TRANSFORMERS:

a. Specifications: Power and distribution transformers as per BIS standards.

b. Installation: Location, site, selection, foundation details (like bolts size, their number, etc), code of practice for terminal plates, polarity & phase sequence, oil tanks, drying of windings and general inspection.

5 Hours

c. Commissioning tests: Following tests as per national & International Standards, volt ratio test, earth resistance, oil strength, Bucholtz & other relays, tap changing gear, fans & pumps, insulation test, impulse test, polarizing index, load & temperature rise test..

7 Hours

d. Specific Tests: Determination of performance curves like efficiency, regulation etc, and determination of mechanical stress under normal &abnormal conditions.

3 Hours

Introduction

Power and distribution transformers are used for the purpose of power transmission and distribution respectively. Power transformer is one of the prime components of power system. The transformer is to be operated as per the specifications for smooth performance. It is essential to keep the down time as minimum as possible, thereby ensuring the continuity in the power supply. As it is an important component of the system, utmost care is necessary in its procurement, installation, testing prior to commissioning, operation and maintenance as per IS code. The transformer is fitted with various accessories, fitments and protective devices for assisting the smooth functioning and initiating necessary actions under abnormal conditions. Various inspection and tests are conducted on the transformer to be installed, in the factory and at site depending upon the capacity of the transformer and facilities available for testing. The transformer should be healthy in all respects before it is energized.

Standards and Specifications

Standards are evolved to meet a generally recognized demand, taking into account the interest of manufacturers and users and fulfilling the needs of economy. At present, a product cannot even be visualized without a standard. A standard is a useful guide in all facets of a product - conception, design, manufacture, testing, installation, operation, maintenance etc.
The international standards published by IEC (International Electro technical Commission) are accepted universally. However each country has its own National standards which are based on particular requirements and practices of that nation. Indian Standards Institution (Bureau of Indian Standards) publishes IS standards. The manufacturers and users in India have to follow IS standards and IEC standards. The word specification or rating denotes the assigned numerical value of capabilities. The transformer is assigned with certain definite ratings. These assigned ratings are guaranteed by the manufacturer. These ratings are confirmed by acceptance test to the satisfaction of the customer. Essential ratings are marked on the rating plate fixed on the equipment.

Need for standardization of specification:

Transformer is a job specific (tailor made) product and requires effort in its design an drafting, even if a single parameter is changed. Standardization of the specification and design parameters of this vital equipment of energy transport will not only help in ensuring optimal deployment of available resources but also go a long way in economizing the capital costs. Efforts to standardize transformer specification have been made in different forums. The Central Electricity Authority (CEA) report and the Central Board of Irrigation and power (CBIP) specifications are the outcome of a concerted effort over years.

Specifications of transformers

The specifications of transformers should be supplied to the purchaser. The transformer is to be operated as per the specifications in order to avoid failure. The life expectancy of transformer is increased by proper handling.

Standard specifications of a Power Transformer

Indian standard IS 2026 "Specification for Power Transformers" is the governing standard on Power Transformers. This has been revised time to time and is now in five parts and is an exhaustive standard on power transformers. The following information must be available with enquiry and order for the design and drafting of the transformer.

- Type of transformer: Separate winding transformer, autotransformer or booster transformer
- Number of phases: single or polyphase
- Frequency
- KVA Rating
- Rated voltages for each winding
- Connection symbol
- Requirements of on-load / off-load tap changers
- Impedance voltage at rated current
- Indoor or outdoor type
- Type of cooling and if different types of cooling involved, rated required power for ea type of cooling.
- Temperature rises and ambient temperature conditions including altitude and in case water cooling, chemical analysis of water.
- Number of cooling banks, spare capacity and cooling pumps & fans.
- Highest system voltage for each winding
- Method of system earthing for each winding Insulation levels
- Over fluxing conditions
- Details of auxiliary supply voltage (for fans, pumps, OLTC, motor alarm, control).
- Controls of tap changers
- Short circuit levels of the system
- Vacuum and pressure withstanding values of the transformer tank Noise requirement
- Number of rails and rail gauge for movement along shorter and longer axes
- Fittings required with their vivid description
- Any other appropriate information including special tests if any and capitization f for the losses.

Specification of outdoor type 3-phase distribution transformer up to and including 100KVA, 11 KV: IS 1180 (Part1):1989

This standard specifies the requirements and tests for oil immersed, naturally air cooled, three phase, and double wound non sealed type out door distribution transformers.

- KVA rating: The standard rating shall be 16, 25, 63 and 100KVA.
- Rated Frequency: The rated frequency shall be 50Hz.
- Nominal system voltage: Nominal system voltage shall be chosen from 3.3, 6.6 and 11KV.
- No Load voltage ratio: 3300/433-250V, 6600/433-250V or 11000/433-250V.
- The winding connection and vectors: The primary winding shall be connected in delta and the secondary winding star Dyn11 (IS 2026 (part 4); 1977) so as to produce a positive phase displacement of 30° from the primary to the secondary vectors of the same phase.
- Tapping ratings and tapping methods. The number of tapings, winding tapped i.e. primary or secondary are to be specified. The total change in voltage as percent of total voltage and percent voltage change per tap change are to be specified. Egg. Total change in voltage is ±10% and is achieved by changing taps with ±1.5% per tap.
- The transformer tank and the transformer oil shall comply with the requirements (IS 335; 1983).
- Standard fittings: Details pertaining to the following standard fittings shall be given.
- Earthling terminals
- Oil Level gauge
- Lifting Lugs
- Rating and terminal marking plates
- Breather
- ·Drain cum sampling valve (3/4 nominal size threads) preferably steel with plug.
- Oil filling hole (11/4 nominal size thread) with cover (for transformers without conservator).
- Terminal arrangements
- Mounting arrangements
- Insulation Levels
- Limits of temperature rise
- Losses and impedance values
- Ability of transformers to withstand external short-circuit
- Any other required relevant information shall be provided.

Procurement and Installation of Transformers Inquiry:

In the initial stage of a transformer inquiry there is nothing as important as a full and explicit statement of the total requirements that, from the users' point of view, have to be met and from the manufacturers stand point have to be considered. Frequently, inquiries are received giving insufficient information concerning the relevant details, so with a view to saving both time and trouble. The general information should be given when issuing transformer enquiry.

- Planned Project
- . Requirements of Load
- Location, environnemental conditions, ambiant température, raina, dus etc..

- Sub-station Layout, system voltage and fault Levels.
- Civil engineering requirements such as room, foundation, trenches for cabling, ventilation aspects etc.
- Limits of variation of the supply voltage and/or frequency, coli nag, earthy nag etc.

Tenders:

The submission of comprehensive and informative tenders is essential from all points of view to all parties concerned to facilitate the duties of others to the greatest possible extent. In addition, to price, manufacturing period, conditions of payment, mode of supply, service after sale, maintenance contract, essential and extra data as per the inquiry, quotations should give the following specifications and performance.

- Type of transformer
- Type of tank
- Type of cooling i.e. self cooled, water cooled, forced oil cooled etc.
- Core loss at normal voltage and frequency
- Copper loss at rated load
- Percentage regulation at up
- Percentage regulation at 0.8 lagging pf (or at any other specified pf).
- Percentage impedance and reactance
- Efficiency at up at 5/4, 1/1, 3/4, 112 and 1/4 full load.
- Performance reference temperature i.e. 75° C.
- Ambient air temperature or assumed temperature of cooling medium, permissible overloads i.e. magnitudes and durations.
- Oil quantity
- Net overall dimensions
- Net weight of core and windings, tank and oil
- Shipping specifications (for export tenders)
- Insulating medium between windings and tank i.e. air or oil.
- Primary and secondary connections
- Overloads
- Locations
- Tapings used for the following purposes.
- Primary tapings to vary primary voltage
- Secondary tapings to vary secondary voltage
- Primary tapings to vary secondary voltage
- Secondary tapings to compensate for variations in primary voltage
- Details about the fittings with the transformer.

In comparing tenders, the simple and effective procedure is to tabulate the dat submitted by different manufacturers, on a sheet, so that a comprehensive summary can b made. Based on the price and performance parameters indicated, depending upon the priority c the organization an order shall be placed for supply of the transformer.

Dispatch:

The transformer is dispatched by the manufacturer by one of the following metho depending upon the size and local conditions.

./ Dried out - filled with oil, ready for service' (small transformers)

./ With oil covering core and coils only (medium transformers)
./ Without oil in the tank, filled with nitrogen at pressure slightly above the atmosphere pressure (large transformers).

In majority of the cases accessories like radiators, bushings, explosion vent pressure relief valve, dehydrating breather, rollers, Buchholz relay, conservator, pipe work, marshalling box are separately dispatched. Transformer oil is sent in separate sealed containers. When transformers are dispatched with inert gas, positive pressure must be maintained throughout the period till the gas is replaced by oil. The transformer may be packed in a strong wooden packing and / or may be sent without packing case or crate depending upon the conditions of transport. Special care is to be exercised finally to prevent movement of the core and windings during transit. To send small and medium transformers trucks and large transformers road trailers or rail wagons are generally used.

Inspection upon arrival at site:

Immediately after arrival at site, it should be inspected for possible damages during transit. The nitrogen gas pressure should be checked. Positive pressure if not found, indicates that there is leakage, and there is a possibility of the moisture entering the tank during transit. This can be ascertained by dew point measurement which indicates the amount of surface moisture content in transformer insulation. Internal inspection should be carried out to the extent possible through inspection covers. Particular attention should be paid to the connections, bolt links, coil clamping bolts, tap changers. Current transformers and the general insulation. Break down strength of oil of transformer tank and drums containing transformer oil should be examined carefully. An inspection of the transformer on arrival at site is to be carried out preferably in the presence of the representative of the manufacturer.

Storage:

The transformers arrived at site and likely to be installed immediately do not need elaborate storage. In case of delayed installation, it requires proper storage to avoid influx of moisture, effect of rain / dust etc. It is preferable to store the transformers indoor on proper flooring with protective covering. The oil should not be drained unless there is a provision of filling inert gas.

Handling:

The transformers are provided with lugs and shackles for the purpose of lifting. The following means are normally used for lift nag operations.

- Overhead travelling crane or gantry crane
- Jib crane
- Derricks
- Jacks and winches

The overhead crane and jib cranes are the convenient and safe means. Precautions mentioned below should be complied with:

- Transformers should be lifted only through lifting points ,/ Cover must always- be bolted in position
- Proper balance should be maintained while lifting.

Installation:

Location, site preparation and foundation details:

The location may be indoor or outdoor. For indoor installation, the following aspects should be considered.

- Ventilation
- Noise level

Space required for movement, maintenance etc
Trenches for cables
Minimum clearances between the transformer and the walls should be as follows.

Clearance on all four sides of wall: 1.25 m
Clearance on all three sides of wall: 1 m
Clearance on a wall on backside only: 0.5 m
The clearance of 0.5 m (minimum) should be provided between the top most point of the conservator and the roof.
Ventilation area: The ventilation area required is as follows.
Outlet: 2m2 per 1000 KVA
Inlet : 1m2 per 1000 KVA minimum

Indoor transformers having oil capacity of more than 2000 liters should be provided with soak pits. Power cables and control cables should never be run in the same conduit or cable tray or and windings during transit. To send small and medium transformers trucks and large transformers road trailers or rail wagons are generally used.

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Testing & Commissioning of Electrical Equipments

Foundation: No special foundation is required for the installation of a transformer except a level floor strong enough to support the weight and prevent accumulation of water. Foundations with oil drainage facilities during fire and emergency is recommended for large transformers. Transformers should be positioned on the foundation so that easy access is available all around to read or reach different fitments.

For outdoor installations, the clearance between live parts and neighboring structures, equipments etc., should be adhered to electricity rules. Simple, firm, horizontal and leveled foundation is necessary. The level of concrete plinth with bearing plates of sufficient size and strength can be adopted. The space between the plinth and base of the transformer should be prevented by use of rust proof bituminous compound. The suitable rail tracks should be provided where rollers are used. Once the wheels of the transformer are in final position and then should be locked to prevent accidental movement. Transformers having oil capacity more than 9000 liters should be provided with drainage facility. For medium voltages, cable connector or bare conductor connection is used.

Code of practice for Rating and Terminal plates: IS 1180 (part 1): 1989

Each transformer shall be provided with non-detachable rating plate of weather proof material.
This plate fitted in a visible position, indicates the information given in fig.. The entries on the rating plate shall be indelibly marked (e.g. by etching, engraving or stamping).

Terminal marking plate: Each transformer shall be provided with a terminal marking plate as per IS 1180 (part 1): 1989. This is in accordance with whichever is applicable. IS 2026 (part 4): 1981 (first revision) also highlights about terminal marking, tapping and connectors.

Phasor Diagram and Phasor Groups

Phases are used to represent the induced emus in pharos diagram of a transformer. The direction employed for the rotation of phases is counter clock wise. In three phase transformers polarity alone is insufficient to represent the relation between he and Live windings. Besides the terminal markings on he and Live side voltage, pharos diagrams are required to show the angular displacement between he and Live winding. The angular difference between phases representing the voltages induced between he and Live terminals having the same marking Letters and the corresponding neutral point (real or fictitious) expressed with respect to the side is termed as the displacement. Under normal conditions, the Line to Line voltages on the side are displaced from corresponding voltages on Live side and the same is true for Line to neutral voltages also. This displacement depends upon the transformer winding connections.

An internationally adopted convention for indicating phase displacement is to use a number which represents the time indicated by a clock, where the minute hand represents the Line to neutral voltage pharos for the he winding and is set at 12 0' clock and the hour hand represents the Line to neutral voltage pharos for the Live winding. It therefore follows that the clock hour number is obtained by dividing the phase displacement angle in degrees by 30. The following standard pharos diagrams are frequently encountered in practice.

Three phase transformers, phase displacement Three phase transformers, phase displacement

Polarity and phase sequence

The induced relative voltage directions in he and live winding of a transformer is termed as polarity. In primary and secondary winding of a transformer when the induced voltages have the same direction i.e. when the polarity of the two windings is same, this is called as subtractive. When, on the other hand, the induced terminal voltages are in the opposite direction, the windings are of opposite polarity, which is referred to as additive.

Phase sequence:

Phase sequence is the angular direction in which the voltage and current phases of a polyphone system reach their respective maximum values during a sequence of time. This angular direction may be clock wise or counter clockwise. It should be remembered that the phase sequence is really a question of the sequence of line terminal voltages, and not necessarily of the voltages across individual windings. When two transformers are to be operated in parallel, phase sequence should be same, which is one of the conditions for parallel operation of transformers. The phase sequence indicator is used to know the sequence. The phase sequence of the supply is decided or fixed by the generating plant.

Tanks and testing of tanks

The transformer tank shall be of adequate strength to withstand positive and negative pressures built up inside the tank while the transformer is in operation. The transformer tank covers shall be welded with tank rim so as to make a leak-proof joint. The exterior of the transformer tank and other ferrous fittings shall be thoroughly cleaned, scraped and given a primary coat and two finishing coats of durable oil and a weather resisting paint or enamel. All steel screws, nuts and f£.?tenors exposed to atmosphere shall either be galvanized or cadmium plated. The space above the oil level in the tank shall be filled with dry air or nitrogen confirming to commercial grade of IS 1747 : 1992. Dry air / nitrogen plus oil volume inside the tank shall be such that even under the extreme operating conditions the pressure generated inside the tan k does not exceed 40KPa positive or negative. The transformer cover and frame shall be such that it is possible to remove the weld and rowel twice.

The tank sizes reach the transportable limits and call for a lot of ingenuity in the design, to meet stringent conditions as minimum electrical clearances from high voltage points of windings and leads proper shaping to reduce oil quantity, transportable profile suitable for loading on rail wagons, transportable weight, etc. From these design considerations, in general and for large power ratings, transformer tanks are structurally quite complicated. For medium size, plain tanks are also used quite often for the sake of ease and economy of cost of fabrication. The structural design of transformer tanks comprises the computation of the combined behavior of plate and shells with stiffeners, which involves a realistic estimate of boundary conditions. For calculating the stresses and displacements at a few selected points the classical method is convenient; however for the stresses and displacements in global sense, one has to make use of rigorous methods such as finite element method.

Transformer tanks may be classified as

- Plain tanks: Plain tanks are rectangular box type in shape and are commonly used for small and medium rating transformers.
- Shaped tanks: Here the profile of the tank body is suitably shaped to make it more economical. The shaping is decided by the electrical layout, considerations of transformer windings and terminal gear/tap changers mounting arrangements.
- Bell shaped tanks: Tanks which are made into two separable parts are known as bell type tanks. When the top portion is removed, the height of the lower portion is such that there is accessibility to the core and winding for inspection and maintenance.

Corrugated tanks: An alternative for providing vertical ribs

- welded to the plates is to form corrugation on the plates by suitably folding the plates.

The merits are additional cooling area on the tank walls and reduction in tank weight.

- Stub-end wagon type tanks: These tanks are of special construction and designed to withstand dynamic loading during transit besides the static load. Such large size transformers are not supported on girders thereby reducing the height during transport. The design is such that these tanks are supported from either end stub-end wagons and the transformer hangs in the vertical position, with minimum clearance between the bottom of the tank and railway track.

Testing of tanks:

The oil pressure and vacuum testing are conducted to ensure against leakages and to check for strength.

Oil pressure test:

The oil is filled up to tank cover and the required pressure is applied using pump. The pressure is maintained for few hours and all the wildings are checked for leakages. In case of leakage, rectification is done by draining out the oil. Th before the starting of oil pressure, at full oil pressure and after releasing the oil pressure.

Vacuum test:

The oil is completely drained. After ensuring all the fitting, the vacuum pump is started and the required vacuum is measured by a vacuum gauge. During vacuum testing the air leakage points are detected by air leakage detecting instrument. If the leakages are found in casketed rims, the bolts are tightened. The deflection reading at the starting and after maintaining full vacuum for one hour and releasing the vacuum are taken to find out the permanent deflection. This shall be within specified allowable limits of deflection, depending on the size of the tanks.

Measurement of stresses:

At various locations stresses are required to be measured.

The strain gauges are fixed to the tank structure with proper adhesive. A gauge consists of a fine wire suitably fixed to the body of the structure. Under load, strains are developed on the body. This results in displacements of the points to which the ends of the gauges are fixed. This changes the resistance of the gauge wire, which is measured electrically using a suitable electric / electronic bridge. One typical strain gauge is Rosette delta with six wires connected to the ends of wire gauges and brought to the bridge for measurement. The bridge is set to null balance prior to the commencement of the measurements. The readings are simultaneously recorded. The tank is subjected to full vacuum and readings are taken. The strain gauges are fixed inside and outside the tank wall to compare the top and bottom principal stresses on the surface. The strain gauge gives values of strains in the direction of Rosettes from which the two principal stresses and their directions are calculated.

Transformer oil

Insulating oil forms important part of transformer insulation system and acts as electrical insulation as well as coolant to dissipate heat. The basic raw material to get transformer oil is a low viscosity lube called as Transformer Oil Base Stock (Tabs). This is obtained by fractional distillation and series of treatment of crude petroleum. Tabs characteristics are kept within permissible limits in order to produce good insulating oils. Tabs is further refined by acid treatment to get transformer oil.

Table 1.2 Characteristics of TOBS

	Characteristics	Requirement
	Viscosity at 40°C	9-14 cost
	Pour point, max	-9°C
	Flash point (Pesky-Marten closed cup method) min	145°C

Transformer oil consists of four major generic class of organic compounds viz. paraffin's, naphthenic, aromatics and olefins. All these are hydrocarbons and hence insulating oil is called a pure hydrocarbon mineral oil. Based on the requirement and predominance, oil is usually called paraffinic base or naphthenic base.

Characteristics of oil and their importance:

The ,characteristics of transformer oil as per IS: 335 are, given in table 1.3.

Properties of insulating oil:

Physical properties:

- Density: The maximum density of insulating oil at 29.50C must be 0.89 g/m2
- Interfacial tension (IFT): This is the measure of the molecular attractive force between oil and water molecules at their interface. A test is carried out for detecting the soluble polar contamination and products of deterioration that reduces molecular attractive force between oil and.water.
- Moisture content: The moisture content is the amount of free and dissolved water present in the oil and is expressed in pap (parts per million by weight i.e. mg/kg). Presence~ of moisture is harmful as it has adverse effect on the elect cal characteristics of oil.
- Flash point: It is the temperature at which the oil gives vapour, that this vapour, when mixed with air,. for.ms ignitable moisture and gives a momentary flash on application of test flame under specified conditions. A minimum flash point is specified to prevent the risk of fire that may result by accidental ignition.

Viscosity: This is a measure of oil resistance to flow continuously without external forces. The oil must be mobile. as heat transfer in

- transformers takes place by convection currents. The viscosity increases with decrease in temperature, it is necessary that viscosity be as low as possible at low tem prelatures.
- Pour point: The temperature at which oil will just flow under specified conditions is known as pour point. If the .Olli becomes too viscous or solidifies, it will hinder the formation of convection currents and thus cooling of the equipment will be severely affected.

Electrical properties:

While selecting the oil to be used in transformer as insulating material, more emphasis is to be given to the electrical properties.

- Electric strength (Breakdown voltage): BDV is the voltage at which breakdown occurs between two electrodes when oil is subjected to an electric field under prescribed conditions. Electric strength is the prime parameter for insulation design of a transformer. It helps to know the presence of contaminating agents like moisture, fibrous materials, carbon particles, perceptible sludge and sediment.
- Specific resistance (Resistivity): This is the most sensitive property of oil requiring utmost care for its determination. Resistivity in Acme is numerically equivalent to the resistance between opposite faces of a centimeter cube of the liquid. Insulation resistance of windings of a transformer is also dependent upon the resistivity of oil. A low value indicates the presence of

moisture and conductive contaminants.

•Dielectric dissipation factor (DDF): DDF is numerically equal to sine of the loss angle (approximately equal to tangent of loss angle for dielectrics) and is a good tool to indicate the quality of insulation. A high value of DDF means the presence of contaminants or deterioration products such as water, oxidation products, metal soaps, soluble varnishes and resins.

Chemical properties:

Neutralization value (total acidity): It is a measure of free organic and inorganic acids present in the oil and is expressed in terms of milligrams of KOH required to neutralize the total free acids in one gram of oil.

Oxidation stability: This gives the presence of natural inhibitors which impart anti-oxidation characteristics to oil. This test is a measure of neutralization value and sludge after oil is aged by simulating the actual service conditions of a transformer.

Sediment and perceptible sludge: These are oil deterioration products or contaminants which are insoluble after dilution of the oil with n-heptanes under prescribed conditions. The oil is not suitable for use, if sediment or perceptible sludge is detected.

Corrosive Sculpture: Crude petroleum usually contains sculpture compounds. most of which are eliminated by refining. The traces of free corrosive sculpture may be present in oil. This will result in pitting and black deposit on the surface of the bare conductor used in transformer which adversely affects the dissipation of heat.

Qualities of good insulating onl:

•The fresh dielectric oil has pale yellow color. Dark or cloud color indicates deterioration.

•The oil should never contain suspended particles, water soluble acids and bases, and active sculpture of colloidal carbon. These impurities accelerate deterioration rate.

•It should be free from dust particles, carbon particles and sludge.

•It should have high dielectric strength.

•It should have low viscosity.

•It should have high flash point.

•It should. posses good electrical characteristics.

Effect of moisture, water and impurities:

The impurities accelerate deterioration of the dielectric oil.

The dust particles, carbon particles and sludge in suspended form gather along the conductor and insulating surfaces in the presence of electric field. This forms a thin conducting layer gradually along the internal surface of internal insulation during service. The flash over ca occur along the surface of the insulation or tank due to tracking. The transformer oil an winding have tendency to readily absorb moisture from the air. This decreases the dielectri strength of the oil. All possible preventive measures are taken to avoid moisture penetratio Oxygen reacts on the insulation and decomposed products cause sludge, which blocks the fr circulation of the oil. The dielectric strength gets diminished significantly in the presence solid impurities.

Procedure of filling oil in the transformer tank:

Before filling with oil, transformer should be fitted with all accessories including va gauges, thermometers and plugs and made oil tight. Oil sample is tested before filling. It sho be ensured that no air packets are left in the tank and no dust or moisture is present. Al vents should be opened. Oil should be filled from the filtering plant. To prevent aeration of the transformer tank should be filled through the bottom drain valve. Enough time shoul allowed (16 to 24 hours) for the oil to settle in the transformer and also the bubbles to escape. Vacuum filling may be used for large transformers. A vacuum pump may be connected to the top valve of the transformer and oil hose to the top filter press valve. The tank shall be tightly sealed.

Oil filtering:

The oil filtering equipment (oil purifying equipment shown in fig 1.8) is a portable device used for filtering transformer oil and switchgear oil. The oil is circulated through the filtering equipment for several hours till the desired dielectric strength of oil is achieved. The purifying equipment removes the dissolved moisture, free water and solid particles. The oil purifier comprises of the following components.

1) Vacuum tank and pump
2) Centrifugal filter unit
3) Oil pump
4) Heater
5) Valves
6) Temperature gauges
7) Vacuum gauge
8) Pressure gauge

Maintenance of Transformer Oil:

Oil maintenance is carried out in accordance with standards titled "Code, practices of maintenance of insulating oil". The code refers to the contamination of oil and determination of suitability of oil for further service. It also gives the procedure of treatment of oil at site. The transformer oil is tested for the desired qualities giving more emphasis to moisture and dielectric strength during periodic maintenance. A sample of insulating oil is taken from the bottom of the transformer tank. The fresh dielectric oil has pale clear yellow color and dark brown and cloudy appearance indicate deterioration. Contamination of oil due to moisture or solids are dealt by centrifugal separators to effectively remove free water and fine solid impurities. Filters are used to remove solid impurities. The dust particles, carbon particles and sludge are responsible for formation of thin layer on the insulation part thereby causing internal flashover due to tracking can be removed by means of filters in the oil filtering unit. Moisture level is to be less than the specified value which otherwise cause internal flashover. Viscosity indicates fluidity. Oil with low viscosity has more fluidity and gives better cooling. Hence, viscosity should be measured at various temperatures.
observation is to be made on flash point. Higher flash point (1450C) is preferred and flash point indicates the tendency to evaporate. For satisfactory use of insulating oil for the desired and specified qualities, periodic checking of the oil is to be carried out.

Testing of transformer oil:
Sampling:

The condition of the oil should be checked before commissioning, during maintenance and re commissioning after overhaul. Sample of oil from the transformer should be taken from the bottom of the tank. The sample should be collected only after the oil is allowed to settle for 24 hours.

Containers of sample:

Containers for samples should be bottles of clear glass, clean and dry with one liter capacity. The samples should not be filled up to the top.

Samples from transformer tank:

, When taking sample remove dirt from the sampling valve plug. Sample should not be taken immediately after opening the valve. Allow some oil to flow first, then collect sample in the bottle. Oil sample from the transformer in service may be taken preferably under switched off or no-load condition.

Oil sample from drums:

Before taking oil for testing allow it to settle for 24 hours without any disturbance so that the heavy contents will settle down. Then oil will be collected from the bottom of the drum.

Testing of dielectric strength:

BDV test: The test sample from the bottom of the drum or transformer tank is collected in the standard test cup (80mm x 60mm x 100cm) size. Electrodes are polished brass spheres of 12.5 to 13 mm diameter mounted horizontally. The gap is 2.5 mm to 4 mm ± 0.2 mm depending upon the magnitude of voltage available for breakdown test. Allow the sample in the cup for 20 minutes for air bubbles to vanish, apply ac voltage gradually and steadily till the breakdown occurs between electrodes.

Six breakdown tests are conducted at an interval of one or five minutes. After each breakdown test, the oil is gently stirred with clean, dry glass rod. Average of five subsequent tests is considered as the BDV (breakdown value) of oil sample.

Crackle test:

This test is performed to determine free water. A sample is heated rapidly over silent flame. The presence of moisture above 50-60 pap of water will give typical crackling sound. The Karl Fisher Solution test is used for determining the moisture more accurately (up to 2 pap). During periodic maintenance crackle test, dielectric test, acidity test and moisture measurement is carried out .

Drying of transformers: IS 10028 (part II) 1981

The transformer oil and insulation are hygroscopic (absorbs moisture). When the transformer is dispatched without oil or is left idle for a long period, the oil and insulation absorb moisture and drying out is required before commissioning. When the power transformer is idle for more than a month, drying out is necessary prior to re commissioning. The main purpose of the drying out is to expel the moisture from the oil, the winding insulation and other internal parts. If the transformer is not dried out properly, it cannot withstand specified voltage for long duration leading to premature failure of insulation. In drying out process the transformer oil/winding is heated by one of the approved methods for a prolonged period (ten hours to four weeks)
Periodic readings of
a)Oil and winding temperature
b)Power input
c)Insulation resistance

are taken. The temperature of oil is maintained at 800e and that of the windings at 90°C. Figure 1.9 shows variation of insulation resistance with time of drying.

Different methods of drying out:

I) Drying of core and coils with oil by oven
ii) Drying of core and coils with oil by short circuit method
iii) Drying with oil removed by using external heat
iv) Drying with oil removed by using both external and internal heat.

Drying with oil:

i)Drying of core and coils with oil by using oven. The core and coils can be effectively dried in a suitable oven, by raising the temperature to a value not exceeding 8o°e. A large volume of air should pass through -the oven to remove moisture and vapors. Insulation resistance check will indicate when the coils are dry.

j)Drying by short circuit method: The transformer can also be dried by heating the coils by short circuiting the low voltage winding and supplying a reduced voltage at the terminals. Current should not exceed 70% of the rated current and oil temperature should not exceed 75°e. The winding temperature under no condition should exceed 90°e. This method is more effective in drying the insulation at site.

Drying without oil:

By external heat: The transformer may be placed in its own tank without oil. Externally heated air is blown into the tank at the bottom through the main oil valve. A small blower or fan should be used to get the proper circulation. It is desired to-force as much of the heated air as possible through the ducts in the transformer windings. To accomplish this, baffles should be placed between the core and the case, closing off as much of the space as possible. The convenient way to get the heated air is by passing air through grid resistors. The resistors are in fire proof box. The temperature of the air should not exceed 115°C. The heat may also be obtained by direct combustion but care is to be taken to avoid the products of combustion entering into the transformer tank.

By both external and internal heat: This is a combination of the hot air circulation and short circuit method. The current circulated in the windings should, of course, be less than that when drying out is done by the method of short circuit alone.

Duration of drying out:

Transformer voltage rating	Duration
11 kV	1 to 6 days
220 kV	10 days to 30 days
400 kV	15 days to 40 days

Precautions to be taken while drying:

1)Only spirit type thermometers are to be used for temperature measurement. Mercury thermometers shall not be used except in the pockets provided for this purpose.

2)The temperature of transformer oil in the top should not be more than 85°C. The maximum sustained temperature to which anything in contact with the oil should be raised, is 90°C.

3)Under no condition the transformer is left unattended during any part of the dry out period. The transformer should be under constant observation throughout the dry out process and all observations shall be carefully recorded.

4)It is recommended to keep firefighting equipment ready during dry-out period. Naked lights and flames should be kept away while the drying operation is in progress.

Preparations of drying out:

•The tank is covered with external shields Like fire resistance mat such as asbestos cloth, glass

(A2) ① ① COMMISSIONING ① ②

Steps prior to commissioning of power transformer

1. Fitment of accessories ②
2. Filling of oil
3. Drying out
4. Charging of breather with fresh silica-gel.
5. Cleaning of porcelains of bushing with trychloroethelene and then by dry cloth.
6. conductors and/or cables.
7. Nertral earthing as per schematic diagram
8. Earthing of tanks and cover
9. Connection of protection circuits and alarm circuits with CTs.
10. Setting of relays (in control room).

After the above preparation, the commissioning test are carried out.

Commissioning ~~test~~ of transformer:-

① (steps prior to commissioning to be written stated above)

② pre-commissioning checks on
(1) Transformer
(2) Tap-changer
(3) Protection-system
(4) Control system
(5) Marshalling kiosks
(6) Main connections
(7) Control connections
(8) Cooling system

③ Commissioning test

④ polarity check and phasing

⑤ Energizing and operation under observation

⑥ Loading and observation.

Commissioning test on power transformer.

(A) General observation – complete transformer
– control and relay panel, etc
– Junction boxes and marshalling ki[illegible]

(B) Secondary injection test – of all the protection relays.

(C) Primary injection test – Test on operation and stability of earth fault relay on side h.v
– Test on line directional elements of high-voltage line relays.
– Test on high speed neutral circuit breaker
– Test on overcurrent relay on H.V side.
– Test on stability of earth fault relay on and L.V side
– Test on stability and operation of standby earth fault relay. L.V side
– Voltage compensation

(d) Ratio test – With 415V applied on high voltage side measure voltage between all phases on low voltage side for every tap position
– To check the phasing, measure volts

A to a, b and c
B to a, b and c
C to a, b and c

A, B, C terminals of 3ϕ on HV side
a, b, c Corresponding terminals on LV side.

(e) Tripping test –
– high and low voltage side breakers
– Intertripping test and winding temperature trips.

(f) calibrate earthing resistance.

(g) Buchholtz relay – Test for angle air injection
– Check there is no air in protector before commissioning
– When energized close in on 'Trip' etc.

arm circuit - Buchholtz relay
- oil and winding temperature thermometer set at 85°c and 100°c respectively.
- cooling gear failure.

) Fans and pumps - Check that oil valves are open in cooling circuit, the rotation of pumps, automatic starting overload devices.

i) Tap changing test to check mechanism indication, buzzer, lamp etc.

k) Phasing test - At 415V, between transformers in a three phase bank and to prove internal and external connection for parallel operation

l) Insulation test - on high and low voltage winding
- on current and voltage transformer circuit etc

(M) Check oil levels.

(N) Voltage compensation test - primary injection
- Load test
- If necessary, switch in with compensated voltage relay connected to correctly from other transformer.

o) Insulation resistance - Main circuits - Auxilliary circuits

(p) Partial discharge - Main circuits for record.

Volt-ratio test :-

* Ratio test is conducted to ensure the corectness of voltage ratio between different winding on each tapping.
* The tolerance allowed for ratio is ± 0.5% of the declared ratio or ± 10% of the percentage impedenie voltage, whichever is less.
* It is done using calibrated voltmeter.
* To get a accuracy of 0.1% a ratio testing apparatus called ratio meter is used. Its accuracy is 0.1% over a ratio ~~change~~ range upto 1110:1
* The ratio meter is used in bridge circuit
* In this bridge circuit the voltages of the winding of the transformer under test are balanced against the voltages developed across fixed and variable resistors of the ratio meter.
* This method also confirms the polarity of the winding
* The ratio-meter can be used to perform test at normal main supply voltage without loss of accuracy.
* This test is conducted on every transformer for position of every tap.

(B) (3)

* These are made on every transformer
* It is done before the transformer leaves the factory, to ensure that it is in accordance with specification.

COMMISSIONING TEST :-

* It is done before commissioning at the site.

TYPE TEST :-

* It is performed on sigle transformer of one type
* It is done to confirm assigned rating characteristic
* Type test usually relates to the first unit manufactured by a firm to a given specification.
  1) Temperature rise test
  2) Impulse voltage test
  3) Noise level test.

ROUTINE TEST :-

1. Ratio and polarity.
2. Load losses.
3. Impedence measurements.
4. Insulation resistance.
5. Resistance of winding
6. No-load losses.
7. No-load current.
8. Core insulation voltage test
9. Voltage test - Windings
   (a) Separate source
   (b) Induced voltage.

IMPORTANCE OF TESTING :-

* Type test, routine test are conducted in accordance with the recommended standard specification.
* Test should be conducted carefully.
* Test results should be compared with the desired value.
* The test result gives information about the health of power transformer.

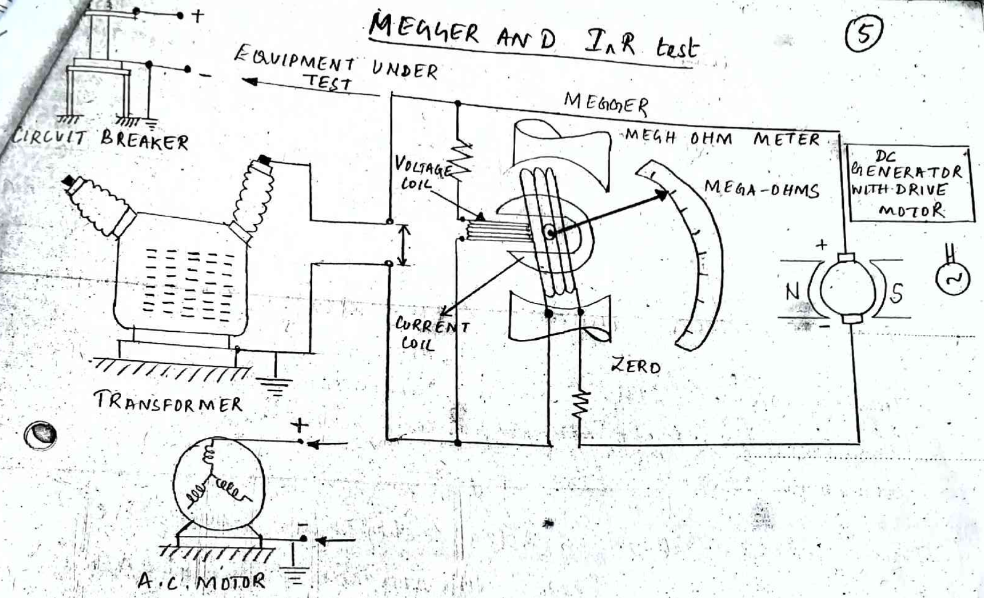
INSULATION RESISTANCE :-

* It refers to the resistance between conductor part and earth, expressed in megaohm.
* It can also be measured between two circuits seperated by insulation.
* It is measured by megger.

MEASURING OF INSULATION RESISTANCE :-

* Two flexible well-insulated conductors should be connected to the line and earth terminal of megger.
* The free-ends of conductors must have metal terminals (probes) with insulated handle.
* The probe marked "ground" should be connected to the transformer tank (that must be grounded)

MEGGER AND $I_R R$ test



Polarisation index and its significance :-

$I_R R_{60}$ = 60 seconds reading of insulation resistance

$I_R R_{15}$ = 15 seconds reading of insulation resistance.

* For large and HV transformer, 10 minute and 1 minute megger readings are taken instead of $I_R R_{60}$ and $I_R R_{15}$
* Polarisation index gives the true idea about the quality of insulation and also the extent of dryness.
* A 2500 or 5000V motor driven Megger is used to measure the insulation resistance.

* Two readings, one after 15 seconds and other after 60 seconds. The voltage being applied all the while.
* The value obtained for 60 seconds showed be higher than for 15 seconds if the material is sound.

* Polarisation index $\frac{I_n R_{60}}{I_n R_{15}}$ gives a positive indication of the good condition of the insulation if it corresponds with the manufacturer's test figures.

* The polarisation index depends upon the temperature at which insulation resistance is measured, the polarisation index at 50°C is more than that at 30°C.

CAUSES FOR LOW VALUE OF INSULATION RESISTANCE:-

i) Dust and dirt sticking on the surface of the insulation. The carbon particles, metallic particles and sludge have a tendency to align along the direction of the electric field on internal & external surface of the insulator and in presence of moisture the tracking is accelerated and reduces the insulation resistance.

i) Absorption of moisture by insulation and the insulating oil results in low insulation resistance value.

mber, etc), windings Hours tio

...ULSE TESTING :-

Lightning is probably the most common cause of flashover on overhead transmission line.

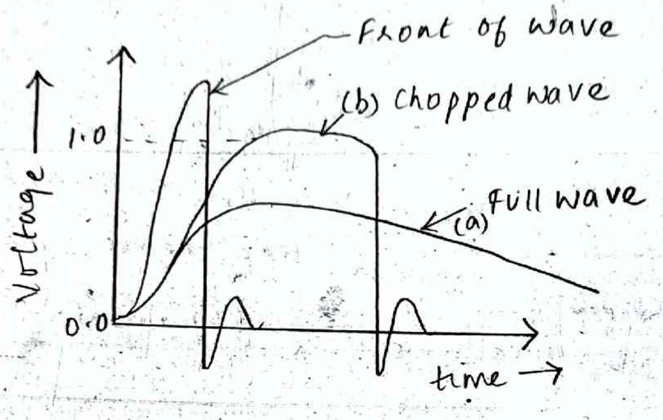
* Lightning stroke makes a direct contact with phase conductor producing a voltage on the line in excess of the impulse voltage level.
* Another, lightning stroke makes contact with an earth wire or tower and combination of tower current and tower impedence produces a voltage near the tower top to produce back flashover.
* The terminal equipments of high voltage transmission line experience lightning impulse in service.
* Switching impulse can occur during all kind of switching operation in system.
* The magnitude and form of impulses generated differ from case to case.
* Magnitude and form of switching impulses generated differ from case to case.
* Magnitude of switching impulses in the network are proportional to system voltage.
* ~~The terminal equipment of high voltage transmission line experience lightning impulse in service.~~
* The maximum voltage can be 3.5 times the service voltage.

system disturbance may be represented by the basic wave shapes.

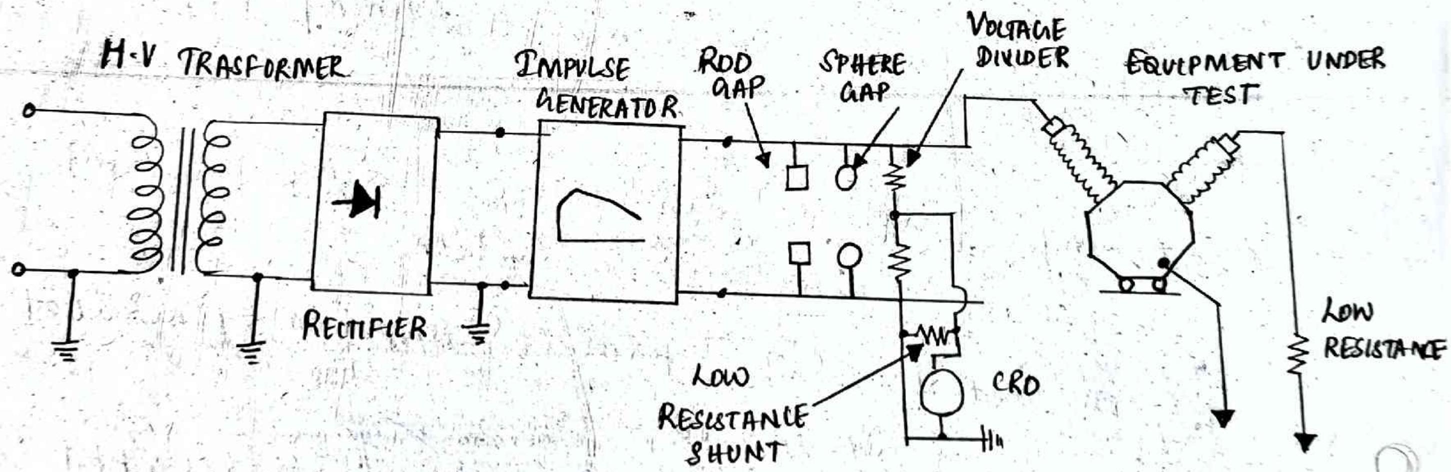
a) Full waves.

b) chopped waves.

c) Front waves.



TEST SET-UP FOR IMPULSE TESTING OF POWER TRANSFORMER



* The impulse voltage is produced by the discharge of a capacitor or number of capacitor into a wave generating Network.

* Produced impulse voltage is applied to the object under test.

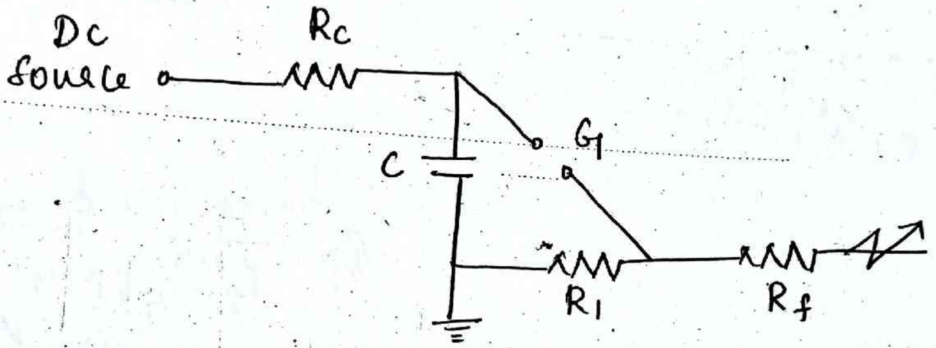
* HV impulse test:

multistage impulse generator which

Modified version of Marx's original circuit is used.

This consists of number of capacitors initially charged in parallel and discharged in series by sequential firing of the interstage gaps.

Single stage impulse generator.



R_C - charging resistor

R_F - Series resistor controlling waterfront

R_t - Discharging resistor controlling wave tail

G - wave gap.

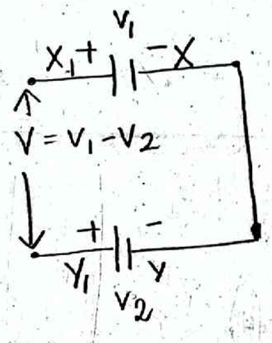
* This test is necessary for all indoor and outdoor transformers.
* Standard impulse wave of specified amplitude is applied twice in succession.
* If there is no flash over or puncture of the insulators, then the transformer is considered to have passed the test, on the other hand, if there is puncture, is considered to have failed the test
* During the test, one wave should be applied

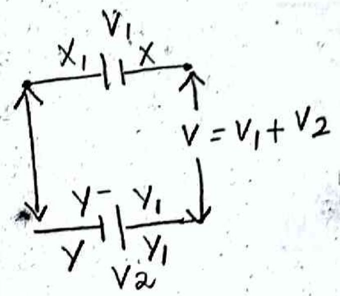
with reversal of polarity.

* The peak value and wave shape of the test voltage is recorded by means of storage oscilloscope with a calibrated voltage divider.

POLARITY OF WINDING :-

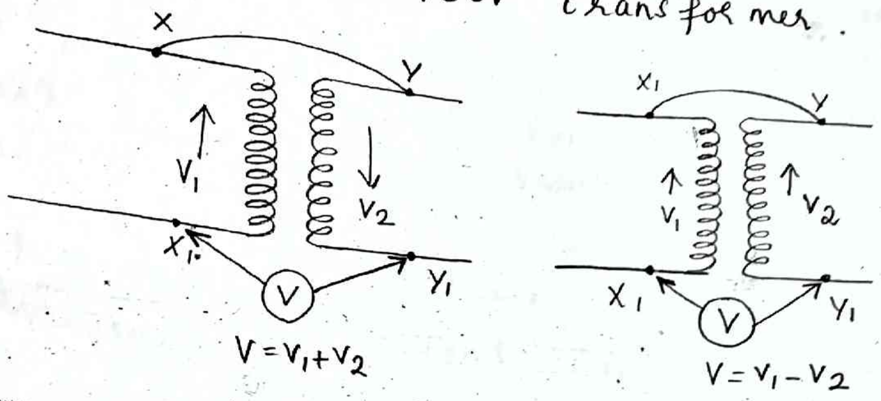
Polarity of winding refers to positive and negative terminals, with reference to induced voltage.





* Consider the two batteries in which terminals X and Y are negative and terminals X_1 and Y_1 are positive.
* If like poles X and Y are connected together, voltage across $X_1 Y_1$ will be zero since the voltage cancel each other.
* This corresponds to parallel connection
* When voltage are in the same direction from the common link, the polarity is called subtractive.
* If on the other hand, the batteries are connected in reverse X to Y_1, the voltage across X_1 and Y will be higher than that of a single battery.
* This corresponds to series connection, and the polarity is called additive.

* . consider the 230/30V transformer.



* The primary and secondary are supposed to have the same polarity when the turns in both the winding go round the core in the same direction and the start and end leads are marked in the same way.

* If X and Y are connected together the voltage across X_1 and Y_1 is found to be 230 - 30V = 200V and polarity is said to be subtractive.

* If on other hand the terminal connection are such that the voltage across X_1 and Y_1 is 260V the polarity of the terminals is additive as the voltages 230 and 30 now get added corresponding to the series connection.

Temperature rise test:-

* It is one of the type test on power transformer.
* This is also called heat - run test.
* This test reproduces condition of continous rated load and the temperature rise following during the load.

* When a transformer is provided with a standard tank it is not necessary to make a test for temperature rise.
* As in such cases the tank dissipation constant is known and conseqvently it is only necessary to measure the transformer losses and to calculate the temperature rise of the oil and the windings on continovs full load.
* However, the tank is not standard, it may be necessary to carry out a temperature rise test on the transformer.
* The various method of conducting the test is as follows.

~~(a) temperature rise~~

(a) Short circuit equivalent test

(b) back to back test

(c) Delta/ delta test.

* general procedure under method (a) short circuit equivalent test is as follows.

(a) one winding of the transformer is short-circuited and voltage applied to the other winding of such a value that the power input is eqval to the total normal full load losses of the transformer at the temperature corresponding to continovs full load.

(b) Hence it is necessary first of all to other probe to a current carrying bar or lead connected to the winding under test. ④

* Megger should be cranked at a speed indicated in its certificate (usually 120 rpm)
* 60 seconds after the start of the cranking the insulation resistance should be read on megger scale.
* The value thus obtained is called 60 second insulation resistance
* Ten minutes reading is taken for a large transformer.
* When measuring the insulation resistance between different winding, the megger probes should be connected directly to the windings.

V↑ deflection of pointer ↑
current ↑ deflection pointer ↓
ckt is short R→0
" open R→∞

MEGGER AND IR TEST SETUP :-

* When dc voltage is applied, initially the insulation draws capacitive current (I_c) in addition to leakage current (I_L). Initial megger reading is given by,

$$I_0 R_0 = \frac{V_{dc}}{I_{dc}}$$

$$I_0 R_0 = \frac{V_{dc}}{I_c + I_L}$$

* After some time the charging current reduces to zero and only leakage current is present.

* Megger reading after 60 sec (for small transformer) and 10 minutes (for large transformer) is taken and given by,

$$I_0 R_{60} = \frac{V_{dc}}{I_L}$$

$$\left[\because I_0 R_0 = \frac{V_{dc}}{I_c + I_L} \quad I_c - \text{reduces to zero} \right]$$

$$I_L < I_c + I_L$$

$$R_{60} > R_0$$

$$I_0 R_{60} > I_0 R_0$$

* Insulation resistance reveals the quality of insulation and the degree of dryness.

* The total direct current I_{dc} seen by the current coil of the megger in insulation resistance measured has four components.

a) I_c - charging current

b) I_d - Dielectric absorption current

c) I_{LC} - conduction leakage current through the insulation.

d) I_{LS} - Surface leakage current.

POLARISATION INDEX AND ITS SIGNIFICANCE

$I_n R_{60}$ = 60 seconds of insulation resistance

$I_n R_{15}$ = 15 seconds of insulation resistance.

...ments are ... copper losses, as
transformer at ambient temperature. 9
(c) The next step to calculate the value of the copper loss at the temperature corresponding to continous full load.

(d) Assuming the copper loss has been measured at 30°C the copper loss at the continous full load temperature will be higher than the measured copper loss.

(e) This assumes the copper loss varies directly as the resistance of the winding.

(f) This assumption may not be true because portion of copper loss ~~and this portion~~ consists of eddy current losses and it will decrease as the resistance of the winding increases.

(g) The inaccuracy is slight, and has the advantage that it tends to increase the power supplied and consequently to shorten the test.

(h) Before commencing the test it is desirable to calculate also approximate current required in order to avoid an excessive current density.

(i) At the commencement of the test, the current is given by,

$$\text{Normal current} \times \sqrt{\left[\frac{\text{Iron loss} + \text{Hot copper loss}}{\text{Cold copper loss}}\right]}$$

and at the end of the test.

$$\text{Normal current} \times \sqrt{\left(1 + \frac{\text{Iron loss}}{\text{Hot copper loss}}\right)}$$

(j) To ensure greater accuracy, the test is made measuring the power input, which is finally incre to include the hot copper loss.

(K) This test is most suitable when copper loss is high compared with the iron loss and conversely and not for the transformers having relatively high iron losses.

* when the normal temperature rise is approached the copper loss should be measured and necessary current- adjustments should then be made in order to correct- the power input to obtain the true losses under normall full-load condition (ie) as regards current- and temperature rise.

Measurement of Stress :-

* At various locations stress are required to be measured.
* The strain guages are fixed to the tank structure with proper adhesive
* A guage consists of fine wire suitably fixed to the body of the structure
* Under load, strains are developed on the body.
* This results in displacement of the points to which the ends of the guages are fixed.
* This changes the resistance of the guage wire which is measured, electrically using a suitable electric / electronic bridge.
* one typical strain guage is Rosette delta with ... connected to the ends wire guages and