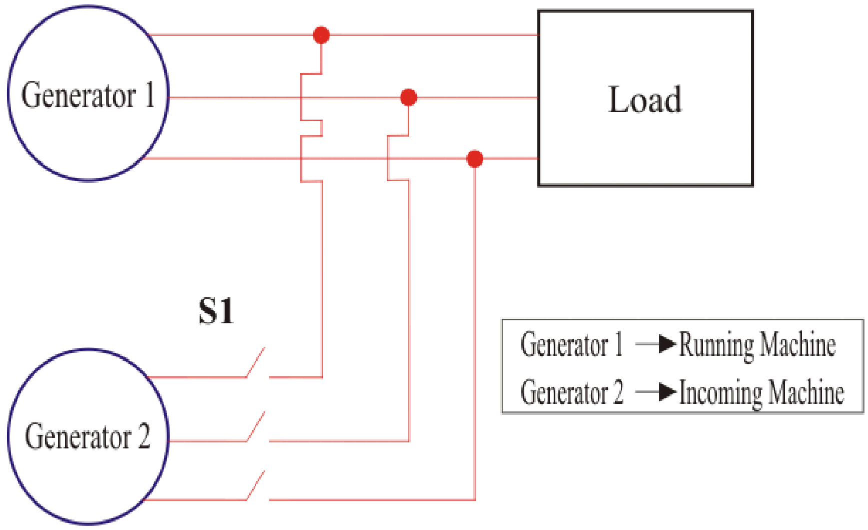


Fig 3.1 Parallel Alternators

1. To make the terminal voltages equal. This can be done by adjusting the terminal voltage of incoming machine by changing the field current and make it equal to the line voltage of running system using voltmeters.
2. There are two methods to check the phase sequence of the machines. They are as follows
    - o First one is using a Synchroscope. It is not actually check the phase sequence but it is used to measure the difference in phase angles.
    - o Second method is three lamp methods (Figure 2). Here we can see three light bulbs are connected to the terminals of the switch, S1. Bulbs become bright if the phase difference is large. Bulbs become dim if the phase difference is small. The bulbs will show dim and bright all together if phase sequence is the same. The bulbs will get bright in progression if the phase sequence is opposite. This phase sequence can be made equal by swapping the connections on any two phases on one of the generators.
3. Next, we have to check and verify the incoming and running system frequency. It should be nearly the same. This can be done by inspecting the frequency of dimming and brightening of lamps.

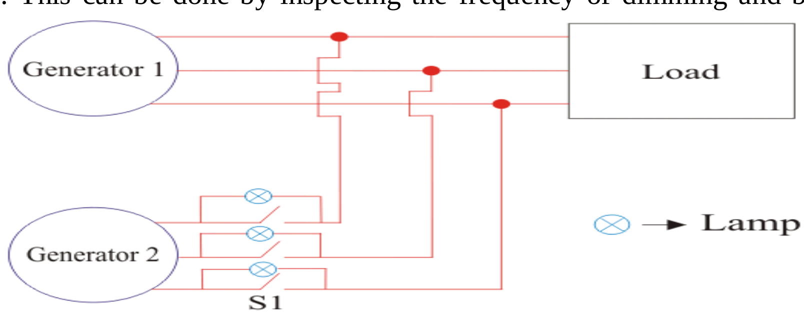


Fig 3.2 Parallel Alternators with Lamp

4. When the frequencies are nearly equal, the two voltages (incoming alternator and running system) will alter the phase gradually. These changes can be observed and the switch, S1 can be made closed when the phase angles are equal.(i.e t the time of middle of the dark period in all the three lamps)

Advantages of Parallel Operating Alternators

- When there is maintenance or an inspection, one machine can be taken out from service and the other alternators can keep up for the continuity of supply.
- Load supply can be increased.(load can be shared among the two machine)
- During light loads, more than one alternator can be shut down while the other will operate in nearly full load.
- During the peak load, the incoming machine can be synchronized to meet the load.
- High efficiency.
- The operating cost is reduced.
- Ensures the protection of supply and enables cost-effective generation.
- The generation cost is reduced.
- Breaking down of a generator does not cause any interruption in the supply.
- Reliability of the whole power system increases.

3.2 Load and Reactive power adjustment between alternators running in parallel:-

When two alternators are running in parallel on a common bus bar, they behave as if the two sets are coupled together mechanically through an elastic coupling. If the speed of one of the machines is raised, it will take a greater proportion of the load and, therefore, the other machine will take correspondingly less load. Variation of field excitation will not alter load sharing of alternators as in d.c. machines, but it is achieved only by altering the speed of the prime mover. Therefore, it is necessary that the two machines have identical speed regulation for satisfactory parallel operation, as contrasted with voltage regulation in the case of d.c. machines where speed regulation of the prime mover has no direct effect. Now if the speed of machine No.1 is slightly raised, or if that of No.2 is lowered, No.1 machine will take a higher load than No.2. If the speed of No.1 is increased unduly it will not only take the whole of the load, but in addition drive No.2 set, as a synchronous motor, speeding up its prime mover. To guard against this, alternators working in parallel are invariably provided with reverse current protection.

3.3 Automatic Voltage Regulator (AVR) Role:-

In many industrial installations, fluctuations of load are heavy, a typical instance being the operation of electrical cranes. Due to rapid variations in the load from instant to instant, the voltage also fluctuates considerably, because of varying voltage drop in the armature circuit.

To overcome this unsatisfactory feature, automatic voltage regulators are usually provided to maintain the generator voltage reasonably constant in spite of the fluctuating load, i.e. to increase the voltage when the load is high and reduce it when the load comes down.

There are several types of automatic voltage regulators in use, but all of them are based on the principle of short-circuiting of a part of the generator or exciter field resistance, thereby raising the excitation of the generator, to compensate for the drop in voltage due to increase load. The rise and fall in voltage itself is utilized to do this automatically, so as to maintain the voltage nearly constant whatever may be the variation in load.

(a) Brown Bowery regulator:

Here a rotating arm moves; depend upon the terminal voltage, across a set of contacts, short circuiting some part or more of the resistance inserted in the exciter field circuit.

(b)Carbon Pile regulator:

Here a set of carbon plates is assembled as a compact unit and connected as a resistance in series with the field circuit. The value of resistance of the carbon pile gets reduced as the pressure applied on it is increased. A solenoid coil connected across the supply controls the pressure applied and thereby the voltage developed by the generator.

(c)Terrill voltage regulator:

Here a pair of vibrating contacts short circuits a portion of the resistance in the field circuit intermittently. The ratio of the time the contacts are closed to that they are open, changes with the load and determines the average field excitation and therefore the voltage.

In all these cases a time lag device, such as a dashpot, is provided to ensure that fluctuation of very short duration is rendered ineffective.

3.4 Causes for alternator fails to buildup voltage:-

Loss of residual magnetism: The ability to build up voltage in case of a self excited generator depends upon the residual magnetism. This residual magnetism is often destroyed if a very heavy overload or short circuit occurs, and also if the field windings are correctly connected. In such a case it will be necessary to re-excite the field temporarily from an independent external source of supply, such as from another generator or battery, and recreate the residual magnetism in the right direction. If it is in the wrong direction, the polarity of the generated voltage will be reversed.

Open-circuit or loose connection in the exciter circuit. Also short-circuited turns in field winding: Check the field current and if all the field windings have equal resistance. Check also for earth faults in the field current.

Reversed field winding: This can occur during overhauls. Connect field circuits correctly and re-excite the generator.

Open or short-circuit in armature windings: Locate and rectify.

Excessive contact resistance on commutator due to incorrect grade of brushes or insufficient pressure or dirty commutator: To be rectified.

Incorrect position of brush: To be checked and adjusted correctly.

3.4.1 Instability of alternators:-

Excessive capacity load results in voltage rise and tendency for the machine to become unstable and self-excitive.

3.4.2 Cyclic Speed irregularity:-

In the case of engine driven alternators, the turning moment of the engine is uneven and, therefore, the speed of the alternator varies slightly from instant to instant. This is called cyclic speed irregularity.

Cyclic irregularity = (Maximum speed-Minimum speed)/Mean speed.

As alternators running in parallel behave as if they were mechanically coupled together, such periodic speed variation causes the load taken by each alternator to fluctuate periodically. For satisfactory parallel operation, it is essential that this cyclic speed irregularity is kept as low as possible not exceeding 1/150. This is achieved by providing fly wheels of sufficient weight on reciprocating type diesel engines to absorb the instant variation of the speed of the engine.

3.4.3 Protective and indicative instruments:-

The following are usually provided on comparatively small engine drive alternator sets:

(a)Indicating instruments:

- Voltmeter.
- Ammeter with 3-position ammeter switch.
- Frequency meter.
- Power factor meter.
- Synchroscope with synchronizing plug.

(b)Protective devices:

- Overload relays,

- Reverse power relays to prevent any alternator running as a motor.
- Earth leakage relay.

(c)control devices:

- Exciter regulator.
- Oil-circuit breaker.

3.4.4 Causes for overheating of armature and field winding of alternators:-

Overheating of armature may be caused by:

- Overloading of one or all phases. Measure current and check if it is O.K.
- Restricted ventilation due to ventilating ducts being obstructed or failure of cooling air fan.
- Excessive negative sequence component, on account of large single phase loads, which cause excessive current unbalance.

Overheating of the field winding may be due to excessive excitation to compensate for heavy armature voltage drop caused by loads of low power factor, or too low a speed, or due to short-circuited turns on the field winding.

3.4.5 Causes for circulating currents between alternators running in parallel:

Such currents are usually of harmonic nature and are set up when the star points of machines with similar characteristics are connected together and if the neutral of more than one generator is earthed separately. When two or more generators are arranged to run in parallel, the neutral of only one generator should be earthed to serve as the neutral for the whole system.

3.4.6 Causes for pitting of alternator bearings:-

This is often caused by circulating currents through the shaft due to unequal gap or out of balance current between the three phases. To prevent this, the exciter bearing and pedestal is usually insulated so that there may be no circulating shaft current. Make sure that this insulation is not by-passed by some metallic conductor, bolts, water pipe, conduit wiring, or dowell pin, earth connection, etc.

3.4.7 Reverse current protection and its necessity:-

Reverse current protection is used to protect parallel incoming feeders at substations and also for generators operating in parallel, etc. This safeguards the system against total interruption of supply in the event of fault in one of the feeders.

In this figure, there are two parallel feeders, with the usual protection, i.e. overload relays at the sending end. This reverse current relay is always provided at the receiving end.

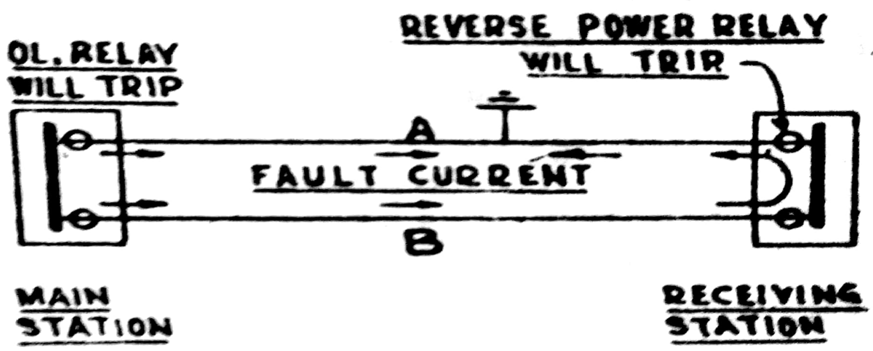


Fig 3.3 Reverse Current Protection

In the event of a fault in a feeder A, fault current will flow in two ways:

- Directly into feeder A. This will trip the overload relay on feeder A at the main station.
- Indirectly through the feeder B and receiving station bus bar into the fault in feeder A. This would trip the reverse current relay on feeder A at the receiving station.

In the absence of reverse current protection, the fault current would have tripped the other circuit breaker controlling feeder B, producing a total shutdown in receiving station, due to the operation of reverse current relay provided at the receiving station, supply will continue to be maintained through the good feeder B.

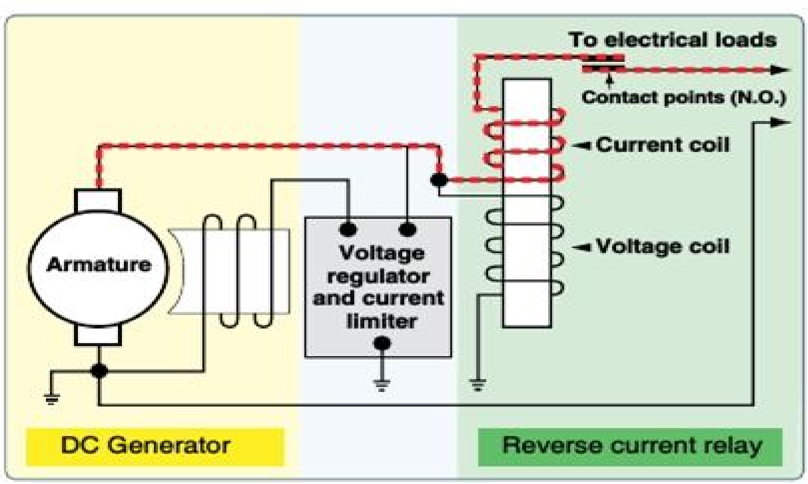


Fig 3.4For understanding purpose

3.4.8 Difference between and Isolator and Circuit Breaker:-

An isolator is a switch intend only for isolating a circuit on no-load. It should never be used for breaking a circuit carrying appreciable currents. If an isolator is opened carelessly, when carrying a heavy current, the resulting arc could easily cause a flash over to earth. This may shatter the supporting insulators and may even cause a fatal accident to the operator, particularly in high voltage circuits. A circuit breaker, on the other hand is designed to cut off the supply under all conditions, i.e. even when a heavy fault current is flowing.

Design of circuit-breakers is a highly specialized field of study and a vast amount of research and ingenuity has gone into reducing the size of circuit breaker into a very small size even when operating at very high voltages and currents. In the case of plain-break oil circuit breakers, the rupturing capacity is determined by the length of break, speed of contact movement, and head of oil above the contacts and the clearance of the live parts with the earthed body. The principle methods employed for securing efficient are suppression are the use of multi-break contacts, securing high turbulence of the oil to cool and take away the heat produced by the arc, making use of the gas pressure created by the arc itself to force the oil into the arc area to quench it, careful design of the arcing contacts, explosion vents, etc.

3.4.9 Rupturing Capacity of a circuit breaker:-

Rupturing capacity represents the maximum power a circuit-breaker can safely interrupt under a fault and is generally expressed in MVA (Mega-Volt Amperes). Several design factors determine the safe rupturing capacity, i.e. length and speed of break, position of arcing contacts, dimension of the parts, mechanical strength of the breaker, etc. all of which enter into the design. The size and cost of a circuit breaker depends, therefore, upon voltage, operating capacity in amp, and the rupturing capacity in MVA. The rupturing capacity is determined by calculating the short circuit current which will flow into a fault taking into account all relevant factors, i.e. generating capacity, impedance of all component parts, i.e, generators, transformers, transmission lines, etc. It is obvious that the circuit breakers at or near the generating station should have a much higher rupturing capacity than those nearer the end of a transmission line or at distribution centers. If circuit breakers of insufficient capacity are installed there will be a grave risk and danger of the circuit breaker exploding and getting wrecked when it opens under a heavy fault.

The actual size of the circuit breaker to be installed at any point depends upon the short-circuit level at that point, which should be calculated for each case. In general, it may be noted that for 400 volts 3 phase system, the maximum rupturing capacity is usually25 MVA. Above this, a change in the system of voltage is indicated. With modern designs, the economic limit of breaking capacity of circuit breakers installed at substations at different voltages is usually noted below:

400 volts	25 MVA
3300 volts	75 MVA
6000 volts	150MVA
11000 volts	250MVA
22000 volts	500MVA
33000 volts	750MVA
66000 volts	1000MVA
132000 volts	1500MVA

Higher ratings may be used if the circuit breakers have to be installed at large power houses or substations

3.5 Short circuit calculations: - (**Base KVA Method)**

Calculate Fault current at each stage of following Electrical System Single Line Diagram having details of.

- Main Incoming HT Supply Voltage is 6.6 KV.
- Fault Level at HT Incoming Power Supply is 360 MVA.
- Transformer Rating is 2.5 MVA.
- Transformer Impedance is 6%.

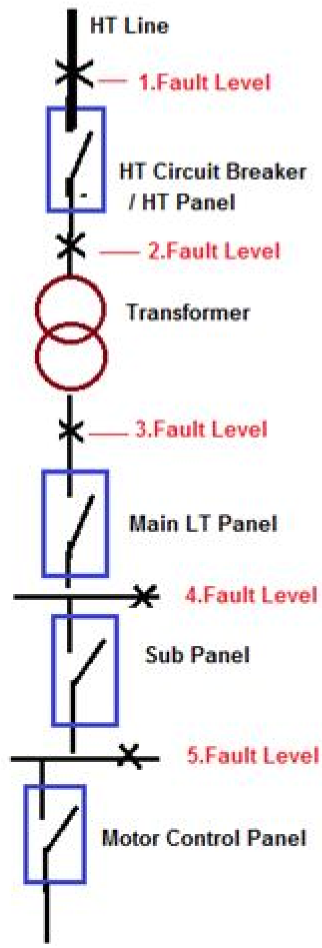


Fig 3.5 Short Circuit

Calculation:

- Let's first consider Base KVA and KV for HT and LT Side.
- Base KVA for HT side (H.T. Breaker and Transformer Primary) is 6 MVA
- Base KV for HT side (H.T. Breaker and Transformer Primary) is 6.6 KV
- Base KVA for LT side (Transformer Secondary and down Stream) is 2.5 MVA
- Base KV for LT side (Transformer Secondary and down Stream) is 415V

Fault Level at HT Side (Up to Sub-station):

(1) Fault Level from HT incoming Line to HT Circuit Breaker

- HT Cable used from HT incoming to HT Circuit Breaker is 5 Runs , 50 Meter ,6.6KV 3 Core 400 sq.mm Aluminum Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0990 Ω/Km.
- Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.
- Total Cable Resistance=(0.05X0.1230) / 5

- Total Cable Resistance=0.001023 Ω
- Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.
- Total Cable Reactance=(0.05X0.0990) / 5
- Total Cable Reactance =0.00099 Ω
- Total Cable Impedance (Zc1)=√(RXR)+(XxX)
- Total Cable Impedance (Zc1)=0.0014235 Ω———(1)
- U Reactance at H.T. Breaker Incoming Terminals (X Pu)= Fault Level / Base KVA
- U Reactance at H.T. Breaker Incoming Terminals (X Pu)= 360 / 6
- U. Reactance at H.T. Breaker Incoming Terminals(X Pu)= 0.01666 PU——(2)
- Total Impedance up to HT Circuit Breaker (Z Pu-a)= (Zc1)+ (X Pu) =(1)+(2)
- Total Impedance up to HT Circuit Breaker(Z Pu-a)=0.001435+0.01666
- Total Impedance up to HT Circuit Breaker (Z Pu-a)=0.0181 Ω.——(3)
- Fault MVA at HT Circuit Breaker= Base MVA / Z Pu-a.
- Fault MVA at HT Circuit Breaker= 6 / 0.0181
- Fault MVA at HT Circuit Breaker= 332 MVA
- Fault Current = Fault MVA / Base KV
- Fault Current = 332 / 6.6
- Fault Current at HT Circuit Breaker = 50 KA

(2) Fault Level from HT Circuit Breaker to Primary Side of Transformer

- HT Cable used from HT Circuit Breaker to Transformer is 3 Runs , 400 Meter ,6.6KV 3 Core 400 sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0990 Ω/Km.
- Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.
- Total Cable Resistance=(0.4X0.1230) / 3
- Total Cable Resistance=0.01364 Ω
- Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.
- Total Cable Reactance=(0.4X0.0990) / 5
- Total Cable Reactance =0.01320 Ω
- Total Cable Impedance (Zc2)=√(RXR)+(XxX)
- Total Cable Impedance (Zc2)=0.01898 Ω———(4)
- U Impedance at Primary side of Transformer (Z Pu)= (Zc2 X Base KVA) / (Base KV x Base KVx1000)
- U Impedance at Primary side of Transformer (Z Pu)= (0.01898X6) /(6.6×6.6×1000)

- U Impedance at Primary side of Transformer (Z Pu)= 0.0026145 PU——(5)
- Total Impedance(Z Pu)=(4) + (5)
- Total Impedance(Z Pu)=0.01898+0.0026145
- Total Impedance(Z Pu)=0.00261——(6)
- Total Impedance up to Primary side of Transformer (Z Pu-b)= (Z Pu)+(Z Pu-a) =(6)+(3)
- Total Impedance up to Primary side of Transformer (Z Pu-b)= 0.00261+0.0181
- Total Impedance up to Primary side of Transformer (Z Pu-b)=0.02070 Ω.——(7)
- Fault MVA at Primary side of Transformer = Base MVA / Z Pu-b.
- Fault MVA at Primary side of Transformer = 6 / 0.02070
- Fault MVA at Primary side of Transformer = 290 MVA
- Fault Current = Fault MVA / Base KV
- Fault Current = 290 / 6.6
- Fault Current at Primary side of Transformer = 44 KA

(3) Fault Level from Primary Side of Transformer to Secondary side of Transformer:

- Transformer Rating is 2.5 MVA and Transformer Impedance is 6%.
- % Reactance at Base KVA = (Base KVA x % impedance at Rated KVA) / Rated KVA
- % Reactance at Base KVA = (2.5X6)/2.5
- % Reactance at Base KVA =6%
- U. Reactance of the Transformer(Z Pu) =% Reactance /100
- U. Reactance of the Transformer(Z Pu)= 6/100=0.06 Ω——(8)
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c)=(Z Pu)+(Z Pu-b)=(7)+(8)
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c)=0.06+0.02070
- Total P.U. impedance up to Transformer Secondary Winding(Z Pu-c)=0.0807 Ω——(9)
- Fault MVA at Transformer Secondary Winding = Base MVA / Z Pu-c
- Fault MVA at Transformer Secondary Winding = 2.5/0.0807
- Fault MVA at Transformer Secondary Winding =31 MVA
- Fault Current = Fault MVA / Base KV
- Fault Current = 31 / (1.732×0.415)
- Fault Current at Transformer Secondary Winding = 43 KA

<u>Fault Level at LT Side (Sub-station to Down stream):</u>

(4) Fault Level from Transformer Secondary to Main LT Panel

- LT Cable used from Transformer Secondary to Main LT Panel is 13 Runs , 12 Meter , 1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0618 Ω/Km.
- Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.
- Total Cable Resistance=(0.012X0.1230) / 13
- Total Cable Resistance=0.00009 Ω
- Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.
- Total Cable Reactance=(0.012X0.0618) / 13
- Total Cable Reactance =0.00006 Ω
- Total Cable Impedance (Zc3)=√(RXR)+(XxX)
- Total Cable Impedance (Zc3)=0.00011 Ω———(10)
- U Impedance at Main LT Panel (Z Pu)= (Zc3 X Base KVA) / (Base KV x Base KVx1000)
- U Impedance at Main LT Panel (Z Pu)= (0.00011X2.5×1000)/(0.415×0.415X1000)
- P P.U Impedance at Main LT Panel (Z Pu)= 001601 Ω ——(11)
- Total Impedance up to Main LT Panel (Z Pu-d)= (Zc3)+ (Z Pu-c) =(11)+(9)
- Total Impedance up to Main LT Panel (Z Pu-d)= 0.001601 +0.0807
- Total Impedance up to Main LT Panel (Z Pu-d)=0.082306 Ω.——(12)
- Fault MVA at Main LT Panel = Base MVA / Z Pu-a.
- Fault MVA at Main LT Panel = 2.5 / 0.082306
- Fault MVA at Main LT Panel = 30 MVA
- Fault Current = Fault MVA / Base KV
- Fault Current = 30 / (1.732X0.415)
- Fault Current at Main Lt Panel = 42 KA

(5) Fault Level from Main LT Panel to Sub Panel:

- LT Cable used from Main LT Panel to Sub Panel is 2 Runs , 160 Meter , 1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0618 Ω/Km.
- Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.
- Total Cable Resistance=(0.160X0.1230) / 2
- Total Cable Resistance=0.008184 Ω
- Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.
- Total Cable Reactance=(0.160X0.0618) / 2
- Total Cable Reactance =0.004944 Ω

- Total Cable Impedance (Zc4)=√(RXR)+(XxX)
- Total Cable Impedance (Zc4)=0.0095614 Ω———(13)
- U Impedance at Sub Panel (Z Pu)= (Zc4 X Base KVA) / (Base KV x Base KVx1000)
- U Impedance at Sub Panel (Z Pu)= (0.0095614 X2.5×1000)/(0.415×0.415X1000)
- P P.U Impedance at Sub Panel (Z Pu)= 13879 Ω ——(14)
- Total Impedance up to Sub Panel (Z Pu-e)= (Zc4)+ (Z Pu-d) =(14)+(12)
- Total Impedance up to Sub Panel (Z Pu-e)= 0.13879 +0.082306
- Total Impedance up to Sub Panel (Z Pu-e)=0.2211 Ω.——(15)
- Fault MVA at Sub Panel = Base MVA / Z Pu-a.
- Fault MVA at Sub Panel = 2.5 / 0.2211
- Fault MVA at Sub Panel = 11 MVA
- Fault Current = Fault MVA / Base KV
- Fault Current = 11 / (1.732X0.415)
- Fault Current at Sub Panel = 16 KA

(6) Fault Level from Sub Panel to Motor Control Panel:

- LT Cable used from Sub Panel to Motor Control Panel is 6 Runs , 150 Meter , 1KV, 3.5C x 400 Sq.mm Aluminium Cable , Resistance of Cable 0.1230 Ω/Km and Reactance of Cable is0.0739 Ω/Km.
- Total Cable Resistance(R)= (Length of Cable X Resistance of Cable) / No of Cable.
- Total Cable Resistance=(0.150X0.1230) / 6
- Total Cable Resistance=0.003075 Ω
- Total Cable Reactance(X)= (Length of Cable X Reactance of Cable) / No of Cable.
- Total Cable Reactance=(0.150X0.0739) / 6
- Total Cable Reactance =0.0018475 Ω
- Total Cable Impedance (Zc5)=√(RXR)+(XxX)
- Total Cable Impedance (Zc4)=0.003587 Ω———(16)
- U Impedance at Motor Control Panel (Z Pu)= (Zc5 X Base KVA) / (Base KV x Base KVx1000)
- U Impedance at Motor Control Panel (Z Pu)= (0.003587 X2.5×1000)/(0.415×0.415X1000)
- P P.U Impedance at Motor Control Panel (Z Pu)= 05207 Ω ——(17)
- Total Impedance up to Motor Control Panel (Z Pu-f)= (Zc5)+ (Z Pu-e) =(17)+(15)
- Total Impedance up to Motor Control Panel (Z Pu-e)= 0.13879 +0.2211
- Total Impedance up to Motor Control Panel (Z Pu-e)=0.27317 Ω.——(15)
- Fault MVA at Motor Control Panel = Base MVA / Z Pu-a.

- Fault MVA at Motor Control Panel = 2.5 / 0.27317
- Fault MVA at Motor Control Panel = 9 MVA
- Fault Current = Fault MVA / Base KV
- Fault Current = 9 / (1.732X0.415)
- Fault Current at Motor Control Panel = 13 KA

Summary of Calculation:

Sl.No	Fault Location	Fault MVA	Fault Current (KA)
1	At HT Circuit Breaker	332	50
2	At Primary Side of Transformer	290	44
3	At Secondary Side of Transformer	31	43
4	At Main LT Panel	30	42
5	At Sub Main Panel	11	16
6	At Motor Control Panel	9	13

3.5.1 Conditions can a circuit breaker arranged to a trip:-

A circuit breaker may be arranged to open under any pre-determined condition, i.e. overload, short circuit, reverse current, over voltage, under voltage, over speed, unbalanced load, earth fault or any other abnormal operating condition. In H.V.A.C. circuits, potential and current transformers are connected to operate suitable sensitive relays which close a pair of contacts in the event of a fault and trip the circuit breaker, making use of the stationary battery power. The subject of relays and protection is so vast that it can be touched upon in this volume only cursorily. In the second volume yet to be published, this subject will be dealt with more fully. Some of the basic principles, however, are mentioned below:

1.An Electrical system is made up of a number of elements,viz., generators bus bars, transformers or converting equipments, switchgear transmission lines, distribution lines and last of all we consumers apparatus at a house or in a factory .Faults may occur at anyone or more of these elements. The protective equipments which comprise the relays and the associated circuit breakers, wiring, batteries and the instrument transformer, should clear any fault which may occur in one or more of these equipments, on a zonal basis. The clearance should be positive, quick and absolutely reliable under all conditions.

2. Where several circuit breakers are provided in the same system at different points, they should be so graded, either with respect to current or time, that only the circuit breakers nearest to the faults on both

side trip and no others. This will ensure that as large a part of the system as possible is kept functioning normally without interruption, and the faulty section is automatically isolated.

3. Backup protection should invariably exist, i.e. if a circuit breaker fails to operate and clear a fault whatever may be the reasons, the fault should nevertheless be cleared by another backup relay and a circuit breaker higher up, i.e towards the source of supply.

4. The operating time of the protective relays should be as short as necessary to preserve systems stability and to prevent danger to life, property and service.

A relay is a precision device requiring highly skilled attention for initial setting, periodical testing and maintenance. Relay systems are, however costly. The cost of the protective relay system should have some relation to the cost of the equipment protected or to the importance of the circuit protected. For simple schemes fuse protection is sufficient. Some circuit breakers make use of fuse wires instead of relays to trip them in the event of a fault. The fuse may be a across a series trip coil so that the circuit breaker is tripped as soon as the fuse blows. In some cases the fuse is immersed in the circuit breakers oil tank and is normally in tension holding up the tripping mechanism. When the fuse wire blows, the spring loaded trip mechanism is released and will trip the breaker. A fuse can, at best, be recorded as a very elementary type of protection and care should be exercised in its proper selection and installation having regard to its limitations.

3.6 AUTO RECLOSE BREAKER:-

An auto reclose breaker is one which is arranged to open the circuit instantaneously when a fault occurs and reclose it automatically after about a second and repeat the operation once more if the fault persists. These two instantaneous openings are instead to clear non-persistent. Faults like lighting flashovers of line insulators momentary contacts of two conductors due to high winds or a stray piece of wire dropped by a bird, momentary contact with tree branches etc. Operating records have shown that nearly 75% of line faults on distribution networks are of this transient natures and little or no physical damage results if those faults are automatically cleared by the operation of protective relays and circuit breakers. Obviously sooner a line can be put back for service by the reclosing of its breaker, the better it would be for everyone.

Auto reclose circuit breakers are increasingly employed in unattended substation and rural distribution schemes where the circuit breakers are installed in outlying areas. The obviate the need for an operator to produced to the point to close the breaker manually every time it trips. Outages are thereby greatly reduced.

If the fault is persisting even after the second recloser the circuit breaker is arranged to get automatically locked out, necessitating manual resetting by a technician after he has investigated and cleared the fault.

Like any other circuit breaker the rupturing capacity of an auto recloses breakers should be properly chosen. In large distribution networks, reclose breakers may be provided to look after each separate zone and fuse protection provided for the subsidiary branch lines in each zone.

3.6.1 Fault clearance time:

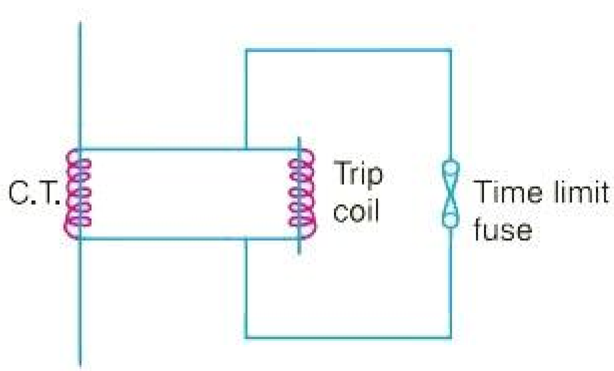
The time taken to trip comprises the time taken for the fault to develop, for the relay to close, for the relay to close, for the tripping mechanism to act on the circuit breaker, and finally the circuit-breaker contacts to open and extinguish the arc. An instantaneous relay is one where no deliberate time lag is introduced.

High voltage circuit-breakers are usually of the high speed type, capable of breaking the circuit within 5 to 10 cycle, i.e., within 0.1 to 0.2 seconds. The primary function of all protective gear is to isolate the fault as rapidly as possible, so that there may be minimum damage to the equipment.

In radial feeders, where several circuit-breakers are in series at different points on the system, discrimination is achieved by setting the time lag on circuit-breakers to increase progressively as you move towards the source of supply, each step being about double the previous one to ensure proper discrimination, such as 0.4 sec., 0.8 sec., etc. if fuse are provided, their characteristics should be taken into account and the setting of the relays made in relation to it. Apart from facilitating isolation of the faulty section, graded time lag ensures that circuit is not unnecessarily tripped on momentary overloads.

3.6.2 Inverse time over current relay:

- In this type of relays, operating time is inversely changed with current. So, high current will operate over current relay faster than lower ones. There are standard inverse, very inverse and extremely inverse types.
- Discrimination by both ‘Time’ and ‘Current’. The relay operation time is inversely proportional to the fault current.
- Inverse Time relays are also referred to as Inverse Definite Minimum Time (IDMT) relay



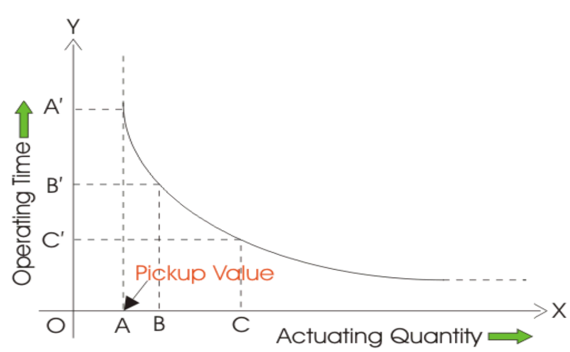


Fig 3.7 Inverse Time over Current Relay

- The operating time of an over current relay can be moved up (made slower) by adjusting the 'time dial setting'. The lowest time dial setting (fastest operating time) is generally 0.5 and the slowest is 10.
- Operates when current exceeds its pick-up value.
- Operating time depends on the magnitude of current.
- It gives inverse time current characteristics at lower values of fault current and definite time characteristics at higher values
- An inverse characteristic is obtained if the value of plug setting multiplier is below 10, for values between 10 and 20 characteristics tend towards definite time characteristics.
- Widely used for the protection of distribution lines.
- Based on the inverseness it has three different types.

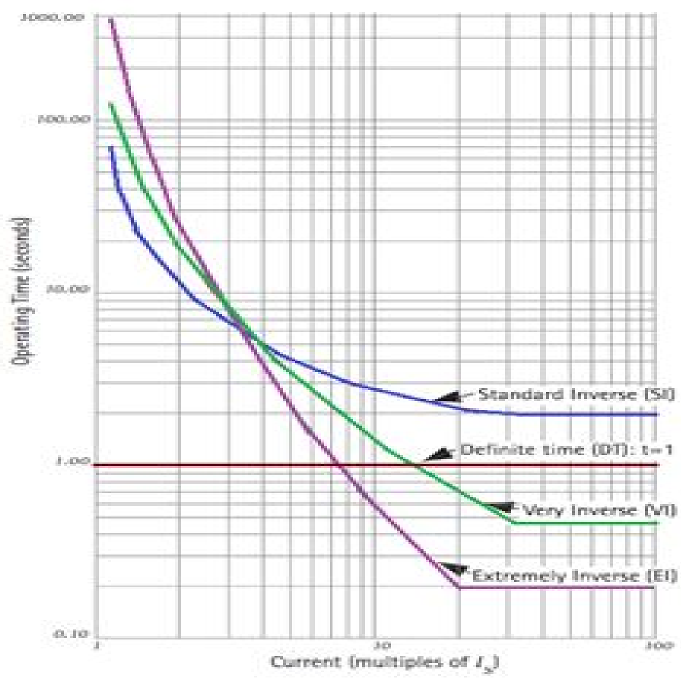


Fig 3.8 Waveform

(1) Normal Inverse Time Over current Relay:

- The accuracy of the operating time may range from 5 to 7.5% of the nominal operating time as specified in the relevant norms.
- The uncertainty of the operating time and the necessary operating time may require a grading margin of 0.4 to 0.5 seconds.

- used when Fault Current is dependent on generation of Fault not fault location
- Relatively small change in time per unit of change of current.

Application:

- Most frequently used in utility and industrial circuits. especially applicable where the fault magnitude is mainly dependent on the system generating capacity at the time of fault

(2) Very Inverse Time Over current Relay:

- Gives more inverse characteristics than that of IDMT.
- Used where there is a reduction in fault current, as the distance from source increases.
- Particularly effective with ground faults because of their steep characteristics.
- Suitable if there is a substantial reduction of fault current as the fault distance from the power source increases.
- Very inverse over current relays are particularly suitable if the short-circuit current drops rapidly with the distance from the substation.
- The grading margin may be reduced to a value in the range from 0.3 to 0.4 seconds when over current relays with very inverse characteristics are used.
- Used when Fault Current is dependent on fault location.
- Used when Fault Current independent of normal changes in generating capacity.

(3) Extremely Inverse Time Over current Relay:

- It has more inverse characteristics than that of IDMT and very inverse over current relay.
- Suitable for the protection of machines against overheating.
- The operating time of a time over current relay with an extremely inverse time-current characteristic is approximately inversely proportional to the square of the current
- The use of extremely inverse over current relays makes it possible to use a short time delay in spite of high switching-in currents.
- Used when Fault current is dependent on fault location
- Used when Fault current independent of normal changes in generating capacity.

Application:

- Suitable for protection of distribution feeders with peak currents on switching in (refrigerators, pumps, water heaters and so on).
- Particular suitable for grading and coordinates with fuses and re closes
- For the protection of alternators, transformers. Expensive cables, etc.

(4) Long Time Inverse over current Relay:

- The main application of long time over current relays is as backup earth fault protection.

3.6.3 Procedure to ensure proper operation of circuit breaker in the event of a fault:-

This can only be ensured by intelligent and regular maintenance of the circuit breaker, relays, trip coil, battery, etc. In particular the following points should be attended to:

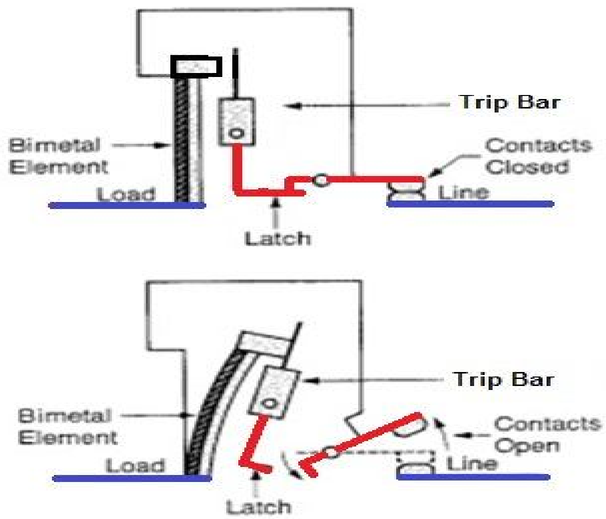


Fig 3.9 Circuit Breaker

- The tripping mechanism of the circuit breaker should be in perfect condition both mechanically and electrically.
- Contact pressure is an extremely important matter, even more than the area of the contact. In this figure, the wedge shape of the contact bars, which ensures a good contact pressure. When the contact pressure is good, even a line contact can pass heavy currents without overheating, whereas even a large surface contact without sufficient pressure is likely to heat up and deteriorate rapidly.
- Trip Coil Battery: Proper maintenance of the trip coil battery is vital for satisfactory operation of all protective relays. The battery should be inspected daily for correct voltage, specific gravity, etc and it should be preferably kept on trickle charge continuously. The inter cell connectors should be in perfect condition. There should be a pilot lamp, or preferably alarm indication to draw the attention of the operator, if the trip coil battery voltage falls down unduly.
- Every relay should be tested by a responsible technical assistant at least once in six months with suitable relay testing equipment and the record of such tests entered a maintenance register. During these test, a check should also be made if any modification in view of the increase or

decrease in the load conditions which may have occurred since the date of last test. Some relays show a tendency to creep even under normal load. This point should also be checked and corrective action taken.

- Even if a relay by itself may function properly on a bench test, it may be ineffective in clearing a fault due to any defect in the wiring or in the circuit breaker operating mechanism as follows.
    1. Poor contact or misalignment of the contact prongs of the trip battery circuit, between the cubicle and the draw out truck.
    2. Fault in the wiring of the trip coil battery, or discharged battery.
    3. Circuit breaker trip mechanism not being quite free due to mechanical defects, or stiffness due to dust or rust.
    4. Incorrect current transformer connections.
    5. Incorrect relay setting for the load connections.

What is important is that the circuit breaker should operate in the event of a fault positively without failure. One simple and conventional way of checking against items 1 to 3 of the above, is to close the relay contacts manually by rotating or moving the operating elements by a finger carefully until it closes the trip contacts when the circuit breaker should open. This should be done occasionally by the electrical chargeman or engineer personally.

3.6.4 Maintenance requirement for oil circuit breakers:

Every circuit-breaker should be thoroughly inspected at regular intervals of three or six months, depending upon usage, during which all the points referred to under above should be checked. In addition check the level and condition of oil. Clean the insulators examine the arcing contacts and attended if necessary, check auxiliary contacts for cleanliness and contact making. Finally, check all bolts and nuts for tightness, particularly those securing heavy current carrying parts, check operating mechanism, adding a few drops of oil where required. The indicating devices and lamps should also be checked, as well as safety shutters, etc.,

In addition , a circuit-breaker which has operated on a heavy fault should be examined as soon as possible, although every breaker should be capable of being closed after the operating duty cycle consisting of B-3’-MB-3’-MB, standing for “break, 3 minutes interval, make-break, 3 minutes interval, and again make-break”, on full fault current, without inspection or change of oil.

The points to be checked during periodical maintenance are:

1. Check all current carrying parts and attend to the arcing contacts.

2. Examine the oil and change it if it is badly discolored, test breakdown voltage if in doubt. Good oil should withstand 30KV for one minute, in a standard oil testing cup with 0.15 inch gap between electrodes. Renew oil if bad, after removing all sludge.
3. Inspect the insulation for possible damage. Clean the surface and remove deposits of carbon. In cleaning circuit-breakers never use loose cotton waste, but only strong, firm and dry fabric, which will not deposit loose fibers.
4. Check closing, tripping and interlock mechanisms.
5. Ensure, before closing the tank that no tools have been left behind, that the tank lining and barriers are in position and secure, and that the tank gasket is in good condition.

3.6.5 Attention required for the contacts of contactors:

A contactor is an electrically operated air break switch capable of making and breaking heavy currents

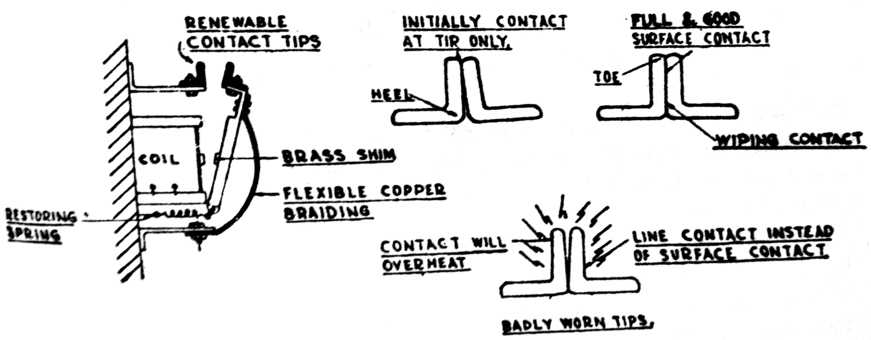


Fig 3.10 Contactors

The following points should be attended to during periodical maintenance:

1. With the supply off, the armature core should be pressed in towards the magnetic core, watching carefully its operation. If the movement is not free, clean the pivot of the armature of all accumulated dirt and wash with petrol if necessary.
2. Contact tips are subject to mechanical wear and electrical burning. They are usually made of copper and bolted in place. If the bolts get loose, the tips will overheat. The heat will affect the surrounding parts and cause further trouble. A poor contact deteriorates rapidly, as the contact resistance becomes higher and higher, producing more and more heat. Therefore, it pays to keep the contact tips perfectly good.
3. Any tip worm to half or three-fourths through should be replaced. The shape of a tip is important. Sometimes wrongly shaped tips are put on a contactor. It is like putting on a wrong shoe and is never satisfactory. Use the right tips and when you mount them, be sure the contact surfaces line up.
4. Contact tips are designed to carry current on the heel and to interrupt it on the toe. Since the heel does not break the current, it should remain in pretty good shape, though it may discolor. The toe will normally get

pitted and discolored. Sometimes drops of copper will form beads on the edge of tips. These should be knocked off. Normally nothing more is necessary than touching up with very fine carborundum paper, but not emery cloth. A smooth file should only be used if the tips are burnt badly. It is bad making a practice of filing tips. Such filing often alters the shape of the contact making it overheat finish off by a light touch of Vaseline.

3.6.6 SF6 Circuit Breaker Maintenance

In addition to that in SF6 CB some extra care to be taken. SF6 circuit breaker must be checked for SF6 gas leakage, if unwanted SF6 low gas pressure alarm comes. This is efficiently done by gas leakage detector. If the circuit breaker is provided with gradient capacitors, these must be checked for oil leakage monthly. If leakage found plug it. Dew point of SF6 should be checked with the help of dew point meter or hydro meters in every 3 to 4 years interval.

Review questions

Part A & B

1. Mention the conditions for paralleling of alternator.
2. What are the advantages of paralleling of alternator?
3. What are the Causes for alternator fails to buildup voltage.
4. Difference between and Isolator and Circuit Breaker.
5. What is auto recloser breaker?
6. What is fault clearance time?
7. What are the points to be checked during periodical maintenance?
8. What are the following points should be attended to during periodical maintenance of contactors.
9. Explain about the maintenance of SF6 circuit breaker.
10. What are attentions required for the contacts of contactors.
11. What is real power and reactive power?
12. What is the Cyclic Speed irregularity?
13. Mention some Protective and indicative instruments.
14. What is the use of reverse current protection?
15. What is the necessity of reverse current protection?

Part C

1. Explain about Inverse time over current relay.
2. Explain the Conditions can a circuit breaker arranged to a trip.
3. Write the Procedure to ensure proper operation of circuit breaker in the event of a fault.
4. Explain Automatic Voltage Regulator (AVR) Role.
5. Explain the General Procedure for Paralleling Alternators.
6. Describe about the parallel operation of alternator.
7. What are the Causes for alternator fails to buildup voltage.

UNIT – IV

OPERATION AND MAINTENANCE OF AC MOTORS AND STARTERS

4.1 Change the direction of rotation:

By interchanging any two of the three main supply leads to the stator. No change is required for the rotor leads in slip ring motors.

4.2 Role of single phase preventer:

The usual magnetic overload releases provided, only act at 500 per cent above full load current, as they have to cater for the heavy starting kick. They are primarily intended as a protection against short-circuits. They will not operate at lower overloads of 30 per cent to 50 per cent as when single phasing. Moreover, dashpot type overload releases do not often function correctly at the currents to which they are set. Thermal overload releases are effective if properly working on nearly full load.

4.3 Types of Enclosures:

The word 'enclosure' refers to the type of housing with which the motor is equipped. Some of the principle types of enclosures are us follows

1. **Screen protected** : General purpose type for used in workshop
2. **Drip proof** : Used wherever there is a possibility of water dripping or spraying over the motor such as in the basement of power houses, outdoor plants like gantry cranes etc.,
3. **Pipe ventilated** : Chemical works, flour and cement works, etc.,
4. **Forced Draught** : Where natural ventilation by the fan provided on the armature shaft will not be sufficient, such as incase of slow speed machines, and traction motors, etc.,
5. **Totally enclosed** : Where admission of air from outside is not permissible, such as in boiler rooms, steel works, foundries, outdoor installations, winches and cranes exposed to the weather, etc.,
6. **Flame proof** : Where the motor has to work in explosive atmosphere, as in gas works, oil plants, coal mines, etc.,

The cost of the motors rises with the type of enclosure provided in the order indicated above. In the case of very large electrical equipment, several methods of extracting the heat produced inside are adopted, like forced hydrogen gas cooling, water cooling through circulating pipes, etc., the principal object is to take away as much heat as possible and as quickly as possible, thereby reducing the dimensions of the machine to reasonable limits

Permissible Overloads

After having attained the temperature rise corresponding to continuous run on full load, a generator should be capable of withstanding 50% overload for 15 seconds; motors shall be capable of withstanding the following excess torque: (ISS: 325 – 1959, BSS: 2613 – 1957).

Upto 50hp	100% for 15 seconds
Above 50 hp	75% for 15 seconds
Above 500 hp	60% for 15 seconds
Motor with short term rating	100% for 15 Seconds

The old Indian standard specifications provided for an overload capacity of

25 percent for	¼ hour upto 4 hp
25 percent for	½ hour upto 10 hp
25 percent for	2 hours above 10 hp

The main point that determines the rating is the maximum temperature permissible in the motor windings. Naturally, it depends upon two factors

i. The ambient temperature which decides the amount of heat that the motor can dissipate
ii. The class of insulation, employed for the motor windings

4.4 Effect of ambient temperature:

Ambient which determines the rating of all electrical equipment temperature is the temperature of the surrounding air in which electrical equipment works. It is a very important factor

The life of any electrical equipment like a motor, generator, transformer, etc., is directly dependent upon the heat stresses to which the insulation is subjected to in operation, i.e., the maximum temperature permitted in the windings. The limits of temperature for different classes of insulation employed are given in (Table 1 column no 3). These limits have been specified to ensure a life of about 25 years while the life will not be increased very much more if a lower temperature is adopted, it will fall rapidly, if these temperature limits are exceeded

The temperature of inner most layer of the insulation depends upon:

a) The amount of heat produced

This is equal to I^2RT, i.e., The square of the current multiplied by the resistance of the windings and the time in addition there are also eddy current and hysteresis losses in the core .

b) The amount of heat dissipated

Heat is dissipated in two ways, by radiation and by convection, radiation is dependent upon the surface area exposed (cooling fins are often added on the body to increase this) and the ambient temperature of the atmosphere in which the equipment is working. The heat lost by convection is naturally related to the amount of air passed through the machine by the ventilating fans mounted on the rotor, and the temperature of the air as it enters the machine (ambient temperature). To ensure quicker dissipation the thickness of the windings is also kept low and air space is and ducts are provides wherever possible.

The ultimate temperature of the windings is a balance between the het produced and heat dissipated

4.5 Insulation classification:-

There are four classes of insulation employed for windings as shown under:

class	Material	Ambient temperature	Maximum Temperature	Maximum temperature permissible by thermistor	
				^oC	^oF
O.	Cotton, silk, paper, etc. when not impregnated or immersed in oil	40^oC	25^oC	65^o	149^o
A.	Cotton, silk, paper, etc. when impregnated or immersed in oil, enameled wire	40^oC	50^oC	90^o	194^o
B.	Mica, asbestos, glass, wool, etc. in built up form combined with binding cement	40^oC	70^oC	110^o	230^o
C.	Porcelain, pure, mica, etc.	Not Specified			

The above table does not apply to traction motors. It will be observed that temperature rise for class O is 15^oC less than for class A. and for Class B it is 20^oC more than for class A.

Every insulation material starts deteriorating if its temperature exceeds the above values. The temperature rise therefore puts a limit on the power which we can get out of a machine safely and therefore determines the rating of the machine.

Overloading a motor beyond its capacity may no doubt enable one to tide over a crisis, but if resorted to frequently will seriously reduce the life of the equipment.

When the permissible rise in temperature is specified as 40^oC for motor winding, normally it refers to the rise above the standard ambient temperature of 40^oC. the actual temperature of the motor winding, with class A insulation thus can rise up to 90^oC. If the ambient temperature is lower, say 30^oC as in a cold climate, the permissible temperature rise is naturally higher, i.e. $90-30=60^oC$. The temperature limit is still 90^oC as before. A motor can thus stand a higher amount of load when working in an cooler atmosphere than otherwise. In tropical countries like India, where the ambient temperature in summer may go up as high as 113^oF, i.e. 45^oC the permissible temperature rise can only be 45^oC. For continuous operation under such conditions, an ordinary motor will have to be slightly derated. Therefore, in placing orders for a new motor, the ambient temperature of 45^oC should preferably be specified.

4.5.1 Function of low-volt release:-

The low volt release in hand operated starters usually consists of a shunt coil connected across the mains, so arranged that it holds the spring loaded started handle in the 'on' position as long as the supply is 'on'. If the supply should fail while the motor is running or if the voltage drops unduly, the shunt coil is weakened and can no longer released and automatically returns to the starting position and cuts off the supply of the motor. This ensures the motor can only be re-started in the normal manner after the supply is resorted. If such stuck in the full 'on' position, it will create an undesirable condition, i.e. full voltage will be applied to the motor terminals without any starting resistance, when the supply gets resorted. This may not only damage the motor, but it may also result in the tripping of the incoming feeder to the shop. In a contactor type starter, every contactor is inherently a no-volt release as it opens automatically if the supply voltage falls unduly.

4.5.2 Function of overload release:-

Overload releases are intended to protect the motor against overloads. All overload devices make use of the current through the motor circuit to lift off a contact in the low-volt coil circuit or make a contact in the trip circuit or mechanically operate the trip bar, thus shutting down the motor in the event of excessive overload. There are mainly two types:

- ✓ Magnetic overload releases: These are usually of the instantaneous type and are intended to protect the motor against internal short-circuits, bearing seizing and rotor getting locked. Alternatively, they may be of the solenoid operated plunger type fitted with dashpots as protection against heavy overloads.

- ✓ Thermal overload release, which protect the motor against sustained overloads. Whatever may be the type, starters are provided with a reset button or handle, which makes it obligatory for a trained electrician to visit the spot, investigate the cause of the tripping and reset the trip. Until the reset device is operated, the motor cannot be started.

4.5.3 Function of thermal overload release:-

A thermal overload release is one, in which the heat produced by the excessive overload current is made use of to trip the motor circuit. Several designs of thermal overload releases have been developed by different manufacturers, but are generally based on one of the following principles:

- ✓ Deflection of a bimetallic strip due to the heat caused by the motor current, which may pass either directly through the bimetal or indirectly through a separate heater provided below the bimetallic strip. This deflection of the bimetallic strip releases the trip bar. The bimetallic strip is made up of two dissimilar metals, having different coefficients of expansion. When such a strip is heated, it bends due to the unequal expansion of the two metals and this bending action is used to trip the overload contacts.
- ✓ Rotation of a spring loaded plug due to the softening of the solder by the heat produced by the motor current, when passing through a heater which surrounds the soldered plug. This operates the trip contacts. In a 3-phase motor, 3 thermal elements are provided, one for each phase winding.

A common trip bar is provided to open the control circuit if any of the overload elements operate. Each of the thermal elements is provided with an adjustment for setting the degree of overload at which it should operate. A thermal overload release is superior to the magnetic overload release in the protection it gives to the motor against sustained overloads since it takes into account the actual heating effect of the motor windings due to the overload. No magnetic overload release can fulfill such a requirement as it depends entirely upon the value of the current and does not take into account the important element of time.

As already known, fuses and magnetic overload releases are ineffective and unsatisfactory for affording any protection against the overloading of motor, since they should be able to withstand the heavy rush of current during the starting period. Thermal overload, on the other hand, protects the motor against sustained overloads, as its thermal characteristic very closely resembles that of the motor winding and, therefore, it trips the circuits just when the motor windings become unduly hot and can no longer bear any further rise in temperature. Fig shows the characteristic curve for a thermal overload release.

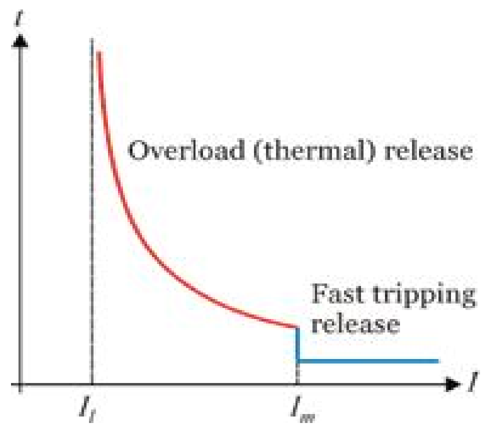


Fig 4.1 Waveform

A combination of a magnetic element with an instantaneous trip against short circuits and a thermal element which takes care of sustained overloads, would together gibe complete protection to a motor.

4.6 Interlocks:-

Interlocks are devices provided on equipment to prevent their being operated incorrectly. They may be either mechanical or electrical in action. Some examples of interlocks are given below:

- ✓ The starter cover is mechanically interlocked with the main control switch so that the cover cannot be opened until the main switch is off. It also ensures that the main switch cannot be closed until the starter cover is put back. This makes it impossible for staff to work inadvertently on live equipment.
- ✓ In automatic contactor type starters, electrical interlocks are provided to ensure the correct sequence of operation. Mechanical interlocks are provided on the star and delta contactors so that they can never both be simultaneously on.
- ✓ In slip ring motors, an electrical interlocking contact is provided on the rotor short-circuiting switch to ensure that it is opened and the starter handle returned to the start position before the slip ring motor is started. Similar interlocks are also usually provided for air-compressor motors, to ensure that the compressor is unloaded before the motor is started, to reduce the starting current.

4.6.1 Indicating and protecting devices for large size motors:-

Indicating devices:-

The most common and useful indicator on a starter is an ammeter, especially if the full load current is marked on the dial in red. This furnishes a ready check on the operation of the motor. Some starters are provided with ‘on’ and ‘off’ flag indications and some with flag indication to show up if any protective device has operated. A voltmeter would also be a useful addition.

4.6.2 If over load mechanism trips frequently what action to be taken:

If an overload trips occasionally, it is indeed a good sign, as it proves that the mechanism is functioning properly. If the mechanism has never operated, it is by no means an indication of good maintenance. On the other hand, it is time that its operation is thoroughly checked.

If, however, the tripping is frequent, check if the machine is overloaded, by inserting an ammeter and measuring the current in each of the phases. If working currents in each of the phase s are equal and less than the full load current, check if the proper grade of oil has been used in the dashpots and if the mechanism is in good operating condition. If they are both o.k.,

Raise the over load setting slightly as the calibration plate may not be quite correct. Keep the equipment under observation.

If a hand operated starter trips frequently when starting, it may be due to the starter handle being moved too rapidly from one step to the next without allowing sufficient time for the motor to accelerate, some training is required before any one learns the proper operation of manually operated starters. A good rule is to watch the ammeter reading and ammeter needle has dropped down sufficiently. If the motor is nearby, the sound of the motor also shows if it has attained the maximum speed corresponding to the notch. In automatic type starter, current relays are provided to ensure sufficient time to elapse from one step to another. If they are defective or wrongly set, the overloads would naturally trip frequently.

4.6.3 Control devices of motor:

There are so many types and designs that it is impossible to mention all of them. The following are just a few examples:

a) *Mechanically operated switches*, such as door switches, limit switches on cranes, hoists or planning machines, float switches operating on rise and fall of liquid level, etc., many of these control devices are suitable to operate the circuits required directly. A separate relay or contactor will only be required if the current or voltage to be controlled is beyond the capacity of the control switch or the control equipment is too far away.

b) *Electrically operated switches*, such as overload relays, reverse power relay, battery cut-in and cut-out relays. In these cases the control device itself functions as a relay.

c) *Pressure operated diaphragm switches,* such as pressure switches on air vessels to control operation of compressors, oil pressure switches o diesel engines to stop them in the events of failure of lubrication and water pressure switches to give alarm indication to staff on failure of circulating water supply to engines, etc.

d) *Thermostats operation on a variation of temperature,* such as mercury-thermometer type thermostats to start and stop air conditioning equipments, sealed bellows type thermostats for giving alarm to the operators of diesel engines, if the lubricating oil temperature rises unduly, embedded type thermocouples in large turbo-generators to give audible and visible warning and to shunt down the set, if necessary, when the temperature of the winding rises unduly, and galvanometer type relays arranged in Wheatstone bridge circuit for maintaining temperature constant in oil-fired furnaces.

e) *Photo electric relay operating on various of light intensity,* such as for switching on street lights, flood lights, etc. in the evenings as soon as it is dark enough, for burglar alarms if any one interrupts a beam of light focused on the photo electric cell, or to detect smoke and give fire signals.

f) *Electronic relays:* There is no limit to what an electric relay can do. It can be made to fulfill any requirement beyond the capacity of any other equipment. For instance, it can automatically maintain the thickness of a sheet of paper or metal within very close limits, or count accurately moving objects flying past an electric eye at thousands per minute, etc. its applications are far too many to be dealt with in the present volume.

4.6.4 Role of relays in motor:

Relays are extensively used for a variety of purposes and several designs have been evolved to suit different needs.

Relay can be connected to any control device desired and in turn, operate very much heavier equipment. For instance, a control device of a few milliamps is sufficient to operate a low voltage relay, whose contacts in turn can operate a heavy contactor which could switch on and off a large amount of power or high voltage equipment at point far away. This is illustrated in fig. This shows a remote controlled pumping installation.

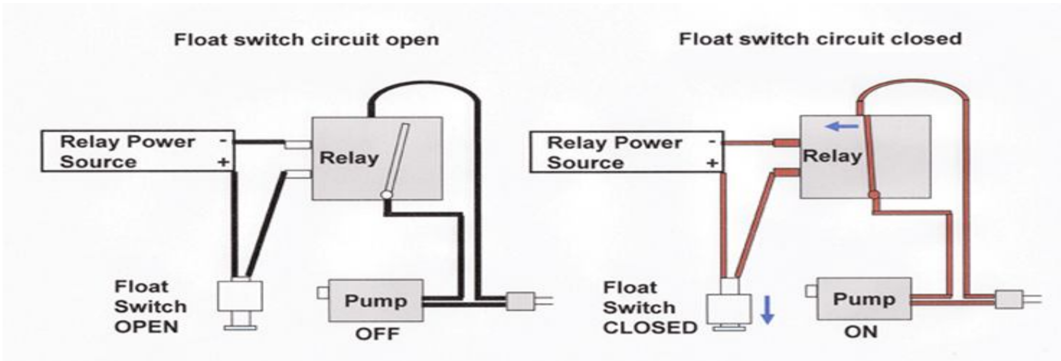


Fig 4.2 Role of relays in Motor

If the control device is a float switch fixed on an overhead storage tank, a few milliamps in the relay circuit is sufficient to start and stop a large motor driven pump, may be of 100 h.p., automatically even if situated several miles away, depending only upon the fall or rise of water level in the tank.

4.6.5 Points to be attend during periodical maintenance:

General cleaning and blowing off of dust with compressed air at a pressure of 80 to 100 lb. per sq.in.

i. Checking of air gap
ii. Greasing or oiling of bearings
iii. Measurement of insulation resistance of windings
iv. Attention to slip ring or commutators
v. Checking up of carbon brushes and brush gear
vi. Checking current taken by motor
vii. Checking tightness of terminal connections
viii. Checking if motor is operating smoothly and without vibration.

N.B. whenever any motor is inspected, it is equally important to check the starter and control gear.

4.7 Air gap measurement:

Air gap depends upon the size of the motor. AC motors have much small air gaps than DC motors. The gap between the rotor and the stator varies from a few mils (thousands of an inch) to 50 miles or more depending upon the size of the motor. The air gap is measured by inserting long steel feeler-gauge leaves in the air gap between the rotor and the stator and ascertaining the maximum thickness of the feelers that can passed. At least four readings should take at different points around the periphery of the motor, i.e. top, bottom, front and back. Unless acre is taken in measuring the gap, the results will not be consistent. When any new motor is installed, air gap readings should be clearly recorded in the motor history sheet and filled for future reference. Later on, if the top air gap is found to be much higher than at the side and the bottom, it clearly shows that the bearing has worn down. Belt-driven machines usually show greater wear on one side than on the other. Several manufacturers of motor provide suitable holes in the end covers so that a feeler-gauge may be inserted for measuring the air gap.

4.7.1 Ball & Roller bearings usage:

Precautions in fitting bearings:

Ball and roller bearing are manufactured to very close tolerances and are therefore easily damaged by careless handling and fitting. Therefore, utmost care is required in fitting up and maintaining them. The following points require special attention:

a. The bearing housing and the shaft end, over which the bearing fits, should be thoroughly cleaned so that the bearing fits neatly and just push tight. Bearings should never be driven tight, because it will distort the race and damage the bearing. Therefore, the fitting surfaces should be carefully checked and any burs or surface injuries should be cleaned up with a smooth file and finished with fine emery where necessary.

b. Scrupulous cleanliness is essential in handling ball and roller bearings. Grit and dirt are enemies to all bearings. Stored bearing should not be removed from their boxes until they are required for fitting and only clean white cotton fluff less cloth (never cotton waste) should be used in their vicinity.

c. When fitting new bearing, the protecting oil put in by the manufacture need not be washed off as it makes a good lubrication for the first few hours of running. Grease, of the best quality, should be lightly packed into the bearing itself and the bearing then fitted into position in its housing. The inner race may be pressed on to the shaft but if this not practicable; it can be fitted into position by lightly tapping with a wooden mallet over a tube passing over the shaft end. If a tube is not available, a copper drift may be used. Care must be taken to ensure that the bearing is square on the shaft. Wooden blocks should not be used unless they are of very hard wood and show no tendency to splinter.

d. In handling ball or roller bearing, avoid dust and grit as plague.

4.7.2 Bearing problems:

Alignment of directly coupled motors:

The alignment is easily checked by laying the edge of a steel foot rule against the sides of the two flanges and checking whether the steel edge bears fully against the sides of the two flanges or if there is any gap. The gap can be readily seen if a light is placed on the opposite side. Any variation in levels is corrected by suitable steel shims. The alignment should not only be correct in the vertical and horizontal planes but the axis of both the shafts should be in the same line and not make an angle with each other. This can be checked by measuring the gap between the flange faces at four points, i.e. top, bottom, front, and back. Fig shows the two types of mis-alignment in an exaggerated way for clarity.

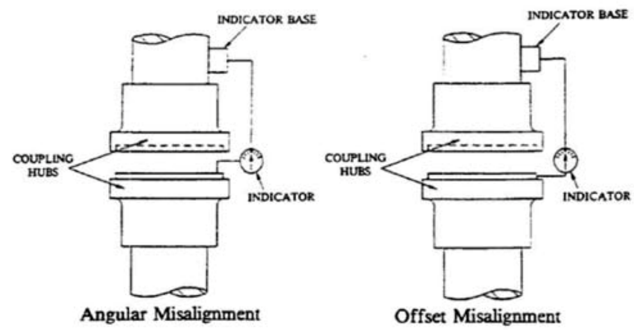


Fig 4.3 Coupled Motors

4.7.3 Static and dynamic balancing of motors:-

Balancing:

However carefully constructed, a motor armature shaft has necessarily some unequal distribution of weights in its body, which results in its axis of gravity being slightly off centre and out of line with the axis of rotation. Therefore, when the armature rotates, centrifugal force is created which act upon bearings. This causes the whole machine to vibrate.

Its intensity varies at different speeds and becomes maximum at some critical speeds due to the effects of resonance. The amount of unbalance determines the degree of vibration. For smooth running and long useful life, the rotating parts should be properly balanced. Then the machine will run smoothly without producing any oscillation, vibration or noise.

Balancing consists of re-adjusting the distribution of masses in the body in such a way as to bring the axis of gravity to coincide with the axis of rotation. This is done by placing a counter-weight on or removing some weight from some part of the armature in such a way that the unbalanced centrifugal force is cancelled out. To do this is necessary to determine precisely where the counter-weight is to be placed or removed, and what the weight should be.

4.7.4 Static Balancing:-

In static balancing, the rotor is supported on a pair of perfectly horizontal knife edges. If the armature is in perfect balance, the rotor should rest in any position. If, on the other hand, the rotor is not well-balanced and has uneven distribution of weight, the rotor will turn round and come to rest with the heaviest portion in the lowest position, and the hollow over portion will occupy the top position.

After noting the lowest point of the armature, small counter-weight should be fixed on the top part of the armature and a test conducted again. The operation should be repeated until the rotor can come to rest equally well in all positions. The amount of weight added and its location has to be found by the trial and error method, remembering that the greater the distance from the centre, the smaller should be the weight. An alternative method is to remove some weight from the heavier portion of the rotor by drilling a hole in the end supports or by chipping as found convenient.

4.7.5 Dynamic Balancing:-

This means carrying out the balancing operation when the rotor is actually rotating. Although a body may appear well-balanced by the static rest, any little residual balance becomes prominent at high speeds. Special dynamic balancing machines are available by means of which the exact amount of weight to be added as well as its location can be accurately determine. The rotor is mounted on a pair of pedestals carrying spring suspension systems, and driven at any speed required. The machine incorporates a visual indicator which amplifies the vibration felt on the bearings due to the unbalance of the rotor. A suitable device is also incorporated by means of which a counter-weight of the right value may be temporarily inserted at the right place on the same shaft to which the armature is coupled, until all oscillations are neutralized. After the weight of the counter-weight, the correct radial length and angle of location are determined, the armature is removed and a permanent counter-weight fixed at the correct point, and a test conducted once again to confirm the correction. When balanced in this way, the armature will run very smoothly at all speeds without any trace of vibration. Care must be taken in securing the counter-weights properly so that they do not fly off at high speeds.

For balancing large armatures which may not permit of being moved and placed on the balancing machine, special electronic equipment has been developed making use of vibration detectors and cathode ray oscilloscopes, so that the balancing operation may be performed in 'situ' on the machine itself.

4.7.6 Causes of low insulation resistance and rectification of low insulation resistance:-

Low insulation is almost invariably the result of absorption moisture by the insulated windings, since most of the insulating windings, since most of the insulating materials employed are hygroscopic. To maintain high insulation values, the following precautions should be taken.

1. Don't allow dust to accumulate on the motor windings. Dust and dirt absorb and retain moisture, leading to leakage of electricity which may finally results in a breakdown. Clean up the motor windings periodically by blowing compressed air, and wipe the outer surface of windings clean and bright by a dry cloth

2. Oil and grease are equally bad if not worse, since they are much more difficult to remove once they reach the windings and soak them, as a result of worn out bearings, over oiling, leaky gaskets of oil level indicators, etc. Oil and grease not only make the equipment messy but are fine repositories for dust. This must not be allowed.
3. Prevent the windings from becoming damp due to water spray in exposed locations. Provide a weather proof cover or housing over the motor if it is installed in the open.
4. Take pre-monsoon precautions. Look for leaky roofs and rain water gutters, clogged up drain pipes, and broken asbestos side panels. Have them repaired in time. Inspect areas which are subject to flooding during the monsoon. Check barrier walls for cracks. Sometimes electrically driven pumps are installed in pits to pump out seepage water. Make sure that they are working well and will not fail when most required.
5. Often conduit wiring between motors and starters give a lot of trouble during monsoon season owing to water getting sealed, or due to the joints being badly done. Attend to these at once. Every pipe joint should be watertight. At locations subject to water logging, it is advisable to replace V.I.R cables in conduit pipes, by multicore 'Tropodur' P.V.C insulated cables which can laid directly below the ground and remain waterproof.
6. See that the gaskets for covers for motor terminal boxes, starters, etc, are intact and in good condition.
7. Protect large motors, rotary converters, etc. against inclement weather when they are idle, by covering them over with a large tarpaulin and keeping the windings warm by connecting up a few electric radiators or infra red lamps all around. Change over the working and stand by sets regularly to maintain both in good condition.
8. Inspite of all precautions, sometimes motors do get submerged under water. Retrieve them as soon as possible and blow the wet surfaces with compressed air. Dry out by putting them in a hot chamber.

Dampness in winding can be removed by drying out the equipment thoroughly in a hot chamber or in an impregnating plant, the inside of which is maintained at a temperature of $80^{o}C$ to $100^{o}C$. The heating should be carried out for several hours and in the case of large equipment for one or two days if required until all the moisture has been driven out. This can be ascertained by recording the insulation resistance readings at regular intervals of one or two hours. If the readings are plotted against time, the general shape of the curve will be as per in the figure. It will be seen that the curve has three distinct parts:

a) Preliminary heating period:

The insulation resistance falls down form A until it reaches a steady value at B which indicates that the whole of the interior of the winding has reached a steady temperature.

An important point is to be remembered is that while the resistance of every electrical conductor increases with the rise of temperature, the resistance of an insulating material decreases as the temperature rises. This is why the insulation resistance of a hot motor is much less than the cold motor. If the resistance in the hot condition is found to be 0.5 mega ohms, the cold insulation resistance is likely to be of the order of 2 or 3 mega ohms.

b) Intermediate period during which moisture is being driven out:

The insulation resistance remains steady from B to C at a low value until all moisture is driven out.

c) Final period when resistance rises to normal when all the moisture has been driven out:

As the last traces of moisture are driven out, the insulation value rises from C to D until it reaches a constant value at E. When this steady state is reached, it is a clear indication that all moisture has been removed. The motor may then be removed out of the hot drying chamber. As the motor cools down the insulation rises to a higher value from E to F.

It is essential that the drying out operation is continued until the final steady value is reached as at E.

4.7.7 Steps to be taken when the motor is unduly hot:-

The following steps should be taken:

- ✓ Feel the motor body and the bearings to know whether they are really hot. Quite often reports are false. If they are abnormally hot, switch off the supply. Look for any smell of burnt-out insulation and ascertain if there has been any smoke from the motor.
- ✓ If it is a 3-phase motor, check if the motor is single phasing by any chance, i.e. examine if any one of the fuses have blown out. Check also whether the full voltage is available at the motor terminals on all the phases.

- ✓ Check also if the motor is overloaded by noting the line current taken by each phase of the motor. If the current is excessive on all the phases, the load on the machine should be reduced. At the same time, the starter overload releases should be inspected to see whether the overload setting is right and if it is right why the overload did not trip. Reset if required.
- ✓ Check the supply voltage. If the voltage is low the motor will draw more than its rated current, for the same load.
- ✓ Inequality of current in the 3-phases may be caused by inequality of the supply voltage due to fault on the supply system or large single phase loads on a 3-phase system. It may also be due to a bad joint on the overhead lines or a bad contact, i.e. one which is overheated, burnt out, worn out, strongly shaped or adjusted, either on the main switch or in the starter. It could also be due to a blown fuse on one supply line.
- ✓ If the currents, on all the 3-phases are equal and normal and yet there is overheating and smell of burnt insulation, check air gap to see whether the rotor is touching the stator anywhere or there is any other mechanical defect.
- ✓ If everything is O.K., then it may be due to an internal fault inside the windings or from a winding to the earth. Open out and examine the windings for signs of overheating and measure the ohm resistance of each winding.
- ✓ If the windings and air gap are alright, check whether the ventilating ducts are clogged up preventing free circulation of air. Of course, you should also make sure that the ventilating fan is existing on the armature.

In d.c. motors, look for signs of flashover on the commutator and take appropriate action.

4.8 Vacuum impregnation:-

Vacuum impregnation is very similar to the hot dip method but is much more efficient. In the hot dip method, one cannot be sure if all the air spaces inside the winding are fully impregnated with the varnish. In vacuum impregnation, all air is first removed out, which ensures that the insulating varnish gets sucked in into the innermost recesses. If the subsequent baking is thorough, there will be no possibility of entry of humid air from outside into the winding and, therefore, the winding is fully protected and will give a long and trouble-free service. The impregnation plant consists of a large air-tight double-jacketed vacuum impregnation chamber A (fig.) with a removable lid B.

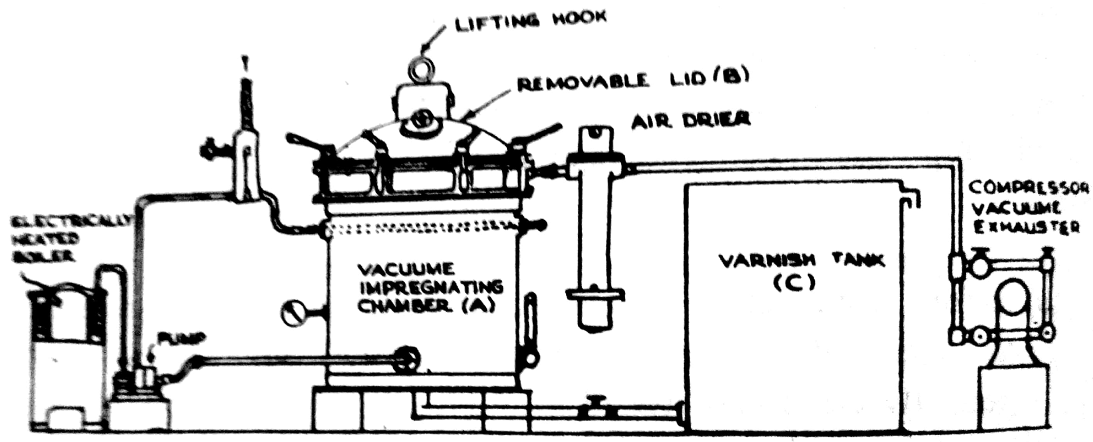


Fig 4.4 Vacuum impregnation

The interior of the tank can be heated up by circulating steam or hot oil through the jacket. The insulating varnish which should be of the baking type is kept stored in another storage tank C. A motor-driven compressor-cum-vacuum exhauster is provided with suitable valves to create either vacuum or pressure of 20 to 30 lb. per sq in. in tank A as required. The various steps in impregnating an armature are as follows:

- ✓ Remove the top cover and place the armature inside the tank. Close the top cover and heat up the chamber A to 100^{o}C for at least 2 to 4 hours by circulating steam or hot oil through the jacket. During this period, the air inside the tank is pumped out and vacuum is maintained. By this means, all the air and moisture inside the coil is completely driven out since all liquids vapourise very rapidly in vacuum even without applications of heat.
- ✓ Now allow insulating varnish by opening the sluice valve to flow into the chamber A, until the armature is fully immersed. Note that at no time is air allowed in contact with the windings.
- ✓ Apply an air pressure of 20 to 30 lb into the space above the varnish level in tank A, after closing the varnish outlet vale. The varnish will now be forced by pressure into all the porous spaces in the interior of the coil.

- ✓ After ½ an hour, allow all the varnish to flow back into the storage tank C under air pressure and the excess varnish in the coil to drain out.
- ✓ Bake the armature for 4 to 8 hours at a temperature of 100^oC to 110^oC. This will cause the varnish in all portions of the coil to set and become bone dry. Never exceed 110^oC in any circumstances as it will endanger the insulation.

If the operation is carried out by trained staff, a first class job can be done and the coil can be confidently expected to give excellent service for long periods.

The baking operation should be thorough. Half baked windings are useless and will give a lot of trouble. In fact, hand varnishing is certainly much better than half-baked vacuum impregnation. Remember that the heat should penetrate and bake the varnish in the innermost recesses of the winding and this takes several hours.

Insulation varnishes are marketed under several trade names such as Ohmaline, Armacell, Esbalite, Synobel, etc. and they are available in two forms, i.e. 'air drying' for hand application and 'baking' type for hardening inside hot ovens. Suitable thinners are also available to dilute the varnish if it becomes too thick.

4.9 Selection of a suitable soft starter for application with conveyor belts

Comparison of starting methods

Conveyor belts can have a lot of different looks and directions of use. It is a typical constant torque load with low to high braking torque depending on how heavy it is loaded.

Let's take a look at the most common motor starting methods and then select the most suitable soft starter for this kind of application:

- Direct-on-line start (D.O.L)
- Star-delta start
- Soft starter

4.10 Direct-on-line start (D.O.L)

Conveyor belts often need a starting torque very near or just above the rated torque of the motor. A direct-on-line start with a normal squirrel cage motor gives approx. 1.5 to 2.5 times rated torque of the motor depending on motor size, type etc.

When making a direct-on-line start there is a very high risk of slipping between the belt and the driving role depending on this high starting torque.

Fig 4.5 D-O-L Starter

Direct-on-line motor starter

Gearboxes and couplings are also exposed to high mechanical stresses. This result is considerable wear and tear and often high maintenance costs. Sometimes fluid couplings are used to reduce the transferred torque.

This method is expensive and requires a lot of maintenance.

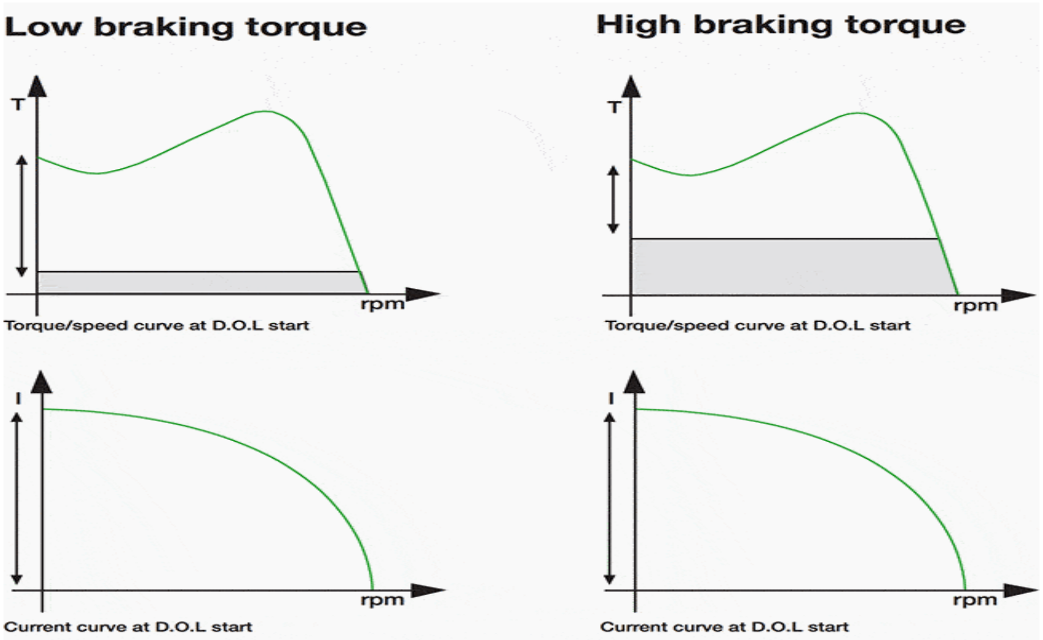


Fig 4.6 Waveform

Low braking and high braking torque of Direct-on-line start (D.O.L)

4.11 Star-delta start

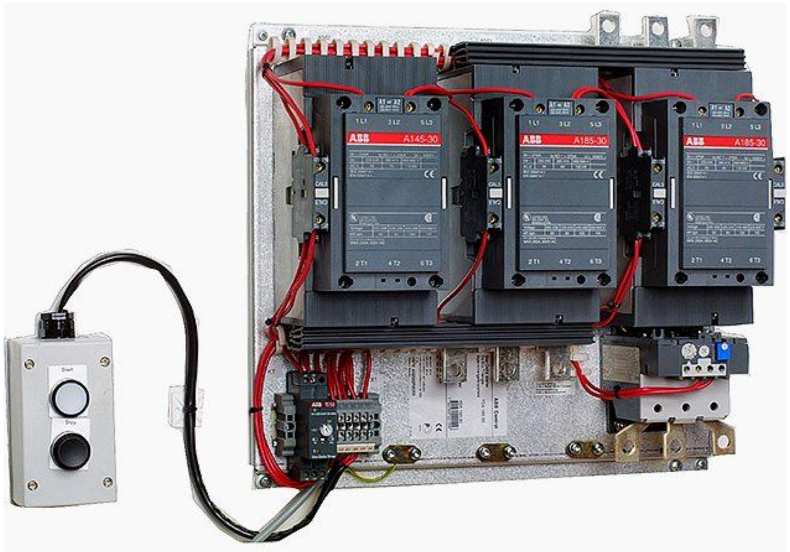


Fig 4.7 Star Delta

This is a starting method that reduces the starting current and starting torque. The device normally consists of three contactors, an overload relay and a timer for setting the time in the star-position (starting position). The motor must be delta connected during a normal run, in order to be able to use this starting method.

Instead we use star-delta motor start.

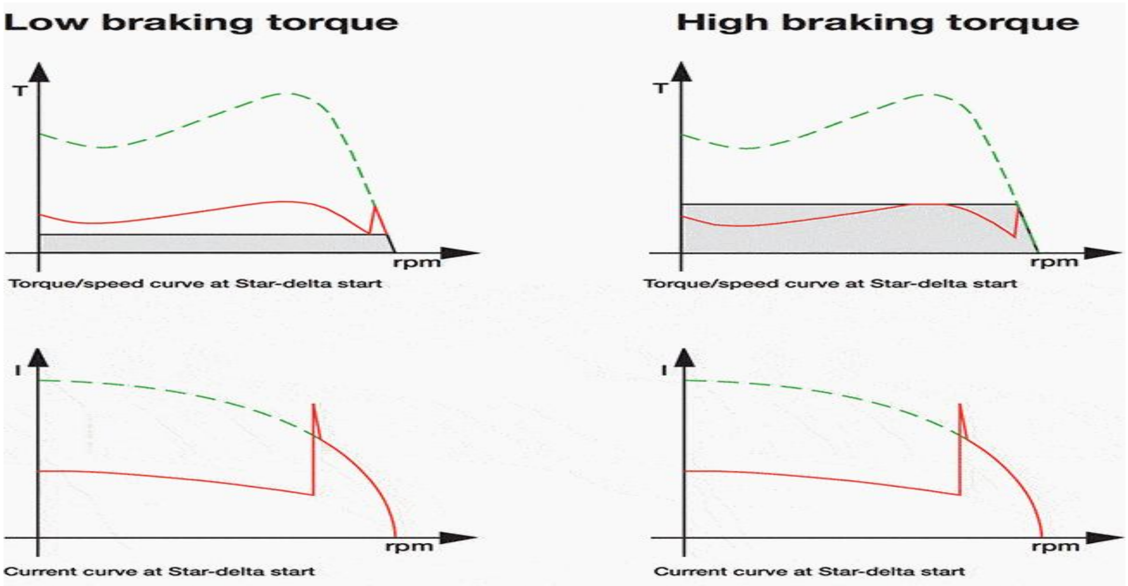


Fig 4.8 Low braking and high braking torque of Star-Delta start

4.12 Soft starter

By using the softstarter, starting torque can be reduced to a minimum value still able to start up the conveyor belt. The setting possibility of the softstarter makes it possible to adjust the torque to exactly the level that is necessary for the start.

The result is the least possible stress on gearboxes and couplings and no slipping belts during start. This will reduce the maintenance cost to a minimum.

When using a softstarter you will receive approx. 3 to 4 times rated motor current during start.

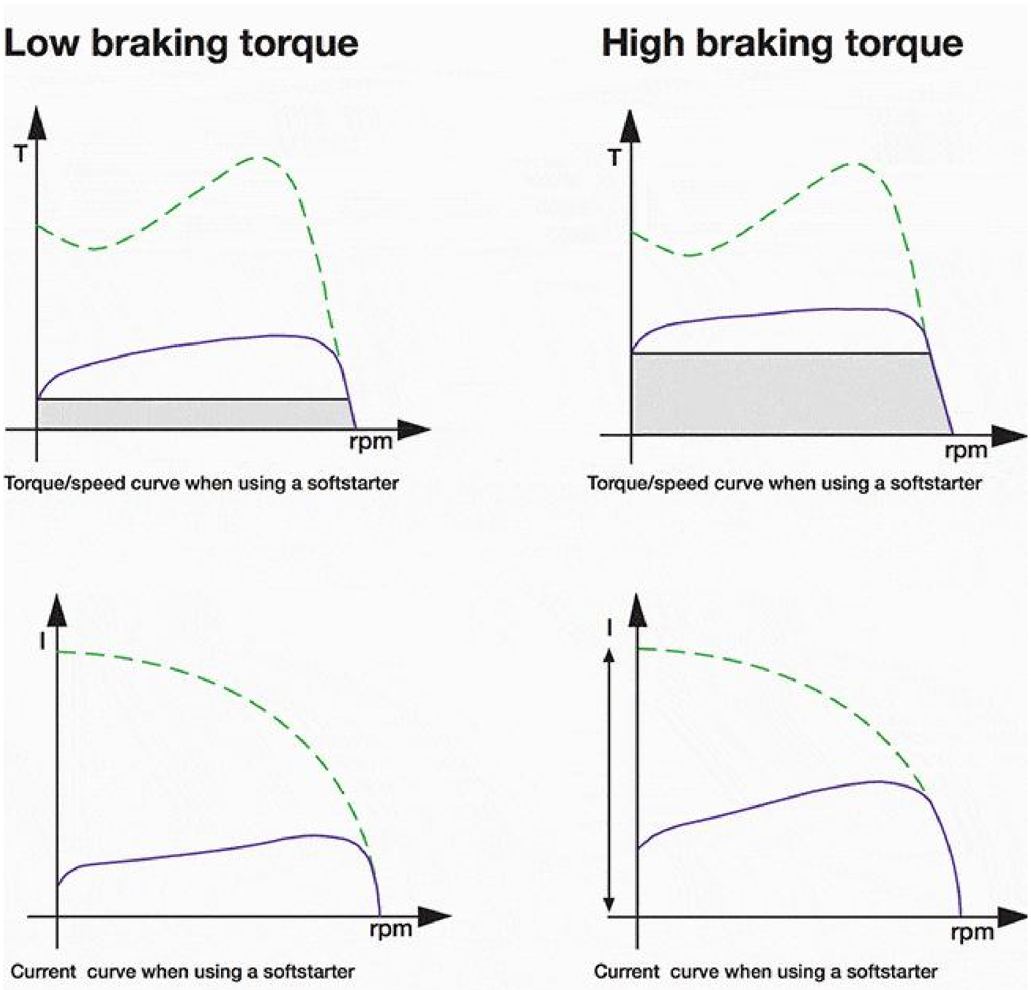


Fig 4.9 Low braking and high braking torque of soft starter

Review questions

Part A & B

1. How will you change the direction of rotation of 3 phase motor?
2. What is the role of single phase preventer?
3. What are the types of enclosure?
4. What is the Function of overload release
5. Mention some Control devices of motor.
6. What is the role of relay in motor?
7. Explain about the soft starter.
8. Draw the speed torque charteristics.

Part C

1. Explain about Causes of low insulation resistance and rectification of low insulation resistance.
2. Explain the Steps to be taken when the motor is unduly hot.
3. Describe Selection of a suitable soft starter for application with conveyor belts.
4. Explain Vacuum impregnation.
5. Explain the Control devices of motor with its type.
6. Explain Static and dynamic balancing of motors.

UNIT – V

OPERATION AND MAINTENANCE OF LIGHTING, TRANSMISSION AND DISTRIBUTION

5.1 Essential of good lighting:-

The expression good lighting is a relative term which may mean different things to different men. What was considered good some thirty years back is rated poor by present day standards? Even today the normal level of illumination taken for granted in the more advanced countries may appear as lavish here; it also varies from a town to a voltage.

During the last two or three decades vast technological advances have taken place and new and highly efficient sources of light are finding universal application. What constitutes good lighting and how it can be achieved should therefore be well understood. Briefly stated, lighting should be:

- Glare-free
- Adequate
- Uniform
- Harmonious
- Economically productive

5.1.1 Glare reduction:-

Glare is harsh and unwanted light which causes discomfort, nervous strain and fatigue. Perhaps the best example of glare is the blinding effect of a powerful headlight of an automobile coming in front when you are driving on a dark road. It is most annoying and leaves you helpless. It is often the cause of an accident, as you cannot see anything else for a short time. What makes it so bad is because of:

- ✓ The bright intensity of the beam itself,
- ✓ This beam is focused at the central region of the retina of the eye which is the most sensitive part of it,
- ✓ It comes suddenly from a dark background to which the eye is accustomed.

The remedies adopted should naturally be such as to eliminate the above three causes of glare. Consider first of all the intensity of the light itself. The disparity in the surface brightness of different sources of light is very wide indeed as will be seen from table

	Brightness in candles per square inch.
Midday Sun	1000000
Arc lamp	500000
Clear gas filled lamp filament 500W	7500
Vacuum lamp filament	1000
Opal lamp bulb surface	58
Fluorescent lamp surface(40W daylight)	4

The levels of the last two sources are low because the light is distributed over a very large surface compared to the surface of the filament. Obviously light sources having low surface brightness should be preferred. If bright source have to be used, glare can be avoided by providing suitable reflectors, enclosing them in diffusing glass globes, by fixing receded Perspex covers or prismatic lenses to diffuse or refract the light and so on. No doubt, there will be some loss of light due to absorption by these devices, but it is more than justified by the increased comfort derived. The transmission factors given below for different translucent materials give a measure of the percentage of light passed through. Even clear glass absorbs some amount of light.

	Transmission Factor (Percentage)
Clear glass and clear Perspex	95
Frosted glass	90
Reeded Perspex	80
Opal Perspex	70
Opal glass, depending upon quality and thickness	40 to 55

The second remedy is to cover the light source from the field of vision. This is achieved by housing the lamps in properly designed reflectors or providing louvred grills below the lamps. The fittings should also be mounted as high as possible so that no lamp surface may appear below the normal line of slight which is usually taken as 10^0above the horizontal plane at eye level of 5 ft. above the ground. A basic idea of good lighting is ‘light to see’ and ‘light to work’ the ideal lighting, therefore, should be from behind or from above, to light up the object to be seen and not in front to strike the face of the person who is to see. This is so elementary and obvious, yet so often it is disregarded. How irritating it is if someone thoughtlessly hands you when you are sitting in a dark inspection pit, a 100W inspection lamp not fitted with a shield. Your primary concern will then be how to avoid the glare. There is no excuse at all for keeping any hand lamp in a workshop without wire guard and shield.

Coming to the third point, it is useful to know how eye functions. Right in front of the eye is iris diaphragm, which is an involuntary muscle, with a central opening called ‘pupil’ through which light enters the eye. It is focused by a lens, on the sensitive screen behind called the retina and an image is formed on it. The centre of the retina is the most sensitive part of it. The pupil diameter is controlled by the iris automatically by reflex action, depending upon the brightness level of the are under observation. When the background is dark, the opening is wide admitting maximum light; in daylight it is narrow. Nature has thus endowed man with an automatic protective device which allows him to see effectively and without discomfort over an extremely wide range of illumination levels.

One peculiarity of the iris is that it acts slowly and cannot respond to sudden changes in brightness levels. You can see in a mirror that pupil contracting slowly if you direct a torchlight beam into the eye in a dark room. It is because of this slow response that you are dazzled by the bright lights of a room when you step in from a dark street, and the night appears much darker than it really is when you step out. Within a short time, however, the eye gets accommodated to the new level of illumination and everything becomes normal.

5.1.2 Adequate lighting:-

Some of the factors which affect adequacy of lighting are discussed below:

- ✓ The eye sees best in daylight, out of doors, when the sky is slightly overcast. Lighting which approaches it is therefore the best. To produce this high level of illumination at night is impracticable and uneconomical. In practice the capital and operating costs of electric lighting have to be weighed against the gains in terms of comfort, efficiency and productivity.
- ✓ The requirement of lighting partly depends upon the age group. As age advances the pupil of the eye becomes less elastic, with the result that a higher degree of illumination is necessary. It has been estimated that a 60 year old man requires about five times as much as one 40 years old, who himself needs three times as much as a boy of 10 years, for reading printed matter.

- ✓ A lot depends upon the nature of the task performed and the characteristic of the objects in the field of vision, such as the size, colour and shape of the object, its contrast with its surroundings, whether it is fixed or moving and the degree of accuracy required. Light magnifies details. An assembly shop for electric motors requires a much lower level of lighting than one for electricity meters. Water assembly and repair obviously call for 20 or 30 fold increase in the lighting. To meet this requirement local lighting from special fittings is the answer.
- ✓ The eye discriminates by comparing the relative brightness of the object and its background rather than by the absolute values of brightness. The dark letters on a printed page are perfectly clear, but a black thread on a dark background is just invisible--a fact fully exploited on the stage by the magician. Where the contrast is low, therefore, a higher level of lighting is required.
- ✓ Eye muscles are there times more fatigued under poor lighting conditions than when they are good. Long hours of work and a high degree of concentration drain nervous energy. Adequate lighting greatly reduces the strain and makes for comfort.

Coming from general considerations to specific levels of illumination, a simple method of assessing the level is by considering the apparent size of the detail to be seen and the degree of contrast between the detail to be seen and its immediate background, as given by the difference in their respective reflection factors. The following table gives the recommended values when the contrast is good:

Apparent sizes of detail to be seen	Illumination in foot candles
Large	2
Ordinary	5
Fairly small	10
Small	20
Very small	50
Minute	100

Another simple guide for selecting the foot-candles of illumination required is given below:

Class of task		Recommended foot candles
1	Precision work to a high degree of accuracy, tasks requiring rapid discrimination and response	100

2	Severe and prolonged visual tasks, such as fine engraving, and discrimination and inspection of fine details of low contrast	50
3	Prolonged critical tasks, such as proof reading, type-setting, drawing, fine machine work, fine assembling, sewing on dark goods	25
4	Visual tasks, such as detailed office work, reading, skilled bench work, sewing on light goods, and retail shops	15
5	Less exacting visual tasks such as in general offices, on large assembly work and in class rooms.	10
6	Work of simple character not involving attention to details	6
7	Casual observation where no specific task is performed	4

The above values may be multiplied by a contrast factor which may be taken as 1 when the contrast between the object to be seen and its background is good, as 3 when it is medium and 10 when it is bad. Thus the range of illumination varies from 1 when the objects to be seen are large and the contrast is good, to 1000 when the object is minute and there is poor contrast.

The values suggested in both tables were considered excellent practice even a decade ago, but according to present day norms they are to be treated as minimum values.

5.1.3 Stroboscopic effect:-

It is the phenomenon which makes moving objects like fan blades to appear to be standstill, and a wave of the hand to appear as if it occurred in a series of jumps. This effect is noticed when objects are lit by gas-discharge lamps. The reason for this is that the light from these lamps is not continuously emitted but in spurts, with short intervals of no light, occurring 100 times a second when working on a 50 c/s supply. Any object lit up, therefore, becomes visible only at intervals a hundredth of a second apart. The stroboscopic effect causes some unusual effects, and is annoying. The blades of a revolving fan may appear stationary at some speed and to move in one direction or the other if the speed is raised or lowered, although it is all the time moving at a high speed in one direction alone. A filament lamp, on the other hand, has thermal capacity because of which the variations in the light output are greatly evened out, and no stroboscopic effect is observed.

5.1.4 Methods to reduce stroboscopic effect:-

The stroboscopic effect is less marked when a choke is used than with a resistance for the ballast. The luminescence of phosphorous powders persists for a short time and bridges the short intervals when no arc current flows. Therefore, fluorescent lamps exhibit fewer flickers than pure gas discharge lamps. Flicker is also more pronounced at 25 c/s than at 50 c/s and is almost completely absent at a higher frequency like 400 c/s.

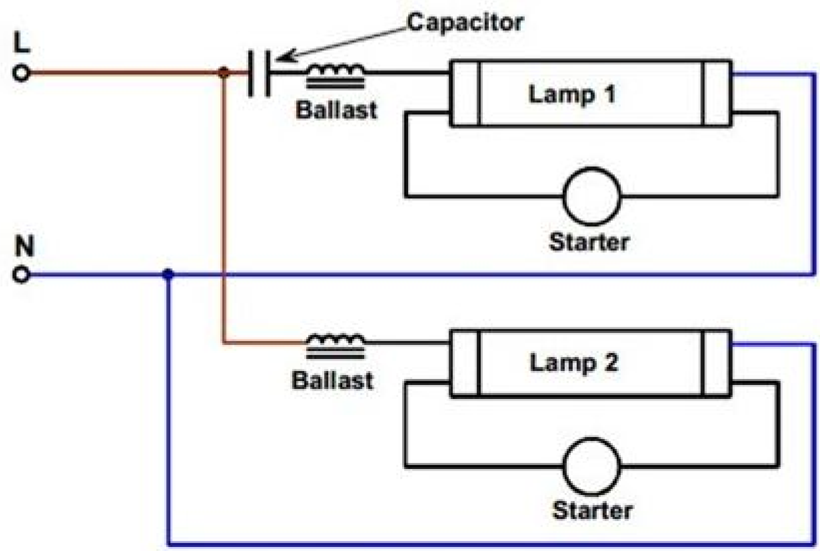


Fig 5.1 stroboscopic effect

If three fluorescent lamps can each be connected to a different phase on a 3-phase supply, the light peaks will occur at different times and no flicker will be noticed. For single phase supply, twin lamp circuits have been developed in which the phase angle between potential and current is altered in the two lamps. The usual power factor improvement condenser C is connected here in series with one lamp instead of across the mains. In normal operation, a voltage higher than 230V is developed across the condenser even through a applied voltage is 230V. The chokes too are dissimilar, the inductance of the choke and the capacity being so chosen that the power factor of one lamp leads as much as it lags in the other. Because of this phase difference between the currents, flicker is greatly reduced.

5.1.5 Steps in designing a lighting installation:-

The basic steps in lighting design are:

- ✓ First survey the area to be lighted and make out a layout plan showing its principal dimensions, supporting structures, beams, trusses and layout of machinery, passage ways or furniture. Examine what would be the most convenient locations for the lamp fittings. Ascertain if work goes on continuously day and night or only during daytime. If there is only daytime work, not the locations of windows and decide if supplementary lighting is called for in areas farthest away from the windows. If an existing lighting installation is to be improved, take a few readings with a light meter in different areas. Examine also the possibility of improving natural lighting during daytime by the provision of sky lights, by repaining the ceiling and wall surfaces to get higher reflection factors. For a new building, co-ordinate fully with the architectural, building and air-conditioning engineers so as to ensure an excellent and harmonious lighting installation.

- ✓ Determine the foot candle illumination required after making a detailed study of the nature of the work. Fix the areas of points where special local lighting is required.
- ✓ Having regard to the nature of business conducted decide if direct, semi-direct or indirect lighting is required. Select the type of lamp, i.e. gas-filled, mercury vapour or fluorescent lamp and also the types of lamp fitting,
- ✓ Ascertain the coefficient of utilization and assume a suitable value for the depreciation factor.
- ✓ Fix the mounting height, the height to space ratio for the fitting selected, and the number and location of points. From the layout plan it should be possible to split the area into a number of identical squares of rectangles, depending upon the configuration of columns and roof members. Locate the lamp fittings as symmetrically as possible within each unit space.
- ✓ Use one or more lamp fittings having regard to the size of each square or rectangle, and the height to space ratio. The spacing of the row nearest to the wall should be half of normal lamp spacing. The area lighted by each lamp and total number of lamp fittings can now be calculated, as also the wattage per lamp fitting. Obviously, lamps are only available in standard wattages, and it may be necessary to try out one or two alternative arrangements of lamp locations to get the requisite illumination in each unit of area.
- ✓ Work out finally the illumination intensity that will obtain at the working place for the design adopted, as also the details of the mounting for the fittings, the method of wiring to be adopted, whether it should be concealed or not and the system of control and fusing. The estimated cost of the work and the annual energy charges may also be evaluated.

To summaries, the following simple formula may be used:

Area per fitting = (Total area in sq.feet)/(No.of fittings)

Lamp lumens per fitting = (Area per fitting*ft-c*Dt)/Coefficient of Utilization)

Where ft-c = illumination in foot-candles

Dt = depreciation factor.

5.1.6 Troubleshooting in fluorescent lamp:-

The defect may be due to one of several causes, and as with any other electrical installation, one should proceed methodically from the obvious to the remote, doing the simplest and easiest tests first before embarking on more complicated work. Have a good look and observe the symptoms. A little thinking saves a lot of time.

If a lamp does not light up when switched on, observe if the cathodes at the two ends are lighting up. If not, check for supply and also the fuses. If a blown fuse, investigate the cause. In a new installation, faulty wiring is possible; in an old installation, insulation breakdown in the wiring or in the power factor improvement condenser is indicated.

If supply is all right and there is still no glow in the lamp ends, the lamp pins may not be making a good contact at eh sockets. Try rotating the lamp to and fro and see that it is fully home; alternatively try a lamp known to be good. Try a spare starter. If these do not help, check with a test lamp for supply at the lamp terminals. If there is no supply, the choke may be opening circuited and of course a connecting lead may have come off.

5.1.7 Methods of controlling street lights:-

The most common method of control is to run independent street lighting mains from the substation, and operate the control switches manually at the appropriate time each day. The disadvantage is that the substation will have to be manned; provision of independent street lighting mains to all outlaying areas is also costly. The difficulty can be overcome by one of several ways:-

- ✓ Group control of lights in different localities. This necessitates provision of a separate street lighting circuit in each are only and not right from the substation. Some recurring expenditure will also have to be incurred as wages for a low paid fuse man to go round and operate the switches daily, but this cost can be partially justified, since in most distribution systems someone will have to be available on call for emergency duty, to attend to failures. He could as well be detailed to switch on and switch off street lights and incidentally make a note of lamps which require renewal.

- ✓ Another method of group control is by installing a time switch which is available in three forms i.e. hand wound, electrically wound or electrically operated with spring storage. The last of types described is the most convenient since the switching on and off times will remain unaltered even if there should be a failure of supply for a short while. The electrically operated time switch uses a self starting synchronous motor, which will keep very accurate time if the mains supply is frequency controlled. Fitted with a solar dial the time switch automatically takes care of seasonal variations in sunset and sunrise times.
- ✓ Alternatively, a photo electric or cadmium cell could be employed for automatic control of street lights. The electrical resistance of both the sensitive elements varies with the amount of light falling on them which could be made use of for controlling street lights through a valve or transistor operated relay. In this arrangement variations in light intensity are viewed by the photo cell trigger a thyratron valve and operate a relay which could in turn switch on or off a considerable amount of power through a contactor. The exact level of twilight at which the photo cell should operate can be readily adjusted by a control knob.
- ✓ An ingenious modern development is the ripple control system. Under this, an audio frequency signal is injected into the power mains at eh main substation, from where it passes to all parts of the distributed system. At selected control points, specially tuned receivers are provided which respond to the audio frequency control signals and operate local contactors, which in turn control supply to the street lights or any other circuits desired. There could be several control frequencies allocated for different functions, such as control of electric sirens, street lights, off peak power loads etc. permitting remote control of switches located far away from the control point, without requiring any other conductor than the mains. It is very economical and convenient.

5.1.8 Fluorescent Lamp Disposal

The disposal of phosphor and mercury toxins from spent tubes can be an environmental hazard. Governmental regulations in many areas require special disposal of fluorescent lamps separate from general and household wastes. For large commercial or industrial users of fluorescent lights, recycling services are available in many nations, and may be required by regulation. In some areas, recycling is also available to consumers.

Spent fluorescent lamps are typically packaged prior to transport to a recycling facility in one of three ways: boxed for bulk pickup, by using a prepaid lamp recycling box, or crushed onsite before pickup. A fluorescent lamp crusher can attach directly to a disposal drum and isolate the dust and mercury vapor.

5.1.9 Precautions in erecting lighting installations:-

The following further suggestions apply to lighting installations in particular:

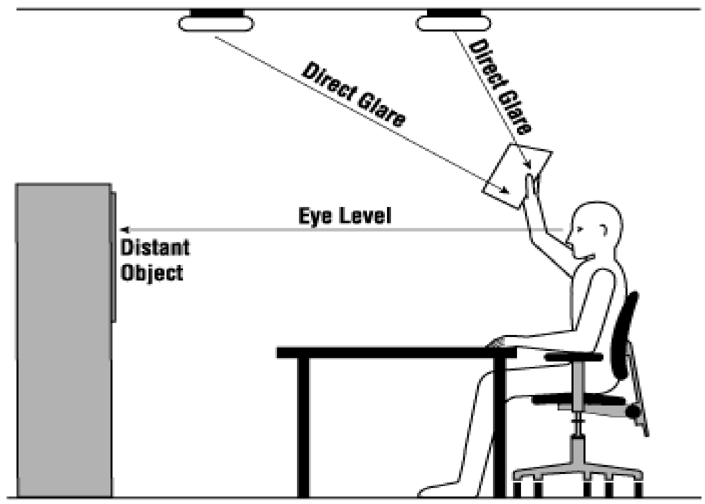


Fig 5.2 Glare in lighting system

- ✓ Selection of fittings---In selecting an outdoor fitting special attention should be paid to its weather proof construction, and the protection it affords against rain, rust and corrosion. The lead in wires should have an inverted U bend at the point of entry to allow rain water to drip down and not gain entry into the lamp housing. An insulated bush should be provided at the end of the pipe and preferably sealed by plugging compound or waste cotton and compound, and the wires should be led through a rubber or plastic grommet where it passes through a metal plate.
- ✓ Location of fittings---Outdoor fittings should be firmly secured to the supporting structure so that they may not swing in breeze. In open varendahs and corridors stiff pendant fittings should be provided. Inside shops, make sure that there is no possibility of rain water dripping down or water spray entering the fitting during the monsoon. Attention should also be given to adequate ventilation of the lamp housing to ensure that the heat generated in ballast and lamp is readily dissipated. Metal filament lamps are particularly susceptible to vibration; avoid mounting lamp fittings on columns supporting crane run ways or other structures subject to heavy vibration. Remember vibration may also cause failure of cable insulation at points of support or of entry into the fitting. Finally do not deviate from the recommended burning position of lamps.
- ✓ Rating of conductors---Since power factor of a fluorescent lamp circuit may be as low as 0.5 without capacitors, the current drawn from the mains may actually be twice as great as may appear possible from its wattage. The rating of cables should therefore be particularly checked.

Individual capacitor for each fitting or a group capacitor for the whole installation is recommended to improve the power factor.

As the current wave drawn by a fluorescent lamp is highly distorted and rich in third harmonics, the neutral current in a three phase circuit may be appreciable. The neutral conductor should ordinarily have at least half the section of the phase conductor to cater for the load not being fully balanced. This may not be sufficient to carry the third harmonic current load. It is therefore desirable to provide a neutral conductor of the same section as the phase conductors.

- ✓ Heating of lamp holders---A considerable amount of heat is generated by lamps and the lamp holder does become quite hot in normal operation. Even with a 100W lamp its terminals could be as hot as 80°C, whereas neutral rubber can withstand temperature only up to 60°C. Do not, therefore, indiscriminately provide higher wattage lamps in fittings meant for a lower wattage. Such a practice will also cause glare, as the metal filament, which should be well within the shroud of the reflector will come below it. Special care should be taken in making connections to lamp holders using lamps of 300W and above. The connecting leads should be kept well apart and insulated by empire slaving where it enters the lamp holder. A good cable grip is imperative especially for portable lamps. For flood lights employing 1000W and 1500W lamps, the conductors should be insulated with heat resisting tape such as asbestos tape and glass tape. Flexible conductors insulated with silicone rubber can withstand temperatures up to 200°C

5.1.10 Symptoms to identify the end of useful life in lamp:-

- ✓ Lamp flickers on and off, continuously, probably with a shimmering effect along the tube.
- ✓ Light output is low; in the first 100 to 150 hours after putting a new tube, light output will fall down by 15 to 20 per cent, but towards the end of this life, there is considerable reduction in the light output.
- ✓ Black rings near the lamp ends, under normal operation some amount of blackening will occur at the ends of tubes but these only become heavy towards the end of its life.
- ✓ A slow pronounced flicker.

5.1.11 Causes of lowering of illumination level:-

A fall in intensity may be due to the following causes:

- ✓ Progressive reduction in light output due to ageing, particularly in fluorescent lamps. Sodium lamps not only become dimmer but also more red in color. They should be replaced in time.
- ✓ Accumulation of dust, dirt and insects. The reduction in light transmitted or reflected can be as much as 30 percent in 3 months and 60 percent in 12 months, on account of dust accumulation in

lamp fittings in an average factory. Efficiency of indirectly lighted installations is seriously impaired by settlement of dust on the reflecting surfaces. It is, therefore, absolutely necessary that staff are detailed to clean the fittings at least once a quarter.

- ✓ Vitreous enameled steel reflectors are best cleaned by wiping with a wet cloth. When they become very dirty or covered with oil matter it is best to bring the fittings drawn and wash them with soap and water. Other non-abrasive detergent solutions may also be used. Enclosed lamp fittings using prismatic bowls or Perspex covers at the bottom of the lamp become quite unsightly and inefficient due to the collection of thousands of insects getting entry into the lamp housing during certain seasons; seal off all the holes and maintain the gaskets in good condition.
- ✓ Perspex covers are liable to develop static charge when polished with a dry cloth; this charge actually attracts dust particles. After rinsing, therefore, allow the lamp fitting to drip dry and do not wipe or polish with a dry cloth. Special anti-static solutions are available to reduce this tendency in Perspex fittings.
- ✓ Gradual darkening of walls and ceilings. An annual repainting programme would not only make the installation more neat and efficient but the environment will also become more pleasant.

5.2 Transmission and Distribution:-

5.2.1 Permissible limit for variation of voltage/frequency as per IS standard:-

The limits of variation are 5 per cent for low and medium pressures and 12 and half per cent for high and extra high pressure circuits from the normal declared pressure.(I.E rule 54)

The maximum variation is 3 per cent from the declared frequency. The standard frequency adopted is 50 cycles per sec.(I.E rule 5)

5.2.2 Factor of safety:-

Every material ultimately breaks down when loaded beyond its capacity, either by tension, compression or shear. For instance, mild steel has an ultimate breaking strength of approximately 28 tons per sq. in. Obviously in designing structural work, the working stress should be kept much below this value, the degree of reduction being expressed as a factor:

Factor of safety = (Ultimate breaking stress)/(Safe working stress)

If a factor of safety of 2 is assumed for mild steel, the working stress of 14 tons per sq. in. should not be exceeded or of 9.3 tons if a factor of safety of 3 is used.

The minimum factors of safety prescribed for overhead lines by I.E rule no 76 are given below:

Metal supports based on crippling load   2.0

Mechanically processed concrete supports based on crippling load   2.5

Hand moulded concrete supports based on crippling load 3.0

Wood supports based on crippling load 3.5

Latticed steel structures, under broken wire conditions 1.5

Guard wires, bearer wire, etc 2.5

Conductors under worst condition 2.0

5.2.3 Safety devices used on overhead wires:-

The following safety devices should be used:

- ✓ Fuses and isolating switches to isolate different parts of the overhead system.
- ✓ Lightning arresters are provided at the ends of H.T and E.H.T transmission and distribution lines and at every point of tapping.
- ✓ Choke coils are also sometimes used. A continuous earth wire running on the tops of the towers serve as a protection against lightning discharges.
- ✓ I.E Rule No. 91 stipulates that every uninsulated line erected in a public place shall be provided with an approved device rendering the lien safe if it should break. To comply with this rule, vee guards are often provided below bare O.H lines running along or across public streets, so that if any one of the lines should snap and fall down, it will come in contact with the earthed guard wire below, trip the circuit breaker feeding the lines and thus render them safe. In madras state, if the O.H conductor is No.5 S.W.G. or thicker no guarding is considered necessary.
- ✓ Guard wires must be provided above or below power lines when they cross telephone or telegraph lines. The guard wires must be galvanized and have a minimum breaking strength of 1400 lb. which corresponds to No. 6 S.W.G galvanized steel wires. The minimum vertical clearance between any conductor and the guard wire should be one foot for low and medium voltages, 2 ft for 11 kV, 3 ft for 33kV, 4 ft for 66kV and 6 ft for 110kV.
- ✓ The guard wires and the steel structure must be solidly connected to earth. Cross wires should be provided between the main guard wires, at frequent intervals. An earth plate should also be provided at each end of the span.
- ✓ Vibration dampers.

5.2.4 Minimum clearance of conductors:-

The minimum vertical clearances above ground prescribed by I.E. Rule No. 77 is given below:

	Low Voltage	High Voltage	Extra High Voltage
In rural areas and places inaccessible to vehicular traffic	15 ft.(bare wires) 13 ft.(insulated	17ft	17 ft+1 ft for every 33kV or part thereof

	wires)		
In villages and towns, along streets	18 ft	19 ft	
In villages and towns, across streets	19 ft	20` ft	

The above figures are the minimum clearances at the lowest point, i.e. at mid span under worst conditions, i.e. when a sag is maximum. In actual practice, however, it is preferable to allow a further safety margin of 1 or 2 ft.

The minimum clearance from buildings where the liens pass over or near buildings should be as under, under the worst conditions, i.e. maximum temperature and wind pressure.

	Vertical clearance above building	Horizontal clearance from building
Low and medium tension	8 ft	4 ft
Up to 11kV	12 ft	4 ft
Upto 33kV	12 ft	6 ft
Above 33kV	12+1 ft for every additional 33kV or part thereof	6 ft+1 ft for every additional 33kV or part thereof

In rural areas, the tree clearance required on either side of the distribution line is left to the discretion of the field staff for low and medium voltage lines; for high voltage lines, trees are cleared for 15 ft, on either side for 11kV lines, 18ft for 22kV and 25 ft for 33kV lines.

5.2.5 Minimum clearance of buildings:-

Where a low or a medium voltage overhead line passes above or adjacent to or terminates on any building, the following minimum clearances form any accessible point, on the basis of maximum sag, shall be observed:

- ✓ For any flat roof, open balcony, verandah roof, lean to roof and pitched roof.
    - When the line passes above the building a vertical clearance of 2.5 metres from the highest point, and
    - When the line passes adjacent to the building a horizontal clearance of 1.2 metre from the nearest point.
- ✓ Any conductor so situated as to have a clearance less than that specified in sub-rule

- Shall be adequately insulated and shall be attached by means of metal clips at suitable intervals to a bare earthed bare wire having a breaking strength of not less than 350 kg.

✓ The horizontal clearance shall be measured when the line is at a maximum deflection from the vertical due to wind pressure.

5.2.6 Effect of temperature on sag:-

Heat expands all bodies and, therefore, the length of the conductor increases with the rise in temperature, and so does the sag. Conductor tension gets reduced with greater sag. Normally two conditions should be investigated, when making sag tension calculations:

- At minimum temperature: - The lowest sag and maximum tension in conductor section occurs when the temperature is minimum and wind maximum. Under these conditions, tension on the conductor should not exceed the breaking strength of conductors divided by a factor of safety of 2.5 as prescribed by I.E. Rules No.76.
- At maximum temperature:- On the other hand maximum sag occurs when temperature is maximum and there is no wind pressure. Under these conditions, electrical clearances should be above the minimum values prescribed.

The temperature variations recommended by the C.W.P.C for Indian conditions are 50^{o}-130^{o}F.

In view of the dependence of sag on temperature, it is essential to observe the temperature at the time of erection of the overhead lines, and to tension the conductors correspondingly. For this purpose, the field staff should have a 'sag chart' which allows the tension and at different temperatures.

5.2.7 Purpose of continuous earth wire:-

In all low or medium voltage distribution lines making use of tubular steel posts or rail posts, a continuous earth wire (usually No.8 S.W.G copper) is almost invariably run at the top of the posts. The earth wire is solidly connected to earth electrodes provided at intervals of about a quarter mile and also to every post, by suitable jumper connections so that all the posts are in effective contact with the ground. This will ensure that in the event of any contact between the live conductor and the post such as by a stray metallic wire or by insulator failure, the fault current may blow the protective fuse or trip the circuit breakers as the case may be, the post itself remaining safe at all times.

In case of high voltages transmission lines the earth wire has considerable shielding effect over the other conductors so far as the lightning discharges are concerned, and therefore, it is provided at the topmost point at the centre of the lower. Usually 7/10 S.W.G or 7/11 S.W.G. G.I or A.C.S.R conductor is used for the earth wire. Every transmission tower, where the span lengths are great are provided with independent earth electrodes each having at least 10 ohms resistance.

5.2.8 Points to be checked when carrying out inspection of overhead lines:-

Foot patrolling of transmission lines should be carried out by patrolmen at least once a week or a month depending on the location. The points to be checked are, the overgrowth of trees on either side, building of birds nests on the cross arms, any cracks on insulator, faulty line regulation, etc. Remedial action should be taken as soon as possible. Once a year every structure should be inspected individually by a qualified supervisory official. A thorough examination is then made of each post or tower and measurements taken of the earth resistance. Whenever possible it would be advantageous to effect shutdown and examine the condition of the various O.H.E fittings on the top of the post particularly the insulators and mechanical connectors. Opportunity may also be taken then to clean insulators and if possible to wash them with water although normally, the seasonal rainfall itself does the washing automatically. Chipped or cracked insulators should be replaced; stay wires tightened up where required; if line wires are poorly regulated, they should be pulled up. In the case of low and medium tension lines, annual check should also cover the various isolating switches or fuses.

One other very important point to observe is the condition of the paint work and any signs of corrosion. Immediate and effective measures should be taken to rectify all the defects.

5.2.9 Prevention rusting on steel posts:-

Generally speaking, the best insurance against rusting of steel structures and fittings is to galvanise them although it makes them costlier. Where no galvanizing is done, the only way to prevent corrosion is to maintain a good coat of paint over the metal work. The effectiveness of the paint as a protection against corrosion is entirely dependent upon how carefully the surface of the metal is prepared before the coat of paint is applied. Very often the important of this is not appreciated. The slightest amount of rust, dirt, oily matter, or mill scale will prevent the first primer coat adhering firmly to the metal, and whatever may be the number of subsequent coats of paints they are useless. Rusting action starts form below at the point where the metal has not been cleaned and very soon it will spread to adjacent areas and show up in due course. Therefore, the greatest care possible should be taken in preparing the surface. If it is a repainting job, the old paint should be scraped clean to the base metal surface. Emery paper is then applied until the bare metal surface shines. A very effective form of cleaning is by oxy-acetylene flame which makes the surface clean and free of all mill scale. After the metal surface is thoroughly cleaned by brushing, washed with water and dried, one coat of primer paint consisting of red lead or any other special base is applied. After it has fully dried up, two or more coats of suitable paint are applied. If the work is properly done, the painted surface should last for as long as 6 to 8 years. When it starts showing signs of corrosion immediate action should be taken to attend to the bad spots locally. If corrosion spots appear all over the surface of the post, it shows that proper care was not taken when applying the primary cost initially. In this case, the whole paint work has to be once again scraped off and a new paint applied as indicated above.

5.2.10 Protection requirements for transmission lines:-

The protective measures are of two types; one at the sub-station and the other on the transmission line itself. In L.T distribution lines, the most common protection used is the fuse, which should have adequate rupturing capacity. In rural H.T distribution networks, drop out type high rupturing capacity fuses are used at tapping off points, while a circuit breaker is provided at the substation end, equipped with inverse time overload releases or relays. Where duplicate feeders are run, reverse current protection is used at the receiving end, to isolate the faulty feeder automatically.

In large E.H.T transmission lines, the protection schemes are more elaborate, comprising systems like Merz-Price which compare the equality of currents at the sending and receiving ends and arranged to trip the circuit if they do not balance out, i.e. in the event of a fault. This generally requires the use of pilot wires which makes the system much more costly. Therefore, modern practice is to use some form of distance protection, employing impedance relays usually having a stepped characteristic, which gives excellent graded zone protection. Here, the phase angle between the voltage and current is measured by the relay which enables it to discriminate between the normal load currents and fault currents, depending upon the line characteristics and the distance of the fault from the feeding point. Suitable time lags are also incorporated, to ensure proper stepped characteristic. An interesting development in recent years is to treat a transformer and feeder as a single unit from the point of view of protection, thereby eliminating provision of costly H.V circuit breakers and elaborate system of protection at the receiving end resulting in substantial reduction of the cost of the whole installation.

Apart from the protective devices provided at the control point, certain further equipment are provided on the transmission line itself to ensure its reliability. Surges and over voltages may occur on the transmission lines either due to lightning discharges, switching operations or even sudden faults. Such transient surges have the characteristics of high frequency waves and will travel along the transmission line with the velocity of light. Lightning is still perhaps the most frequent cause of breakdown of overhead line systems. One method of protecting the lines is to provide a continuous earth wire above the phase conductors on the top of each post to shield the lines from the lightning effects. Lightning arresters are also provided to protect the equipment at every point where the overhead lines are tapped off. As a further precaution it is usual to provide choke coils at the terminal points to block sudden surges and over potentials on the line from reaching substation equipment and force them to get discharged through the lightning arrester.

Transmission line conductors are subjected to considerable degree of wind action. To arrest the vibration and prevent conductor failure due to fatigue, armour rods are provided at the point of support. Stockbridge dampers are also often fitted on the conductor.

Insulation level and insulation co-ordination:-

The insulation level of any transformer or transmission line is the highest voltage which it can stand without damage. There are several methods of determining it. The most frequent one is what is called the impulse voltage test, in which a voltage of particular wave shape as shown in figure which is applied to the equipment under test and its ability to withstand it is checked.

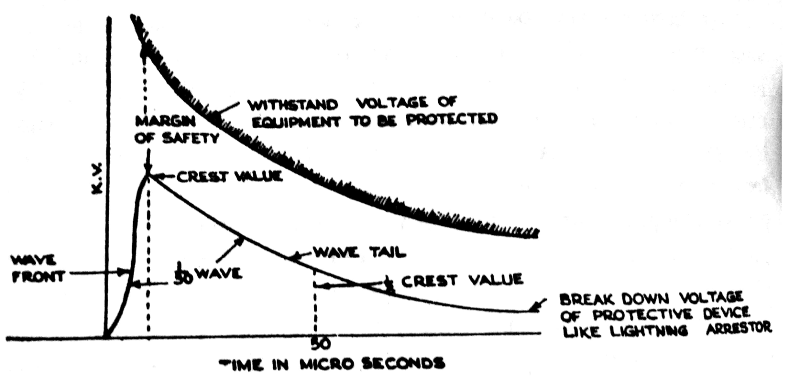


Fig 5.3 Insulation level and insulation co-ordination

The crest value of the wave is proportional to the insulation level. The shape of the wave is specified by two figures such as 1/50 in which the first figure represents the number of microseconds for the voltage to rise from 0 to its crest value, while the second figure 50 refers to the number of microseconds for the voltage to drop to 50 per cent of its crest value. Another test is the one-minute power frequencies withstand voltage. The following are the voltages electrical equipment rated for different voltages, as per I.E.C specifications No 71 which may be consulted for further particulars.

System voltage (line to line) in kV (R.M.S)		Impulse withstand voltage 1/50 wave positive and negative polarity kV(crest)	One minute power frequency test withstand voltage kV(R.M.S)
Normal	Highest		
3.3	3.6	45	16
6.6	7.2	60	22
11	12	75	28
22	24	125	50
33	36	170	70

66	72.5	325	140
110	123	450*	185*
132	145	550*	230*
220	245	900*	395*

*---Applicable where the system is effectively earthed.

The expression insulation co-ordination refers to the grading of the insulation levels of the different equipment in an installation so that the most important and costly equipment is adequately protected at the expense of the less costly equipment. To give an example, the high voltage windings of a transformer should have the highest impulse voltage, the bushing on the transformer may have a slightly lower voltage below which the lightning arrester comes in. the insulators used in a transmission line should have an insulation level higher than that of the lightning arresters which will ensure that the surges will be taken care of by the lightning arresters instead of causing a flashover of the insulators and damaging them. Conservative protection of transformers requires that lightning stresses should be limited to 50 per cent of its impulse test level.

Precautions in erecting underground cables:-

There are several methods of laying underground cables:

- Laid directly in ground: The depth of trench may vary between 2 ft 6 in to 3 ft 6 in. The bottom of the trench is leveled, freed from stones and sharp edges of rock. A layer 4 in thick of clear river sand is laid at the bottom of the trench. After laying the cable, it is covered once again with a 4 in. layer of sand, where the soil conditions are not good. In other cases soft earth may be employed instead of sand. R.C.C. slab or one layer of bricks is usually laid, not only as a protection against mechanical damage, but also to facilitate identification of the cable route.
- Drawn in pipes or ducts the pipe may be of earthen ware, cast iron, galvanized iron or spun cement pipe. This is resorted to when crossing across streets or under railway tracks. The size should be sufficiently large to put in additional cables later if required. The advantage of laying in ducts is that the cable may be drawn out and replaced without disturbing the ground above.
    - Laid solid in bitumen: This is done where the soil is chemically very active and/or corrosive and, therefore, deleterious to the cable. R.C.C channel section 2 to 3 ft. long are first laid level at the bottom of the trench, and after the cable is laid bitumen is heated and poured over until cable is entirely covered, the whole being protected by warning R.C.C top caps.

- Supported on brackets: When the cable is installed above the ground, it should be suitably supported or suspended at sufficiently close intervals. On vertical runs suitable clamps should be used.

Whatever be the type of construction, it is extremely important to handle the cable carefully and ensure that it is not, under any circumstances, bent unduly. The minimum bending radius during installation should be as under (BSS: 480):

Cables up to and including 11KV	12D
22,000 volts cable	15D
33,000 volts 3-core cables	20D
33,000 volts single-core cables	30D

Where D is the diameter of the cable

When planning trenches or ducts a bending radius of 9 ft. should be kept for high voltage cables and 6 ft. for lower voltages. For smaller size or 1.t. cables, a radius of 4 ft. may be permitted.

The cable drum should be properly secured and supported a shaft which should rest on properly lubricated bearings which are mounted on trestles, so that the drum with its shaft may be free to rotate. Cable should be taken from the top supporting ramp, if necessary, the drum being braked to avoid over-running. The practice of rolling the drum on the ground to release the cable is to be deprecated as it will result in excessive strain on the cable causing fine cracks to develop on the lead sheathing which will ultimately result in failure.

Sufficient number of cable route indicators should be provided, at points which will not be disturbed, to show the route of the cable, as well as at every derivation in its direction, straight through or T joint box. Simultaneously, a detailed drawing should be prepared and recorded in the drawing office for future reference. This should show full particulars of the cable and its disposition to other cables in the vicinity and other landmarks.

Causes of failure of underground cables:-

- The most common point of failure is at the cable sealing box mostly due to bad workmanship of the cable jointer when the end was sealed. A properly done box should last for 20 to 30 years. Damage caused to the insulation on account of improper handling at the time of lying will also ultimately result in a failure.

- Another very common cause is the mechanical puncturing of the lead sheathing of a cable, such as by a crowbar, especially in industrial installations where excavation and building operations are carried on in areas having several underground cables. It is essential in such cases, to depute an intelligent supervisor to locate the cable route indicators, trace the route of the cable, and take adequate precautions to ensure that unskilled workmen do not inadvertently puncture the cable and perhaps suffer an electric shock too. Warning tiles, R.C.C slabs or a course of bricks would be a great help in identification.
- Electrolytic and chemical corrosion:- This is the next in the order of importance. The lead sheathing of underground cable has a very high degree of resistance against corrosion, but in spite of it certain soils are chemically active and cause severe pitting and corrosion. As protection against it, it is usual to specify application of at least two layers of impregnated paper over the compounded surface of the lead sheath. Another precaution is to surround the cable with a 4 in layer of pure sand, or better still lay it in U shaped concrete troughs with top covers
- Vibration fatigue or overheating:- Special precautions should be taken where cable supports are subject to vibration, or where it passes in close proximity to steam pipes, boilers, furnaces, etc.
- Leaking of oil through cable boxes:- Where a cable is led vertically up posts, or walls, the impregnating oil is likely to leak from the cable box at the lower level due to the hydrostatic pressure. Leakage can be generally prevented by ensuring that the stranded cable is soldered solid inside the cable box, and taking particular care when making the joint. If the difference in level is considerable, oil impregnated cables should not be used but some other type like the tropodur.

Locations of Cable Fault:-

The first thing to do is to test the cable and find out the exact nature of the faults, whether dead short between phases, or between phase and earth, discontinuity, or merely low insulation. In the case of long length of cables, the position of the fault should be located as accurately as possible by means of the Murray Loop test. But when the length of the cable is short, this is hardly necessary and the fault can usually be located easily, if the most probable causes are looked into immediately, step by step as follows.

- First isolate the two end boxes and inspect them. If the fault such as a dead short or earth is in the box, the external appearance of the box usually shows it up, particularly if it is a high tension box. The terminal boxes are the most common point of failure and they should, therefore, be looked into first.

- If the boxes are O.K., then send someone to walk along the route of the cable to see if someone has carelessly damaged the cable by hitting with a crowbar or pickaxe and puncturing the cable when digging a trench or carrying out some other construction work in the vicinity of the cable. If any such work is going on over the route, it is very probable that the cable may have suffered damage. In such cases expose the cable and inspect it carefully.
- It is also possible that one of the straight through boxes or T boxes below the ground has failed. Locate its position from the drawings or route indicators and inspect.

If the fault cannot be located quickly by the above methods then one of the electrical methods of fault location should be adopted, either by the fall of potential or Murray loop test method.

Fall of potential method:-

This method is based on the principle that the voltage drop is uniform per unit length of the cable. The test requires the use of another good core so that a loop may be formed.

The test is conducted after forming a loop, making use of another sound cable, and passing a current round the loop. The higher the circulating current, the more accurate the test will be. On a short loop of heavy cable, it may be necessary to use a stout piece of iron wire to limit the current. About 6 to 8 amp, from a well charged 12 volts motorcar battery would be convenient. The voltages between each end of the loop and the fault are measured, using a sensitive high resistance voltmeter having a long scale.

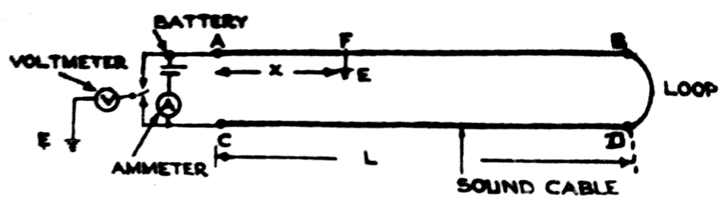


Fig 5.3 Fall of Potential Method

AB is the faulty core with an earth fault at F, while CD is the sound core. There will be uniform fall of potential from one end to the other along ABDC. If V' and V'' are the voltages recorded between A and E, and C and E by making use of the changeover switch, the distance X to the fault from end A will be given by

$$X = (V' / (V' + V'')) \times 2L \quad ; \text{where L is the length } AB = CD$$

Assuming that the loop ABDC has uniform resistance throughout its length.

Sometimes cables of different sectional area from that of the faulty cable may have to be used. In such cases, the equivalent length of cable to a common base will have to be calculated.

In actual practice, the method is not to simple as it appears, due to the potential developing at the earth fault due to stray currents. This may overcome by taking two sets of reading by reversing the battery and voltmeter leads and averaging the readings. Care should be taken to add the two readings algebraically and dividing by 2 to get the average.

Murray loop test:-

The Murray Loop is the most popular method in use for the exact location of faults. It is also accurate and should be used where ever possible. This method also requires the use of another sound core. The sound cable CD and the faulty cable AB are looped at the far end, and connected to the two ratio arm as shown in figure to form a Wheatstone bridge network, four arms of which are a, b, AF and FBDC.

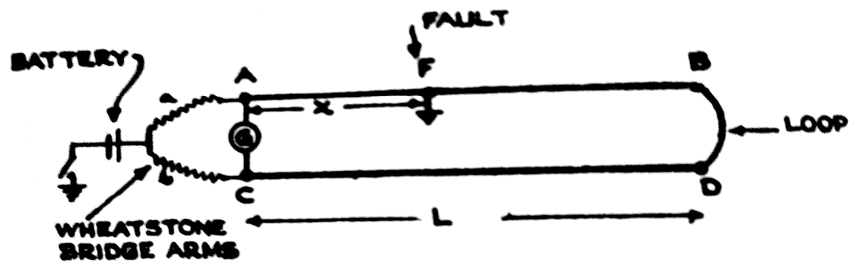


Fig 5.4 Murray Loop Test

A galvanometer G is placed across the ratio arms. One ole of the battery is connected to the junction of the ratio arms while the other pole is connected to earth. When balance is obtained, the distance X is found from the following formula:

Distance X = a/(a+b)*2L

The galvanometer may be connected directly across the ends of the loop instead of the ratio arm. If the arms are of high resistance and the connecting leads are kept short, accurate results will be obtained.

The sensitivity of the Murray Loop test depends upon the types of instruments used. Faults upto 100000 ohms resistance can be easily located when a battery of 100 volts or a 500 volts megger, the earth and guard terminals should be used. If a Wheatstone bridge is used for the ratio arms, one having ratio arms of 10100 and 1000 ohms, and a variable arm of units, tens, hundreds and thousands giving a total resistance of 11110 ohms in suitable. The galvanometer used should be of a very low resistance, say of 10 ohms, and a sensitivity of 3 micro volts per division. If a slide wire is used for the ratio arms, its resistance should be about 10 ohms, and the leads between the slide wire and the loop should be part of the ratio arms, and an allowance made in making the scale of the slide wire. Slide wire fault locators embodying this principle are manufactured by various makers.

Locating cable discontinuity:-

The localization of the exact position of a discontinuity is not difficult when the insulation resistance of the cores is very high. Difficulties arise, however, if the core has a very low resistance to earth.

The principle employed is to compare the capacity of the faulty core with that of the sound core, either by measuring the deflection on a galvanometer or by an a.c. bridge. In the galvanometer method switch No. 1 is connected to the faulty line.

Now switch No. 2 is placed on the battery side so that the cable length AF gets charged up. Then quickly change over switch No.2 on the galvanometer side and note its deflection. Let this be d. Then change over switch No. 1 to C position, i.e. connected to the sound core and note the deflection d by

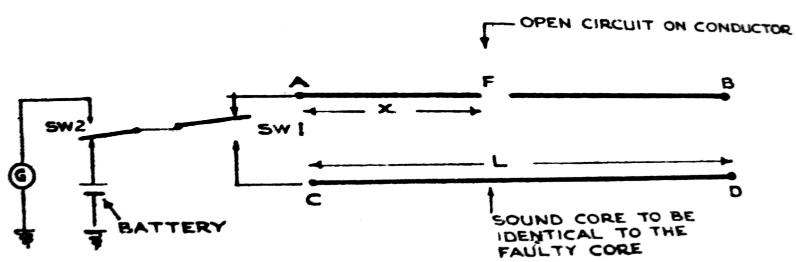


Fig 5.5 Murray Loop Test 2

putting switch No. 2 first to the battery and then to the galvanometer positions as done before. Now the deflection d1 and d2 obtained on the galvanometer are proportional to the accumulated charge on the cable's length AF and CD respectively because of their capacity to earth. It is assumed that the cables AB and CD are identical. Since the charge is directly proportional to the length, the distance of the fault is given by:

$$X=(d1/d2)*L$$

Cable fault location is a specialist work. An experienced engineer is often able to locate the fault within a few metres. A direct earth fault is comparatively easy to find. If the fault resistance is high, momentary application of a high potential derived from a high voltage test set will breakdown the fault further and helps in locating the fault more easily.

Another method employed for locating the faults in underground cables is the induction method, in which interrupted d.c. or audio tone is applied to the fault core and earth, at one end. If a search coil having a large number of turns of wire is held close to the ground above the cable, the tone applied to the faulty core can be picked up and heard through a head phone if the signals are amplified through a sensitive portable amplifier. By walking along the route of the cable the fault site could be easily located.

Review questions

Part A &B

1. What is the Essential of good lighting?
2. What do you mean by glare?
3. What is stroboscopic effect?
4. Mention the Troubleshooting in fluorescent lamp.
5. Explain about Fluorescent Lamp Disposal.
6. What are the Symptoms to identify the end of useful life in lamp.
7. Write the Causes of lowering of illumination level.
8. Explain the Effect of temperature on sag.
9. What is the Purpose of continuous earth wire.
10. Mention the Points to be checked when carrying out inspection of overhead lines.
11. Mention some Precautions in erecting underground cables.

Part C

1. Explain the methods of identifications of Locations of Cable Fault .
2. Explain Precautions in erecting underground cables.
3. Explain the Precautions in erecting lighting installations.
4. Describe the Methods of controlling street lights.
5. What are the Steps involved in designing a lighting installation.
6. What is stroboscopic effect? Methods to reduce stroboscopic effect.