GOVT CO-ED POLYTECHNIC

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LAB MANUAL

Branch : Electrical Engineering

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2024565(024) – Installation & Maintenance of Electrical Equipment (Lab)

CONTENTS

Experiment No: - 1

Date: ___________

Experiment name:

To Measure the Polarization Index and Dielectric Absorption Test.

Apparatus-

1. Meggar-
2. Transformer-

Theory:

The polarization index (PI) and Dielectric Absorption (DA) ratios indicate the condition of the insulation system of the motor and power circuit. Both of these tests use ratios of measurements of insulation resistance taken at two different times. There are three different currents that flow through an insulator when a voltage potential is applied. Since the RTG test measures the voltage and current to calculate insulation resistance, all of these currents must be taken into account. First, the "charging current" starts out high and drops to nearly zero after the insulation has been charged to full test voltage. This is normally negligible after the first few seconds of the test. Second the "absorption current" also starts out high and drops off.

Finally, the charging developed by these three different currents does not dissipate immediately when the voltage is removed at the end of the test. The insulation system must be allowed to discharge sufficiently between resistances to ground tests in order to obtain accurate results. A rule of thumb states that a motor takes four times the amount of charge time to discharge.

The significance of polarization index test.

Protect Equipment Resources has a wide variety of insulation resistance test sets, or meg-ohmmeters (meggers) in our equipment inventory from known manufacturers such as Megger. Resistance-to-ground readings involve three different current components: charging, absorption and leakage. The PI test allows the charging and absorption currents to decay so that only actual leakage current is measured. As a voltage is continuously applied, healthy insulation slowly polarizes and the absorption current diminishes. This causes a steady rise in resistance until the majority of the current is from the small amount leaking to ground. In poor insulation, leakage current is high enough to overshadow the lowering absorption current and provide little increase in the resistance over time. An important property of insulation is that it “charges” during the course of a test.

The polar DC field applied by the meg-ohmmeter causes re-alignment of the insulating material on the molecular level, as dipoles orient themselves with the field. This movement of charge constitutes a current. Its value as a diagnostic indicator is based on two opposing factors: the charging current dies away as the structure reaches its final orientation, while “leakage current” promoted by deterioration in the insulation passes a comparatively larger, constant current.

The net result is that, with "good" insulation, leakage current is relatively small, and resistance rises dramatically as charging goes to completion. Deteriorated insulation will pass relatively large amounts of leakage current at a constant rate for the applied voltage. This will "flood out" the charging effect. Time-Resistance Methods, take advantage of this effect.

When the testing device is applied to an insulation system, there are generally three types of current flow:

Leakage current is the resistive current that flows through the insulation and is what is being measured by the IR tester. Obviously, a lower leakage current implies an insulation system in better condition. The leakage current should stay more or less constant over the test period.

Capacitive charging current is the current that flows upon application of the DC voltage to charge the capacitance between insulation system under test and earth.
This will draw a high current in the first instance before dropping off quickly to zero as the capacitor is charged (i.e. within 1s)

Dielectric absorption current is the polarising current that is drawn by the insulation system (dielectric) to align the dipoles within the dielectric with the applied electric field. This current draws a high current initially but then gradually drops off as the dipoles in the dipole become increasingly polarised (i.e. in the order of 5 to 10 minutes).

Let I is the total initial current during polarization index test or PI test.

$$ = {}_C + {}_R + {}_S + {}_P$$

I_C is the capacitive current.
I_R is resistive or conductive current.
I_S is surface leakage current.
I_P is polarization current of the insulator.

Value of insulation resistance test or IR value test, i.e. value megger reading just after 1 minute of the test, is-

$${}_1 = \frac{}{{}_R + {}_S + {}_P}$$

Megger value of 10 minute test, is

$${}_{10} = \frac{}{{}_S + {}_R}$$

From the above equation it is clear that, if the value of $(I_R + I_S) >> I_P$, the PI of insulator approaches to 1. And large I_R or I_S or both indicate unhealthiness of the insulation.
The value of IP becomes high if $(I_R + I_S)$ is very small compared to I_P. This equation indicates that high polarization index of an insulator implies healthiness of insulator. For good insulator resistive leakage current I_L is very tiny.

It is always desired to have polarization index of an electrical insulator more than 2. It is hazardous to have polarization index less than 1.5.

Polarization Component

Every insulator is hygroscopic in nature. Some contaminant molecules and mainly moisture in insulator are very poor. When an electric field is applied across insulator the polar molecules align themselves along the direction of electric field. The energy required for this alignment of polar molecules, comes from voltage source in form of electric current. This current is called polarization current. It continues until all the polar molecules allied themselves along the direction of electric field.

It takes around 10 minutes to align the polar molecules along electric field and that is why if we take megger result for 10 minutes, there would be no effect of polarizing in megger result.

So when we take megger value of an insulator for 1 minute, the results reflects the IR value which is free from effect of capacitive component of leakage current. Again when we take megger value of an insulator for 10 minutes, the megger result shows the 12 value, free from affects of both capacitive component and polarization component of leakage current.

Polarisation Index (PI)
In this test, the testing device is applied and IR measurements are taken at 1 minute and 10 minutes. The polarisation index (PI) is calculated as:

$$\frac{1min}{10min}$$

Where and are the IR test measurements at $R_{1\ min}$ and $R_{10\ min}$ minutes respectively (Ω A general guide to interpreting the PI test results are as follows:

PI Value	Insulation Condition
< 1	Dangerous
< 2	Questionable
< 4	Good
> 4	Excellent

In this test, the testing device is applied and IR measurements are taken after 30 seconds and 60 seconds. The dielectric absorption ratio (DAR) is calculated as:

$$= \frac{1min}{10min}$$

A general guide to interpreting the DAR test results are as follows:

DAR Value	Insulation Condition
< 1.25	Dangerous
< 1.6	Questionable
> 1.6	Excellent

Observation Table:

Equipment to be tested: ____

Sr No.	Time (Sec)	Resistance (Ohm)
1		
2		
3		

Calculations-

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Signature of Teacher

Experiment No: - 2

Date: ____________

Experiment name:

Study of troubleshooting of electrical equipment based on actual visit to repair workshop (Any One)

1. Three phase induction motor
2. Transformer
3. Power Cable

Report of visited workshop: ____

Work Shop Visited: ____

Electrical equipment: ____

Sr. No.	Type of fault	Possible causes	Remedy
1	....	....	....
2	....	....	....

Sr. No.	Type of fault	Possible causes	Remedy
3	....	....	....
4	....	....	....
5	....	....	....
6	....	....	....

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Signature of Teacher

Experiment No: - 3

Date: _____________

Experiment name:

Study of thermograph images and analysis based on these images.

Introduction:

Infrared Thermography is science of using electronic optical devices to detect and measure radiation and correlating that to surface temperature. Thermal imagers can convert infrared radiation being emitted from the body into electric signals and thus present them visually. The various advantage**s** of Infrared Thermography are as below: It is of great significance in preventive service and maintenance, building condition, Production Monitoring, technical diagnostics etc. A thermal imager makes anomalies visible, thus making an exact search for errors or fault possible. It

Thermography is the practice of quantitatively measuring radioactive heat emissions from objects for predictive and preventative maintenance programs. Thermographic Inspection can be used to pinpoint components that are operating at a temperature higher than other components, indicating degradation, or to locate where energy losses are occurring such as in cryogenic fluid lines or steam pipes. Infrared thermographyis the science of acquisition and analysis of thermal information by using non contact thermal imaging devices. Infrared thermography (IRT), thermal imaging, and thermal video are examples of infrared imaging science.

Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 9–14 µm) and produce images of that radiation, called **thermograms**. Since infrared radiation is emitted by all objects above absolute zero according to the black body radiation law, thermography makes it possible to see one's environment with or without visible illumination. The amount of radiation emitted by an object increases with temperature; therefore, thermography allows one to see variations in temperature. When viewed through a thermal imaging camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible

Experiment procedure to determination of thermal image System set up-The system that is based on IR image sequence processing is recorded the temperature variation history on the surface with periodical heat flow generation by using of infrared camera, and then, the image sequences are processing with the signal processing algorithms to obtain the amplitude and phase image, which are used to FFT method. Fig.3.1 shows the principle of the Lock in thermography based on the image sequence processing. Thermal imaging cameras convert the energy in the infrared wavelength into a visible light.

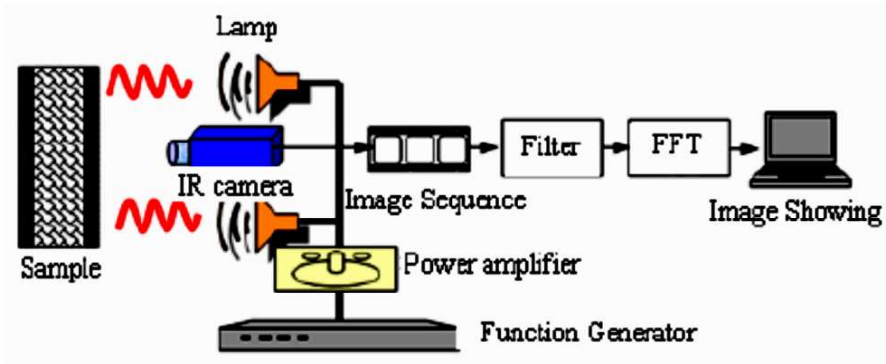

Fig 3.1: Block Diagram of Thermography

The diagram of IR Lock in thermography based on image sequence object's surface temperature. This makes it possible for a thermal imaging camera to display an object's temperature. However, other factors also influence the radiation, which limits the accuracy of this technique. For example, the radiation depends not only on the temperature of the object, but is also a function of the emissivity of the object. Also, radiation originates from the surroundings and is reflected in the object, and the radiation from the object and the reflected radiation will also be influenced by the absorption of the atmosphere.

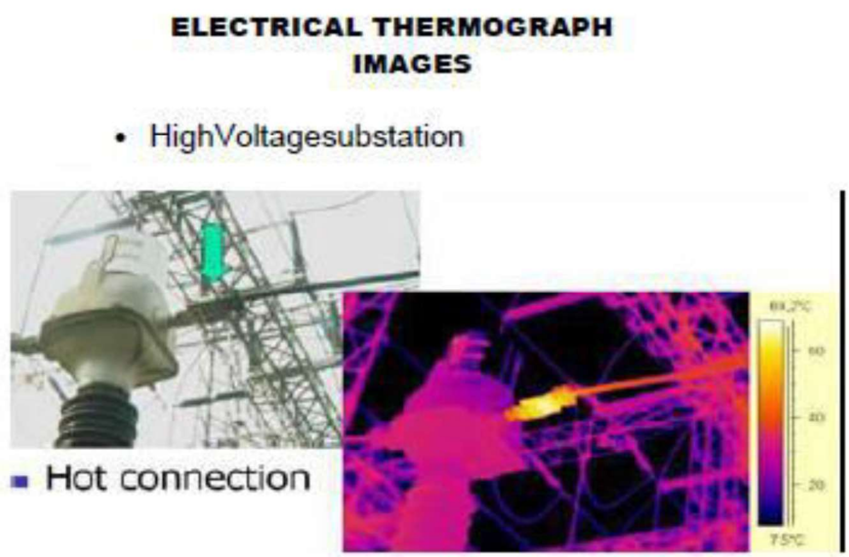

Fig 3.2: Thermography Image of CT

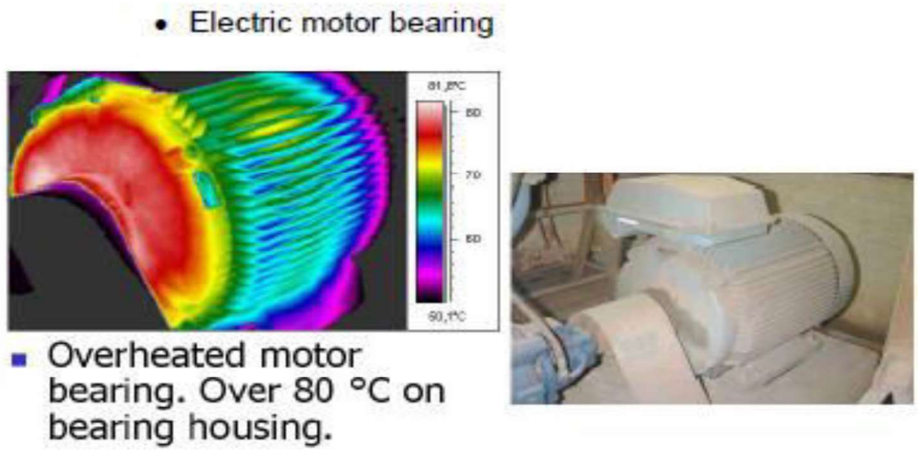

Fig 3.2: Thermography Image of Induction Motor

Advantages

- Use of Thermography in predictive and preventative maintenance programs reduces equipment (both facility and GSE) down time,
- Prevents schedule impacts due to untimely failures, and increases availability.
- It shows a visual picture so temperatures over a large area can be compared
- It is capable of catching moving targets in real time
- It is able to find deteriorating, i.e., higher temperature components prior to their failure
- It can be used to measure or observe in areas inaccessible or hazardous for other methods
- It is a non-destructive test method
- It can be used to find defects in shafts, pipes, and other metal or plastic parts.It can be used to detect objects in dark areas

Limitations

- Quality cameras often have a high price range (often US$ 3,000 or more), cheaper are only 40x40 up to 120x120 pixels.
- Images can be difficult to interpret accurately when based upon certain objects, only able to directly detect surface temperatures.
- Condition of work, depending of the case, can be drastic: 10°C of difference between internal/external, 10km/h of wind maximum, no direct sun, no recent rain

Application-

- Condition monitoring.
- Low Slope and Flat Roofing Inspections.
- Thermal Mapping.
- Digital infrared thermal imaging in health care.
- Breast thermography: tele-thermography (medical), contact thermography and dynamic angio-thermography.
- Peripheral vascular disease screening.
- Neuro-musculoskeletal disorders.
- Extracranial cerebral and facial vascular disease.
- Thyroid gland abnormalities.
- Various other neoplastic, metabolic, and inflammatory conditions.
- Archaeological Kite Aerial Thermography.
- Veterinary Thermal Imaging Night vision.
- Condition based maintenance.

Conclusion:

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Signature of Teacher

Experiment No: - 4

Date: ____________

Experiment name:

Study the various types of earthing for electrical systems, Practice of earthing and Measurement of Earth resistance of Campus premises.

Apparatus:

Sr. No.	Description	Qty
1	Earth Tester	1
2	Connecting wire	5m
3	Measurement Tape	1

Theory:

The process of electrically connecting to the earth itself is often called "earthing". The main reason for doing **earthing** in electrical network is for the safety. When all metallic parts in electrical equipments are grounded then if the **insulation** inside the equipments fails there are no dangerous voltages present in the equipment case. If the live wire touches the grounded case then the circuit is effectively shorted and fuse will immediately blow. When the fuse is blown then the dangerous voltages are away.

The main reason for doing earthing in electrical network is for the safety. When all metallic parts in electrical equipments are grounded then if the insulation inside the equipments fails there are no dangerous voltages present in the equipment case. If the live wire touches the grounded case then the circuit is effectively shorted and fuse will immediately blow. When the fuse is blown then the dangerous voltages are away.

Connection to earth is achieved by embedding a metal plate or rod or conductor in earth. This metal plate or rod or conductor is called as "Earth electrode". Effectiveness of the earthing connection made by embedding a metal plate in earth is quantified as "Earth Resistance". This earth resistance is measured in ohms.

Need of good earthing:

1. To save human life from danger of electrical shock or death by blowing a fuse i.e. to provide an alternative path for the fault current to flow so that it will not endanger the user.
2. To protect buildings, machinery & appliances under fault conditions ie. To ensure that all exposed conductive parts do not reach a dangerous potential.
3. To provide safe path to dissipate lightning and short circuit currents.
4. To provide stable platform for operation of sensitive electronic equipments i.e. To maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.
5. To provide protection against static electricity from friction

Main Objectives of earthing systems are:

1. Provide an alternative path for the fault current to flow so that it will not endanger the user.
2. Ensure that all exposed conductive parts do not reach a dangerous potential.
3. Maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.

Types of Earthing

The earthing is broadly divided as

1. System or Neutral Earthing
2. Equipment Earthing

System Earthing or Neutral Earthing

This is primarily concerned with the protection of Electrical equipment by stabilizing the voltage with respect to ground (Connection between part of plant in an operating system like LV neutral of a Power Transformer winding and earth).

Ground or **earth** in a mains (AC power) electrical wiring system is a conductor that provides a low-impedance path back to the source to prevent hazardous voltages from appearing on equipment. Under normal conditions, a grounding conductor does not carry current.

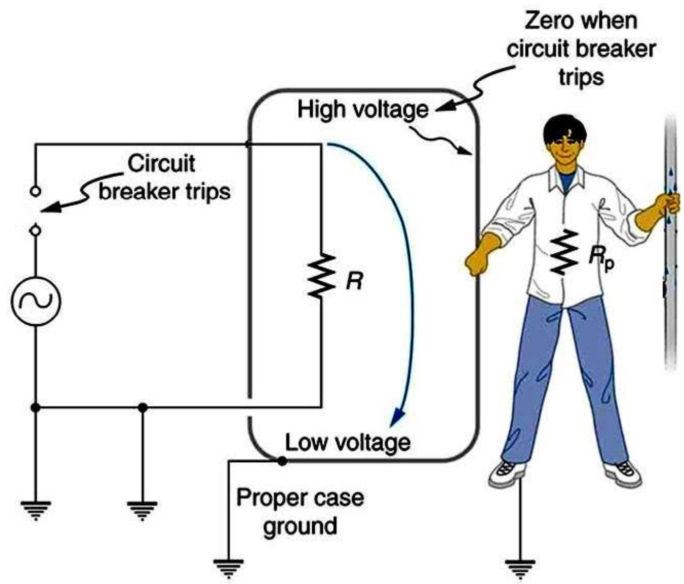
Neutral is a circuit conductor that may carry current in normal operation, and is connected to ground (earth) at the main electrical panel.

In a poly-phase or three-wire (single-phase) AC system, the neutral conductor is intended to have similar voltages to each of the other circuit conductors.

Equipment Earthing

This is primarily concerned with the protection of personnel from electric shock by maintaining the potential of noncurrent carrying equipment at or near ground potential. Connecting frames of equipment (like motor body, Transformer tank, Switch gear box, operating rods of Air break switches, etc) to earth.

The system earthing and safety earthing are interconnected and therefore fault current flowing through system ground raises the potential of the safety ground and also causes steep potential gradient in and around the Substation. But separating the two earthing systems have disadvantages like higher short circuit current, low current flows through relays and long distance to be covered to separate the two earths. After weighing the merits and demerits in each case, the common practice of common and solid (direct) grounding system designed for effective earthing and safe potential gradients is being adopted.



Types of Earth Electrode
1. Rod electrode.
2. Pipe electrode.

Plate Type Earthing

In this, cast Iron plate of size 600 mm X 600 mm X 6.3 mm thick plate is being used as earth plate. This is being connected with hot dip GI main earth strip of size 50mm X 6mm thick X 2.5 meter long by means of nut, bolts & washers of required size. The main earth strip is connected with hot dip GI strip of size 40mm X 3mm of required length as per the site location up to the equipment earth / neutral connection.

The earth plate is back filled & covered with earthing material (mixture of charcoal & salt) by 150mm from all six sides. The remaining pit is back filled with excavated earth. Along with earth plate, rigid PVC pipe of 2.5 meter long is also provided in the earth pit for watering purpose for to keep the earthing resistance within specific limit.

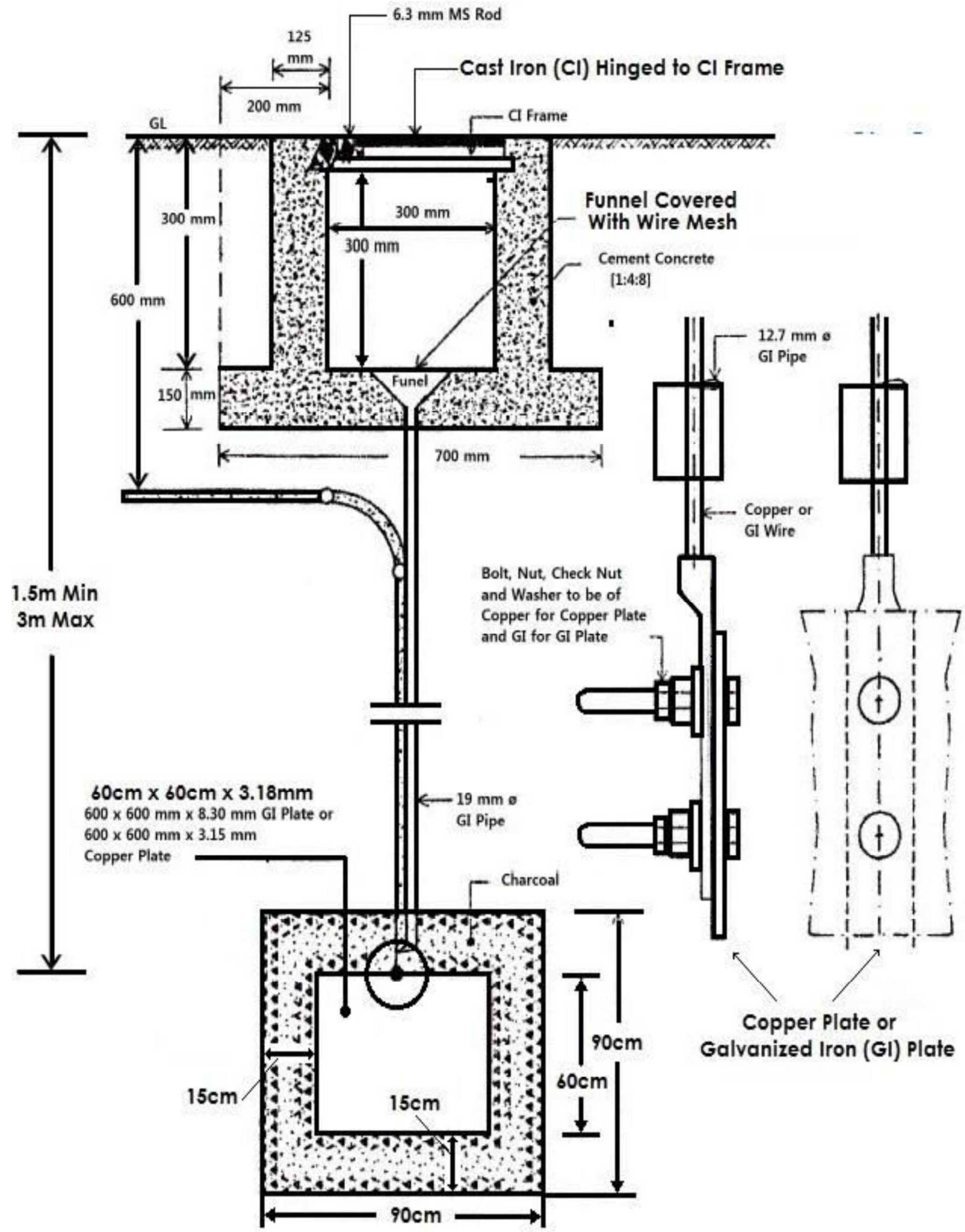


Fig: Plate Earthing

Pipe Type Earthing

In this hot dip GI pipe of size 40mm dia X 2.5 meter is being used for equipment earthing. This pipe is perforated at each interval of 100mm and is tapered at lower end. A clamped is welded with this pipe at 100mm below the top for making connection with hot dip GI strip of size 40mm X 3mm of required length as per the site location up to the equipment earth / neutral connection. On its open end funnel is being fitted for watering purpose. The earth pipe is placed inside 2700 mm depth pit.

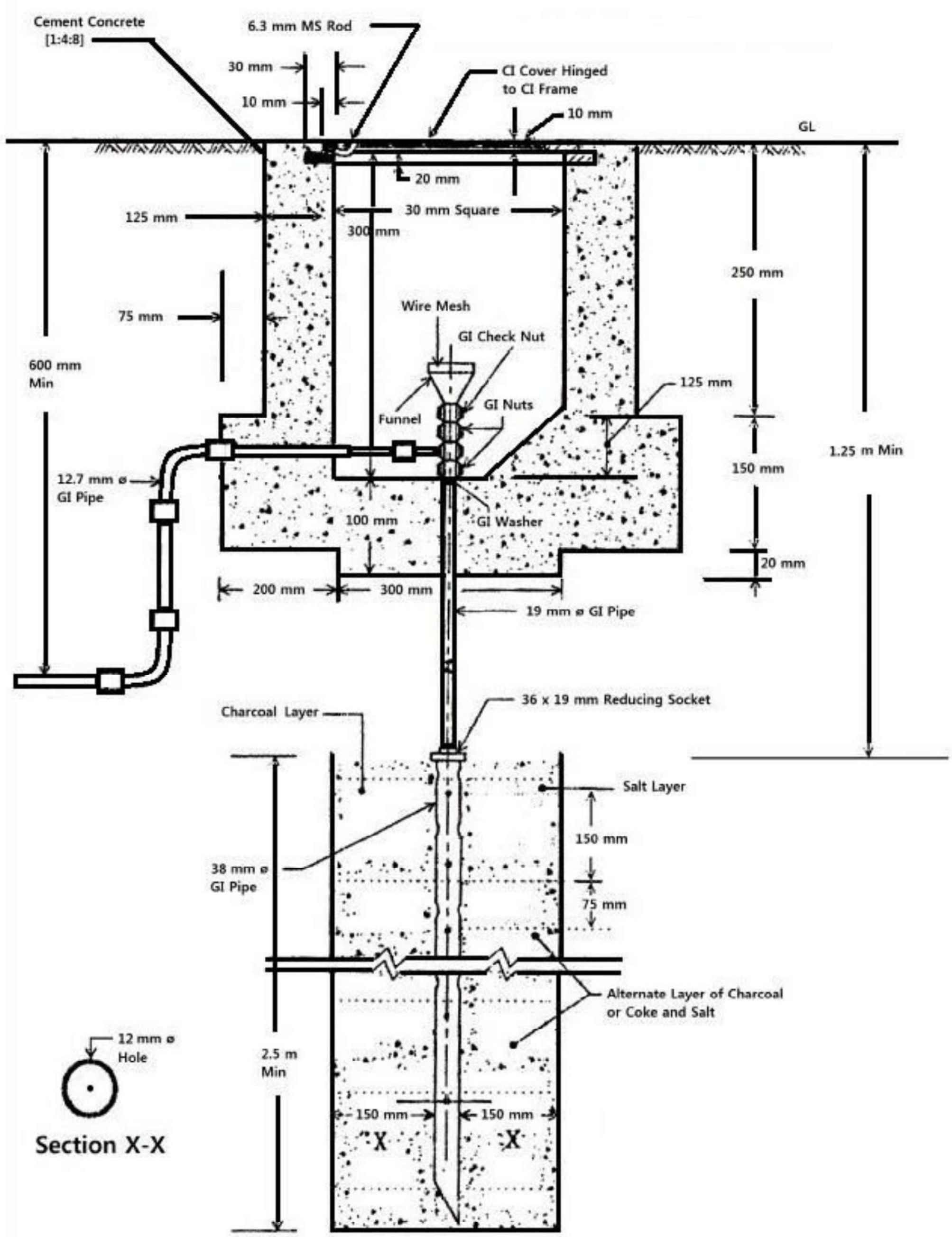


Fig: Pipe Earthing

A 600mm dia of GI sheet in two halves is placed around the pipe. Then the angular space between this GI sheet and earth pipe is back filled with alternate layer of 300mm height with salt and charcoal. The remaining space outside of GI sheet will be backfilled by excavated earth. The GI sheet is gradually lifted up as the backfilling up progresses. Thus the pit is being filled up to the 300mm below the ground level. This remaining portion is covered by constructing a small chamber of brick so that top open end of pipe and connection with main earth pipe will be accessible for attending when necessary.

The chamber is closed by wooden / stone cover. Water is poured into the pipe through its open end funnel to keep the earthing resistance within specific limit.

Other types of earthing: When the capabilities of certain equipment are limited, they may not with stand certain fault currents then the following types of earthing are resorted to limit the fault current. (a) Resistance earthing (b) Reactance earthing (c) Peterson coil earthing. (d) Earthing through grounding transformer.

Factors That Change the Requirement of Earth Electrode

- If an electrical facility can expand in system, it creates different routes in the electrode. What was formerly a suitable low earth resistance can become obsolete standard.
- More number of metallic pipes, which were buried underground become less and less dependable as effective low resistance ground connection.
- Most of the location, the water table gradually falling. In a year or two, area ends up with dry earth of high resistance.
- These factors emphasize the importance of a continuous, periodic program of earth resistance testing

Why Measure Soil Resistivity measurement is required?

Soil resistivity measurements have a threefold purpose.

1. Such data are used to make sub-surface geophysical surveys as an aid in identifying ore (a type of rock) locations, depth to bedrock and other geological phenomena.
2. Resistivity has a direct impact on the degree of corrosion in underground pipelines. A decrease in resistivity relates to an increase in corrosion activity and therefore dictates the protective treatment to be used.
3. Soil resistivity directly affects the design of a grounding system, and it is to that task that this discussion is directed. When designing an extensive grounding system, it is advisable to locate the area of lowest soil resistivity in order to achieve the most economical grounding installation.

Measurement of Earth Resistance by use of Earth Tester by Three point method or fall Potential Test

The Fall of Potential method is the most recognized method for measuring the resistance to earth of a grounding system, or the ground system performance. It is based on an IEEE standard, and when properly performed, is a very accurate test.

Take measurement in different directions as shown in below fig. If we rotate generator handle with specific speed we get directly earth resistance on scale. Spike length in the earth should not be more than 1/20th distance between two spikes. Resistance must be verified by increasing or decreasing the distance between the tester electrode and the spikes by 5 meter. Normally the X-Z distance should be proportion of 62% of D (Distance between Earth Electrode & Current spike).

Procedure

1. Connect C1 and P1 terminals on the test set to the earth electrode (Fig.).
2. Drive a probe into the earth 100 to 200 feet from the center of the electrode and connect to terminal C2.This probe should be driven to a depth of 6 – 12 inches.
3. Drive another probe into the earth midway between the electrodes and probe C2 and connect to terminal P2. This probe should be driven to a depth 6 – 12 inches.
4. Record the resistance measurement.
5. Move the potential probe 10 feet farther away from the electrode and make a second measurement.
6. Move the potential probe 10 feet closer to the electrode and make a third measurement.
7. If the three measurements agree with each other within a few percent of their average, then the average of the three measurements may be used as the electrode resistance.
8. If the three measurements disagree by more than a few percent from their average, then additional measurement procedures are required.

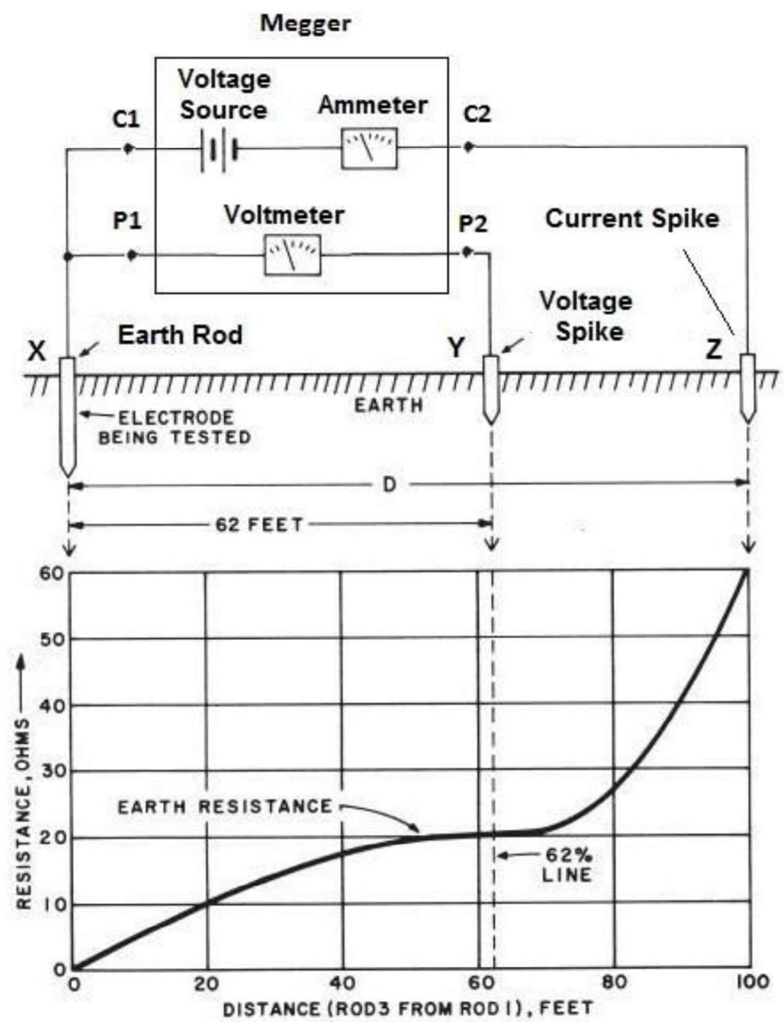


Fig: Fall Potential Method

Observation Table:

Sr. No.	Voltage in Volt	Current in Amp	Resistance	Distance in meter

Treatments to for minimizing Earth resistance

- Remove Oxidation on joints and joints should be tightened.
- Poured sufficient water in earth electrode.
- Used bigger size of Earth Electrode.
- Electrodes should be connected in parallel.
- Earth pit of more depth & width- breadth should be made.

Conclusion:

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Signature of Teacher

Experiment No: - 5

Date: ____________

Experiment name:

Design, Estimation and costing of earthing pit and earthing connection for computer lab, Electrical Machines Lab, HT Substation.

The earthing system in a plant / facility is very important for a few reasons, all of which are related to either the protection of people and equipment and/or the optimal operation of the electrical system. These include: Equipotential bondings of conductive objects (e.g. metallic equipment, buildings, piping etc) to the earthing system prevent the presence of dangerous voltages between objects (and earth).

- The earthing system provides a low resistance return path for earth faults within the plant, which protects both personnel and equipment.
- For earth faults with return paths to offsite generation sources, a low resistance earthing grid relative to remote earth prevents dangerous ground potential rises (touch and step potentials)
- The earthing system provides a low resistance path (relative to remote earth) for voltage transients such as lightning and surges / overvoltages
- Equipotential bonding helps prevent electrostatic buildup and discharge, which can cause sparks with enough energy to ignite flammable atmospheres
- The earthing system provides a reference potential for electronic circuits and helps reduce electrical noise for electronic, instrumentation and communication systems [1- 3] this calculation is based primarily on the guidelines provided by IEEE STD 80 (2000), "Guide for safety in AC substation grounding".

“Earthing means an electrical connection to the general mass of earth to provide safe passage to fault current to enable to operate protective devices and provide safety to personnel and Equipments.”

The earth resistance shall be as low as possible and shall not exceed the following limits
Maximum allowable Earth resistance

1) Major power station= 0.5 Ohm.
2) Substations= 1 Ohm
3) Service connection = 5 Ohm
4) Medium Voltage Network =2 Ohm
5) L.T. Lightening Arrestor= 4 Ohm
6) L.T. Pole= 5 Ohm
7) H.T. Pole =10 Ohm

Design of Earthing for Domestic or Commercial Load *(As per IS 3043):*

Number of Earthing Electrode and Earthing Resistance depends on the resistivity of soil and time for fault current to pass through (1 sec or 3 sec). If we divide the area for earthing required by the area of one earth plate gives the number of earth pits required. First the leakage current to be carried is calculated and then size of the strip is determined.

Number of earth pits is decided by considering the total fault current to be dissipated to the ground in case of fault and the current that can be dissipated by each earth pit. Normally the density of current for GI strip can be roughly 200 amps per square cam. Based on the length and dia of the pipe used the number of earthing pits can be finalized.

The strip connected should be capable to carry at least 70A (neutral current) which means a strip of GI 25 x 3mm should be enough to carry the current and for body a strip of 25 × 3 will do the needful. Normally we consider the strip size that is generally used as standards.

However a strip with lesser size which can carry a current of 35A can be used for body earthing. The reason for using 2 earth pits for each body and neutral and then shorting them is to serve as back up. If one strip gets corroded and cuts the continuity is broken and the other leakage current flows through the other run by completing the circuit.

Similarly for panels the no of pits should be 2 Numbers. The size can be decided on the main incomer circuit breaker. For example if main incomer to breaker is 400A, then body earthing for panel can have a strip size of 25 × 6 mm which can easily carry 100A.

As per IS 3043 Pipe, rod or strip has a much lower resistance than a plate of equal surface area.

Example:

An earthing pipe of 100mm diameter, 3 meter length. System has fault current 5KA for 1 sec and soil resistivity is 72.44 Ω-meters. Calculate number of Earth rod is required for good earthing for Domestic Purpose.

Procedure:

1. Data Collection
   - Length of earth electrode (L) = 3 meter
   - Diameter of Earth Electrode(D) = 100 mm
   - Soil Resistivity (ρ) = 72.44 Ω-m
   - Fault of surge current (*If*) = 5KA
   - Fault time (t) = 1 sec
2. Max. allowable current density

$$= \frac{\quad}{\sqrt{\rho}}$$ **A/m2**

$$= \frac{\quad}{\sqrt{\quad}}$$ = 889.419 **A/m^2**

3. Surface area of one 100mm dia. 3 meter Pipe = 2 x 3.14 x r x L
   = 2 x 3.14 x 0.05 x3 = **0.942 m^2**

4. Max. current dissipated by one Earthing Pipe (*Id*)
   ***Id* =** Current Density x Surface area of electrode
   Id = 889.419x 0.942 = 837.83 A say **838 Amp**

5. Number of earthing pipe required (Ne)
   Ne = Fault Current / Max. Current dissipated by one earthing pipe.
   Ne = 5000/838 = 59.66 Say **6 No's.**

Total number of earthing pipe required = 6 No's.

6. Resistance of earthing pipe (Re)

$$_e = \frac{\rho}{\Pi}\left[\ _e\left(\frac{}{}\right)\right]$$

Re = 100 ×72.44 /2×3.14 x 300 x (loge (4X300/10)) = 7.99 Ω/Pipe

Overall resistance of 60 no of earthing pipe = 7.99/6 = 1.33 Ω.

Estimation & Costing

Sr. No.	Particular with Specification	Quantity	Rate

Conclusion:

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Signature of Teacher