CMR INSTITUTE OF TECHNOLOGY	USN	

Internal Assesment Test - I

Sub:	Testing &Commissioning Of Electricla Equipments							Code:	10EE756
Date:	21/09/2017	Duration:	90 mins	Max Marks:	50	Sem:	7	Branch:	EEE

Answer any five full questions

	Note: **Sketch figures wherever necessary**.	Marks	OBE	
			CO	RBT
1(a)	Enumerate standards and specification of power transformer	4	CO707.1	L1
(b)	With neat sketch name the various accessories and fitments on transformer and briefly. Explain the function of each accessories.	6	CO707.1	L1
2(a)	Why drying of power transformers are necessary? Explain the procedure for drying power transformer.	8	CO707.3	L3
(b)	What is polarizing index? Explain its significance	2	CO707.1	L1
3	Explain various commissioning test conducted on transformer.	1 0	CO707.2	L2
4	Discuss various abnormal conditions in power transformer and necessary remedial actions	10	CO707.4	L4
5	Which are the four phasor groups adopted for standard connection of transformers? Explain anyone with phasor diagram and winding connection	10	CO707.1	L2
6	What is impulse testing? Explain the test set up used for impulse testing of transformers.	10	CO707.2	L2
7	Explain the necessary test to determine no load and load losses of transformer and hence obtain the condition for maximum efficiency an zero regulation.	10	CO707.2	L2

Q. 532. State the various essential Rated Quantities of a Power Transformer.

Rated Quantities. These include :

- Rated voltages of each winding
- Rated insulation level of each windings
- Rated frequency
- Rated apparent power (kVA or MVA)
- Rated current of each winding
- Rated short circuit withstand ability
- Impedance voltage
- Rated voltage ratio, etc.
- Bushing and Tap-changers have respective ratings.

Q. 533. What is the significance of 'Standards' ? What is a typical coverage of a standard for Power Transformer.

Standard Specifications for Power Transformers. The international standards published by IEC (International Electrotechnical Commission) are accepted universally. However, each Nation has its own National Standards which are based on particular requirements and practices of that nation. Indian Standards Institution (Indian Bureau of Standards) publishes IS Standards. The Manufacturers and Users in India recognise IS Standards and IEC Standards.

The standards for *Power Transformers* are applicable to three phase transformers rated above 5 kVA. The *Special Transformers* and transformers below 5 kVA are covered by separate standards.

A *typical standard* on power transformer covers the following data :

- Service conditions
- Definitions
- Ratings
- Tappings
- Cooling system identification
- Limits of Temperature Rise
- Ability to withstand short-circuits and corresponding tests for short-circuit withstand ability.
- Information to be given on the Rating Plate and Diagram Plate.
- Terminal Markings
- Vector Diagrams, Connection, Method of connections, procedure and interpretation
- Tolerances
- *Tests.* Acceptance tests, type tests, routine tests, special tests.
- Fitments
- Insulation Levels
- Information for Tenders
- Practice for Maintenance

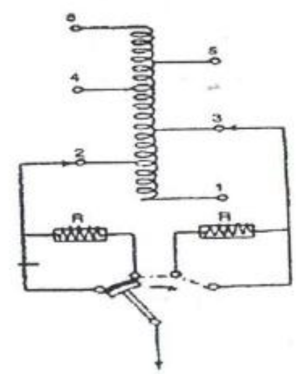


Fig.1.23 OLTC

1) Flow or oil level indicator: It is fitted in oil circulation system which indicates the flow rate. It is used for control purpose in combination with float switches for starting and stopping of oil pumps.
2) Pressure relief valve: It is fitted on the tank to act as an exit for gases formed of oil. A major fault inside the transformer causes sudden vaporization of the oil, leading to rapid build up of gaseous pressure. If this pressure is not relieved within few milliseconds, the transformer tank gets ruptured, spilling oil over wide area. The consequent damage and fire hazard possibilities are obvious.
3) Buchholz Relay: This is a gas operated relay fitted in the pipe between tank and conservator. In the event of minor fault like damage to core bolt insulation, local overheating etc., causes slow generation of gas in the oil. Buchholz relay gives an alarm for incipient faults in the transformer. The decomposition of transformer oil due to fault contain more than 70% of hydrogen gas which being light, rises upward and tries to go into the conservator.

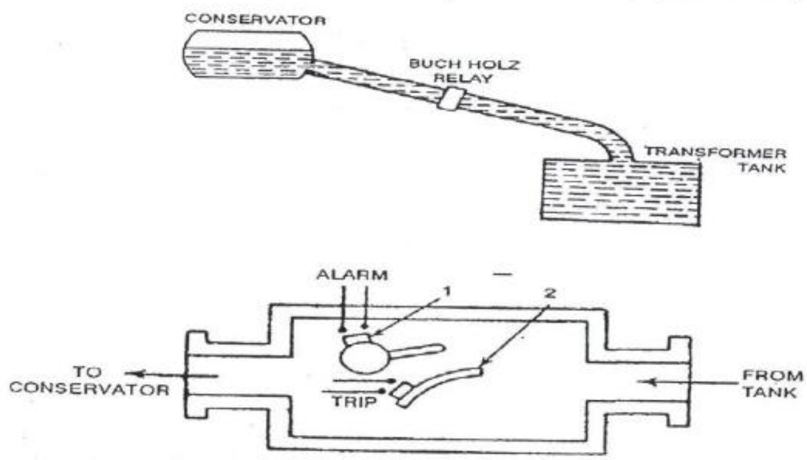


Fig.1.24 Buchholz relay

The gas gets collected in the upper portion of the Buchholz relay, thereby oil level in the relay drops. The float in the relay tilts with the reduced oil level. The mercury switch attached to the float is closed and the switch closes the alarm circuit. The transformer is disconnected as early as possible and the gas sample is taken for test. The testing of gas reveals the type of fault and insulation level. Buchholz relay gives an alarm so that the transformer can be disconnected before the incipient fault grows into a serious fault. The relay operation is slow (operating time 0.1 sec and average time 0.2 sec). Buchholz relay is not used for transformers below 500KVA and faults below oil levels are detected. When short circuit occurs in the transformer, the pressure in the tank increases. The oil rushes towards conservator. The baffle (plate) gets pressed by the rushing oil thereby close another switch which in turn close the trip circuit of circuit breaker. Setting the mercury switch cannot be too sensitive otherwise there can be mal-operation by vibrations, earth quakes, mechanical shocks to the pipe etc. The places where disturbance like earth tremors is more, magnet operated reed switches in place of mercury switches are used.

4) Sudden pressure relay: (Rate of rise of pressure relay): The rate of rise of pressure relay responds to sudden rise of pressure due to internal arcing. The relay is fitted on the tank.

5) Conservator: It is a large cylinder connected by pipe to the transformer. The oil is filled upto certain level in the conservator. The remaining portion is filled with air. Conservator oil is in communication with tank oil. Expansion and contraction of transformer tank oil is accommodated by the air cushion in the conservator. Direct contact with external air is avoided. Conservators are of two types.

   a) Air cushion connected with external atmosphere through breather. Air that enters the conservator is dried by silica gel in the breather.

   b) Air cushion contained rubber bag (bellow) installed within the conservator. Contact with external air is avoided. Rubber bag is filled with air of positive pressure.

6) Breather: One end of the breather is connected to air cushion in conservator and the other end is towards the external air.

   Breather is filled with dry silica gel which is pink in colour. When oil in the conservator rises, air is let out through the breather. When oil gets contraction during low loads/low temperatures, air is breathed in by conservator through breather. Silica gel absorbs the moisture and admits only clean/fresh air. When silica gel absorbs moisture it becomes blue. Then it is to be dried during periodic maintenance or fresh silica is to be used.

DRYING-OUT OF POWER TRANSFORMER

Q. 554. Explain the procedure of drying-out of Power Transformers.

Drying-out of Power Transformers

Purpose. The transformer oil and insulation is hygroscopic (absorbs moisture). If the transformer is despatched without oil or is left idle for a long period, the oil and insulation absorbs moisture and drying out is necessary prior to commissioning. If a large power transformer is idle for more than one month, drying-out may be necessary prior to recommending. The main purpose of the drying out is to expell the moisture from the oil, the winding insulation and the other internal parts. If the transformer is not dried-out, it cannot withstand service voltage for a long duration and its insulation may fail prematurely.

Procedure of drying-out. In the drying-out process, the transformer oil/winding is heated by one of the following methods for a prolonged period (ten hours to four weeks). Periodic readings of (1) oil and winding temperature (2) Power input (3) Insulation Resistance are taken. The temperature of oil is maintained at 80°C and that of windings at 90°C.

The values of insulation resistance start falling in the beginning of the drying out process. This indicates that the moisture drops are getting distributed in the winding and the oil in form of vapour. After several hours, the insulation resistance becomes steady. This indicates that water vapours are distributed in the insulation and oil. *On further continuation drying-out, the insulation resistance values start rising. This indicates that the moisture is being expelled from the windings and oil.*

The drying-out process is stopped when the insulation resistance value (hot) is more than the specified value, during the rising mode of the drying-out process and the polarisation index, dielectric strength of oil are satisfactory. (P.I. 1.3 ; BDV 45 kV for 4 mm gap).

Dry-out by Circulation of Transformer-Oil through Purifier (Filtering Plant), The modern method of drying-out of transformer consists of circulation of the transformer oil through oil filtering plant. The modern oil filtering and purifying plants are portable and have the following components :

- Vacuum tank, vacuum pump
- Spray Chamber
- Strainer
- Heating Chamber, Heaters
- Centrifugal Blower
- Pumps for Circulation of Oil.

The oil from the transformer tank is circulated through the filtering plant for (*i*) removing moisture and (*ii*) for removing sludge, dirt and solid impurities.

While using the oil filtering plant for the purpose of drying-out ; the thermostat of the filtering plant is set at out-let temperature of 90°C. The oil is drawn from the transformer tank through a pipe dipped to the bottom of the tank. The outlet of the filtering plant is delivered back into the transformer tank at the top.

The purifier (filtering plant) is operated continuously except for one hour per day for cleaning the cones of centrifugal type of filter or filter pads of the vacuum type filter.

Preparations of drying-out

- Lagging the tank with fire resistance mat such as asbestos-cloth, glass sheet provide external shields to prevent drought of cold air.
- Connecting thermocouples, placing thermometer, calibration, arranging measuring instruments.
- To bring-out the well insulated leads from the windings from the terminal bushings for the measurement of the insulation resistance.
- To bring-out thermocouple leads through one of the opening in the tank.
- To prepare a log-book.

Precautions while Drying-out

1. Never leave the transformer unattended during any part of the process. The transformer should be watched and observed.

2. Transformer to oil temperature should never exceed 85°C. The maximum temperature of anything in contact with the oil should never exceed 90°C.

3. Maintain log sheet.
4. Use lagging to prevent loss of heat through the tank walls and effect of cold draughts.
5. Use proper ventilation to remove the moisture given off by the transformer oil.

Duration of Drying-out

1 to 6 days for 11 kV transformer.
10 days to 30 days for 220 kV transformer.
15 days to 40 days for 400 kV transformer.

The drying-out process should be continued till the oil samples taken from the bottom of the tank and top of the tank have desired dielectric strength (Break-down value of 40 kV with 2.5 mm gap, cold) and the insulation resistance is of desired value. The actual time required *will vary widely* depending upon the size of the transformer, amount of moisture and the method adopted for the drying-out, capacity of filtering plant.

Log Sheet of Drying out (An Example)

Details about Transformer :

Details about Method of Drying :

Date of Start : **Date of Completion :**

Hours from Start	*Top Oil*	*Temperature Bottom Oil*	*°C Average*	*Insulation Resistance Mega-ohms*	*Input kW*
0	25	25	25	22	0
1	30	28	26	16	15
2	38	37	37.5	13	15
3	45	44	44.5	9	15
4	50	48	49	6	15
5	65	58	59	5	15
6	75	69	69.5	4	15
7	80	79	78	4	6
8	80	79	78	4	6
9	80	79	78	4	6
10 to 19 ,					
20	80	79	78	4	6
21	80	79	78	5	6
22	75	74	73	6	—
23	70	69	68	8	—
24	60	59	58	10	—
25	55	54	53	12	—
26	51	51	49	14	—
27	50	49	48	18	—
28	45	44	43	20	—
29	40	39	38	22	—
30	38	37	38	24	—

Stage	*Duration (example)*	*Average Temp. of oil*
Initial heating-up	4—8 hour	Ambient to 80°C
Steady Temperature	6—48 hour	80°C
Cool Down	48—60 hour	80°C to Ambient

— In the first stage of dying-out, the insulation resistance reduces. This indicates release of moisture within insulation and oil. In the second stage, the insulation resistance is steady. In the third stage, insulation resistance starts increasing indicating that moisture is being expelled.

— Drying out process is stopped when sufficient insulation resistance and Polarisation Index is reached during third phase.

— BDV of oil samples is measured after every four hours.

Q. 555. Explain the steps in drying out of a Power Transformer.

Steps in Drying-Out :

1. Preliminary preparation of the machine, source of heat, measurements etc.
2. Arrange the set-up.
3. Apply heat by one of the suitable means gradually.
4. Take periodic reading of
   — Clock time
   — Temperatures of windings, body and air, ambient
   — Insulation resistance values of 15 second Megger Reading and 60 second Megger Reading
   — Winding Resistance (At the beginning and at the end).
5. Maintain steady temperature or specified value (winding temperature not to exceed 60°C or 70°C depending upon insulation class). Measure periodically of the insulation resistance values.
6. *Initially, during the first few hours (for medium motors), the values of Insulation Resistance* **reduces** even though the heat is being applied **for Drying-out. Why ?**
   During initial heating period, the moisture trapped in the insulation in form of small globules gets released *within* the insulation. Hence the insulation resistance value starts reducing.
7. *Intermediate Stage.* After a span of a few hours (for a medium sized machine having good condition) or a few days (large machine or a wet machine) the insulation resistance *reaches a steady value*. This indicates that the moisture has spread all over the insulation.
   The input power is reduced to reduce the temperature rise.
8. *Rising Stage. After a few hours of steady value, the insulation resistance* **starts rising,** This indicates that the moisture has vaporised and is being expelled (released) from the winding. The input power is reduced further.
9. *The drying-out process is stopped when the desired value of Insulation resistance (hot) and polarisation index is reached. In case of large machine both the insulation resistance and the Polarisation Index are equally important.*

The Input power is switched-off.

Note. Megger (Insulation Resistance Tests) is used for measuring the Insulation Resistance between winding and earth. Temperature Measurement is by thermometer or thermocouple or self-resistance method.

Q. 556. What is Polarisation Index ? What is its significance ? How is it calculated/ measured ?

The Polarisation Index (P.I.) is defined as a ratio of 10 min resistance to 1 min insulation resistance.

$$\text{Polarisation Index P.I.} = \frac{I_n R_{10} \text{ minute}}{I_n R_1 \text{ minute}}.$$

Polarisation Index. The Polarisation Index gives a quantitative information about the insulation with respect to moisture dirt and other contaminations. The P.I. is obtained by taking the ratio of the 10 min. to 1 min. insulation resistance measurements, the recommended Polarization-Index

Q. 491. What is polarisation index ? What is its significance ?

The ratio I_nR_{60}/I_nR_{15} is called polarisation index.

where I_nR_{60} = 60 seconds reading of insulation resistance

I_nR_{15} = 15 seconds reading of insulation resistance.

For large and HV transformers, 10 minute and 1 minute Megger readings are taken instead of I_nR_{60} and I_nR_{15}.

Polarisation index gives the true idea about the quality of insulation.

A 2500 or 5000 V motor driven Megger is used to measure the insulation resistance. Two readings, one after 15 seconds and the other after 60 seconds ; the voltage being applied all the while. The value obtained for 60 seconds should be higher than for 15 seconds if the material is sound. The ratio I_nR_{60}/I_nR_{15} *(the polarisation index)* gives a positive indication of the good condition of the insulation if it corresponds with the manufacturer's test figures. Table gives reference values for a large transformer.

Experience shows that the above methods of non-destructive testing gives reliable values of the condition of insulation, moisture, surface cleanliness and quality of insulation. It is easy to perform at site also.

Reference Values of Insulation Resistance of Power Transformers, Mega-ohms

Measurement	*30°C*			*50°C*		
Between	I_nR_{15}	I_nR_{60}	$I_nR_{60/15}$	I_nR_{15}	I_nR_{50}	$I_nR_{60/15}$
HV and ground	750	1000	1.34	250	300	1.2
LV and ground	1000	2500	2.5	500	750	1.5
LV and HV	1000	2500	2.5	600	1000	1.67

Note. 1. Insulation resistance at 50°C is lesser than insulation resistance at 30°C.

2. I_nR_{15} refers to 15 second reading of Megger. I_nR_{60} refers 60 second reading of Megger.

For Large Transformers and for EHV Transformers I_nR_{600} for 10 minute reading and I_nR_{60} for 1 minute reading considered. P.I. = $I_n R_{600/60}$ for large transformers.

TROUBLES IN TRANSFORMERS

Q. 528. State the various causes of troubles and failures of cores of power transformers ?

Troubles with Core

S. No.	*Class of Trouble*	*Description*
	Failure in Magnetic Circuit	
1.	Failure of insulation of bolts used for clamping core and yoke.	Failure of insulation bolts used for clamping the core and yoke causes heavy circulating short circuit currents resulting in core heating.
.	Vibrations in core.	The loose core clamping bolts and bolts between core and structure results in vibration of core. This results in weak core insulation.
	Excessive core heating high magnetising currents, high in rush current.	Excessive heating of core result in temperature rise of winding.
	Failure of core bolt Insulation.	Moisture absorption and dielectric failure.
	Overfluxing of power transformer. Melting of core bolts, burning of core bolt insulation, burning of insulation between laminations.	Flux density depends on V/f ratio. The generator transformers fail by overfluxing if excitation maintained during starting or stopping the unit. Over fluxing relay should be provided for protection of generator transformer.

Q. 52 Causes of troubles and failures in power transformers and preventive actions

	Trouble	Cause	Remarks
1.1.	Overheating	— Overloads — Failure of cooling system — High ambient temperature	Check cooling system, whether fans are operating whether cooling oil/water is circulating. Reduce the load on the transformer. If temperature of oil high, switch off transformer till safe temperature reached. If over-load problem is occuring for long durations, install another transformer in parallel. If ambient temperature is higher than that considered in specifications of transformer de-rate the transformer.
1.2.	Sustained higher voltage on primary resulting in overheating of core due to over fluxing.	Poor voltage control of power system use of shunt reactance and tap changing transformer to control busbar voltage within specified limit.	Transformers fail due to sustained over voltage. Provide overfluxing protection and over-voltage protection for bus-bar. Flux density depends upon V/f ratio. Generator transformers, get overfluxed during low frequency operation.
1.3.	Frequent external short-circuits.	Insufficient clearances on overhead lines, accumulation of dust on insulation.	Transformer windings should be capable of withstanding repeated external short-circuits without failure. Transformer should be provided with over current protection.
1.4.	Short-circuit between adjacent turns, usually high voltage winding.	— Sharp corners on conductors cutting into insulation. — External short circuits (1.3). — Moisture in oil. — Fluctuating loads. — Transient over voltage.	Buchholtz relay should operat and sound alarm. Over-curren and differential protection shoul operate and open the circu breaker.
1.5.	Internal short-circuit	— Sustained overload and insulation failure — Fault in tap changer — Failure of end turns of coil due to over voltage surges — Bad solder joint causing local overheating and open circuit — Ageing of insulation	— Overcurrent protection. — Earth fault protection. — Differential protection.
1.6.	Moisture in oil	— Moisture in the oil while filling — Breather saturated — Defective seals	— Oil should be filtered. Sil should be replaced, ga should be replaced. Trans should be dried out.
1.7.	Rapid deterioration of oil ; Solid insulation	— Excessive overloading — Presence of moisture — Poor quality of oil. — Partial discharges	— Cause should be dete and corrective actior taken.
1.8.	Carbon and other conducting particles in oil	— Sparking in oil, excessive temperature of oil	— Conducting particles li insulation surface reduction in ins resistance and fail tracking. Transforme overhauling.

Q. 529. State various causes of troubles and failures of power transformers.

Causes of troubles and failures in power transformers and preventive actions

	Trouble	*Cause*	*Remarks*
1.1.	Overheating	— Overloads — Failure of cooling system — High ambient temperature	Check cooling system, whether fans are operating whether cooling oil/water is circulating. Reduce the load on the transformer. If temperature of oil high, switch off transformer till safe temperature reached. If over-load problem is occuring for long durations, install another transformer in parallel. If ambient temperature is higher than that considered in specifications of transformer de-rate the transformer.
1.2.	Sustained higher voltage on primary resulting in overheating of core due to over fluxing.	Poor voltage control of power system use of shunt reactance and tap changing transformer to control busbar voltage within specified limit.	Transformers fail due to sustained over voltage. Provide overfluxing protection and over-voltage protection for bus-bar. Flux density depends upon V/f ratio. Generator transformers, get overfluxed during low frequency operation.
1.3.	Frequent external short-circuits.	Insufficient clearances on overhead lines, accumulation of dust on insulation.	Transformer windings should be capable of withstanding repeated external short-circuits without failure. Transformer should be provided with over current protection.
1.4.	Short-circuit between adjacent turns, usually high voltage winding.	— Sharp corners on conductors cutting into insulation. — External short circuits (1.3). — Moisture in oil. — Fluctuating loads. — Transient over voltage.	Buchholtz relay should operate and sound alarm. Over-current and differential protection should operate and open the circuit breaker.
1.5.	Internal short-circuit	— Sustained overload and insulation failure — Fault in tap changer — Failure of end turns of coil due to over voltage surges — Bad solder joint causing local overheating and open circuit — Ageing of insulation	— Overcurrent protection. — Earth fault protection. — Differential protection.
1.6.	Moisture in oil	— Moisture in the oil while filling — Breather saturated — Defective seals	— Oil should be filtered. Silica jel should be replaced, gaskets should be replaced. Transformer should be dried out.
1.7.	Rapid deterioration of oil ; Solid insulation	— Excessive overloading — Presence of moisture — Poor quality of oil. — Partial discharges	— Cause should be determined and corrective action to be taken.
1.8.	Carbon and other conducting particles in oil	— Sparking in oil, excessive temperature of oil	— Conducting particles line up on insulation surface causing reduction in insulation resistance and failure by tracking. Transformer needs overhauling.

Energizing and operation under observation   Loading and observation

Q. 559. State the various commissioning tests on a Power Transformers.

Commissioning Tests on Power Transformer. After the above preparations, several commissioning tests are conducted on the transformer and tap-changer. The test to be carried out at site before commissioning the transformer will depend upon the voltage and kVA rating of the transformer, facilities available at site and conditions of the control list of typical tests are given below :

(A)	*General observation*	— Complete Transformer — Control and relay panels, etc. — Junction boxes and marshalling kiosks.
(B)	*Secondary injection Tests*	— Of all the protection relays.
(C)	*Primary injection Tests*	— Tests on operation and stability of earth fault relays on side h.v. — Tests on line directional elements of high-voltage line relays — Tests on high speed neutral circuit breaker — Tests on overcurrent relays on l.v. side — Tests on operation and stability of earthfault relays on l.v. side — Tests on operation of standby earth fault relay l.v. side. — Tests on overcurrent relay on h.v. side (when current transformers are not in transformer) bushings. — Voltage Compensation.
(D)	*Ratio Tests*	— With 415 V applied on high voltage side, measure the voltage between all phases on the low-voltage side for every tap position. — To check phasing, measure volts : A to a, b and c B to a, b and c C to a, b and c Where A, B and C are the terminals of three phases on high-voltage side and a, b and c are the corresponding terminals on low voltage side.
(E)	*Tripping Tests*	— High voltage side breaker — Low voltage side breaker — Intertripping tests — Winding temperature trips.
(F)	*Calibrate earthing resistance*	
(G)	*Buchholtz relays*	— Tests for angle air injection, etc. — Check that there is no air in protector before commissioning — When energizing, close in on 'Trip', etc. — Check for stability when oil pumps are started : 1. at ambient temperature 2. at a winding temperature of 80°C or above.
(H)	*Alarm Circuits*	— Buchholtz relay — Oil and winding temperature thermometer set at 85°C and 100°C respectively — Cooling gear failure.
(J)	*Fans and Pumps*	— Check that the oil valves are open in cooling circuit — Check the rotation of pumps, automatic starting overload devices, etc. — Check stability of Buchholtz relay.
(K)	*Tap changing tests to check mechanism, indication, buzzer, lamp, etc.*	
(L)	*Phasing tests*	— At 415 V — Between transformers in a three phase bank — To prove internal and external connections for parallel operation — On auxiliary supplied and voltage transformers.
(M)	*Insulation tests (reduced voltage)*	— On high and low voltage windings — On current and voltage transformer circuit, etc.
(N)	*Check oil levels*	
(O)	*Voltage Compensation test (if compensating transformers are fitted)*	— Primary injection — Load tests — If necessary, switch-in with relays connected to correctly compensated voltages from the other transformer
(P)	*Insulation Resistance*	— Main Circuits — Auxiliary Circuits.
(Q)	Partial Discharge	— Main circuits for record.

Q. 506. Explain the standard vector groups of 3-phase transformer connections. Give summary of common 3-phase connections.

In 3 phase transformers polarity alone is insufficient to represent the relation between H.V. and L.V. windings. In addition to the terminal markings on H.V. side and L.V. side voltage vector diagrams are required to show the angular displacement between H.V. and L.V. winding.

The angular difference between vectors representing the voltages indeed between H.V. and L.V. terminals having the same marking letters and the corresponding neutral point (real or imaginary expressed with reference to H.V. side is termed as phase displacement of the transformer.

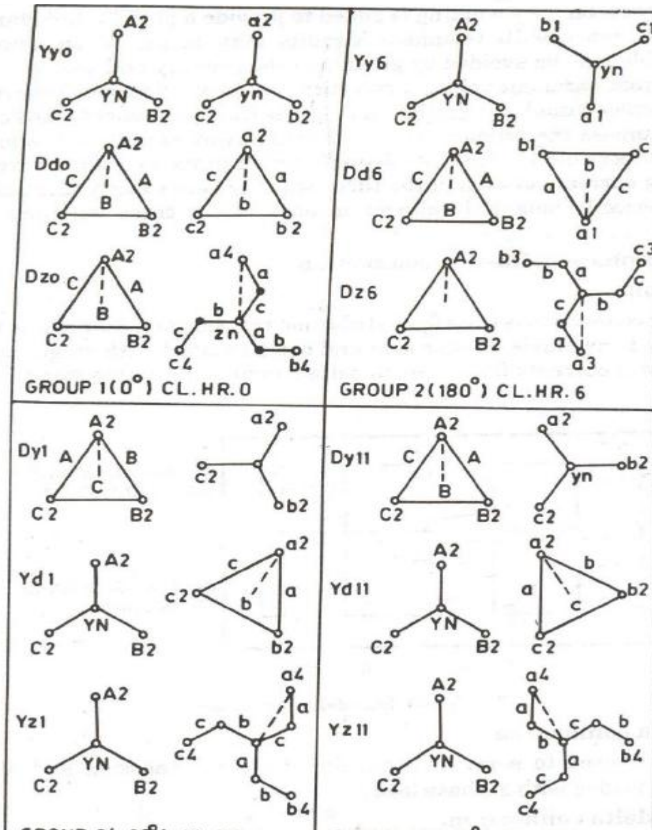


Fig. Q. 506.1. Vector groups of 3-phase transformers.

Even under normal condition the line-to-line voltages on H.V. side are displaced from corresponding voltages on L.V. side. Also line to neutral voltage on H.V. side are displaced from corresponding voltages on L.V. side. This displacement depends upon transformer connections (star/delta). IS 2026—1972 gives four vector groups of standard connections. These whole groups are explained below :

Terminal markings on H.V. : A, B, C Terminal markings on L.V. : a, b, c

Each windings has two subscripts 1, 2

e.g., A_1, A_2 for H.V. winding a_1, a_2 for L.V. winding etc.

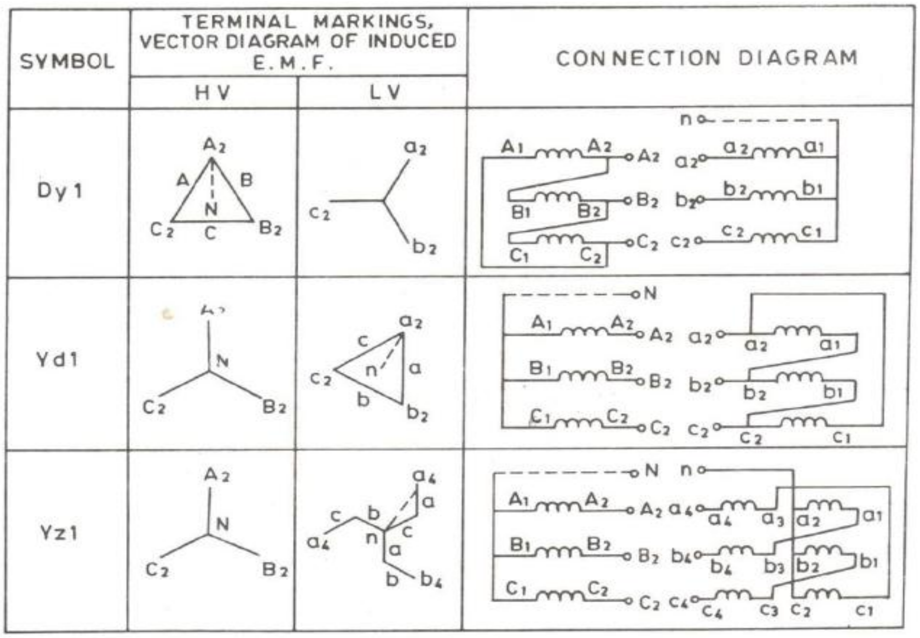


Fig. Q. 506.2. Vector Groups of 3-phase Transformers.

Transformers are classified in 4 vector groups 1, 2, 3, 4 depending upon phase displacement as follows :

Standard Vector Groups

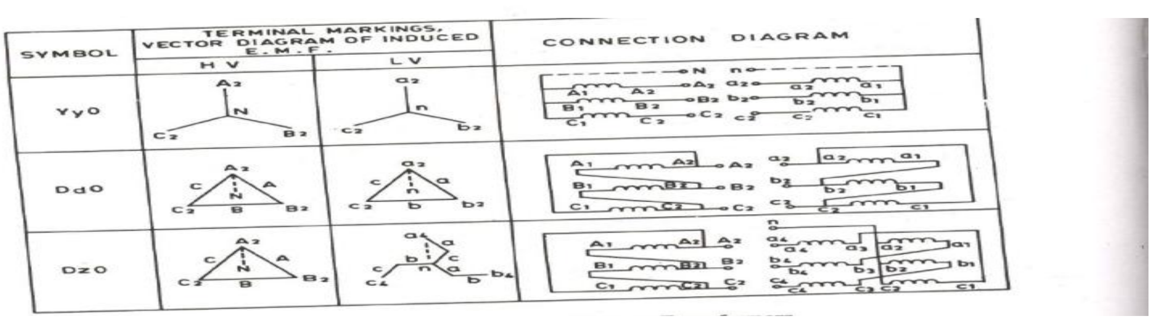
Group	*Phase displacement*	*Connections*
1	zero	Yy0, Dd0, Dz0
2	180°	Yy6, Dd6, Dz6
3	30° lag	Dy1, Yd1, Yz1
4	30° lead	Dy11, Yd11, Yz11

The phase displacement is indicated by the angle in terms of clock face. The H.V. vector being at 12 O'clock (zero) and the corresponding L.V. vector at hour hand number thus,

Phase displacement zero = 0
Phase displacement180° = 6
Phase displacement 30° lag = 1
Phase displacement 30° lead = 11

Letter Y represents star-connected H.V.
Letter y represents star-connected L.V.
Letter D represents star-connected H.V.
Letter d represents star-connected L.V.
Letter Z represents star-connected zig-zag.

Thus the symbol *Yy*0 represents a star/star winding with 0° displacement.



IMPULSE TESTING

Q. 499. Describe the Test Setup for Impulse Testing of Power Transformers.

Impulse Voltage Tests and Standard Impulse Waves

This is a type test for all indoor and outdoor transformers. The test is carried out as follows : Standard impulse wave of specified amplitude is applied two times in succession. If flash-over or puncture of insulators does not occur, the transformer is considered to have passed the test. If puncture occurs or flash-over occurs, the transformer is considered to have failed the test. During the test one wave should be applied with reversal of polarity. Test voltage is applied to each winding.

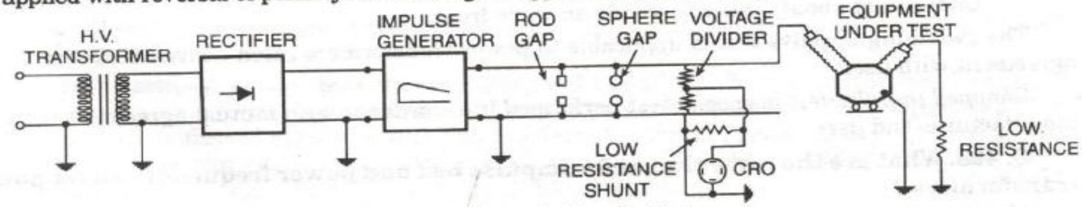


Fig. Q. 499. Setup for Impulse Test.

The impulse voltage wave is generated in an Impulse Voltage Generator. During the test one terminal of the impulse generator is connected to the terminal of the transformer. Other terminal of winding under test, frame and other windings are earthed.

The peak value and wave shape of the test voltage is recorded by means of Cathode Ray Oscillograph with a calibrated voltage divider. Voltage divider is used to reduce the voltage for measurement.

Sphere-gaps are used for calibration.

Impulse Voltage. An impulse voltage is characterized by

(*a*) Polarity (*b*) Peak value

(*c*) Virtual front T_1 (*d*) Virtual half time T_2

(*e*) Virtual time chopping T_e. Ref. Fig. Q. 499.1

Chopped wave represents condition created by spark-over of protective gap, across insulator.

Standard lightning Impulse is a full impulse having a front time 1.2 μ-sec and time to half value of 50 μ-sec. It is described as 1.2/50 impulse.

Standard switching Impulse wave is characterised by prolonged wave-front and wave tail. The typical switching impulse wave has front time of the order of 250 μs and half-time of 2500 μs. The permissible deviation in the crest value is of the order of 4 to 12%. The switching impulse wave has been specified for high voltage transformers rated above 220 kV.

Impulse Generator. In impulse tests impulse voltage wave having a steep wave front and flat wave tails and high amplitudes are usually applied to called 'Marx Circuit' Capacitor C_1, C_2.. ... are charged by the rectifier to certain voltage. When the gap S is triggered by means of a spark, the capacitors C_1, C_2.... etc. discharge through series gap S_1, S_2 etc. and the impulse wave is applied to the apparatus under test. The total d.c. voltage is sum of voltages of capacitors.

Sphere Gaps

Purpose. Sphere-gaps are used for measurement of high voltages such as peak value of

(*i*) Power frequency alternating voltages. (*ii*) Impulse voltage waves.

(*iii*) Direct voltages.

The procedure consists of establishing a relation between high voltage as measured by the sphere gap and indicating voltmeter, an oscillograph or other device connected for voltage measurement. Under standard test conditions the voltage measured by sphere-gap can be derived from the spacing. It means from the known diameter of spheres, known test conditions and known spacing of gaps the peak value of disruptive discharge voltage can be derived from the standard table. From this value the other measuring instrument can be calibrated.

Description. Standard sphere-gap is a peak voltage measuring device constructed and arranged according to rules specified by the standards, some of which are given below. Before conducting a test, the standards pertaining to High Voltage Testing Techniques and Sphere Gaps should be thoroughly studied. The sphere-gap consists of two metal spheres of equal diameter (D) with their shanks, operating gear, insulating support, supporting frames, leads upto the point at which the voltage is to be measured. The standard values of diameter D recommended by I.E.C. specification are the following twelve values :

$$D = 2 - 5 - 6.25 - 10 - 12.5 - 15 - 25 - 50 - 75 - 100 - 150 - 200 \text{ cm}$$

(12 Standard Diameters)

One sphere is preferably connected directly to earth and the frame of the transformer. The resistance connected in this circuit should be of a low value.

The other sphere is connected to winding under test and lead coming from high voltage transformer or impulse generator.

Measurement

Direct and Alternating Voltage. The voltage with a low magnitude is applied so that the transient switching surge voltage should not cause disruptive discharge. The voltage is increased gradually so that the voltage at which the disruptive discharge occurs, can be read accurately on low voltage indicator. Alternatively a constant voltage is applied across the gap and the spacing between spheres slowly reduced until disruptive discharge occurs.

The final measurement should be the mean of three successive readings agreeing within 3%.

Impulse Voltage. Impulse are obtained from impulse generator. The interval between application of impulses should be at least 5 seconds. The charging voltage or spacing of the gap is adjusted till 50% probability of disruptive discharge is obtained. To obtain 50% probability, final readings is obtained by interpolation between the readings obtained with either (1) Two gaps or, (2) Two voltage settings.

The readings should be such that in one case out of six applications of voltage 2 or less discharge occur. In the second case out of 6 applied voltages 4 or more discharges occur.

Transformer Ratio Method. An indicating voltmeter is connected on L.T. side of high voltage testing transformer. This voltmeter is calibrated by means of sphere-gap connected on H.T. side. Once the voltmeter is calibrated, the voltage cf L.T. side can be measured by the same voltmeter and the voltage on H.T. side be obtained on multiplying with turns ratio.

Potential Divider Methods. In this method, capacitor potential divider (or resistance divider) is connected across the H.T. winding of high voltage transformer. The potential divider consists of several air capacitors in series. The voltage across one capacitor is a definite fraction of the total voltage. This smaller voltage is measured by means of electrostatic voltmeter.

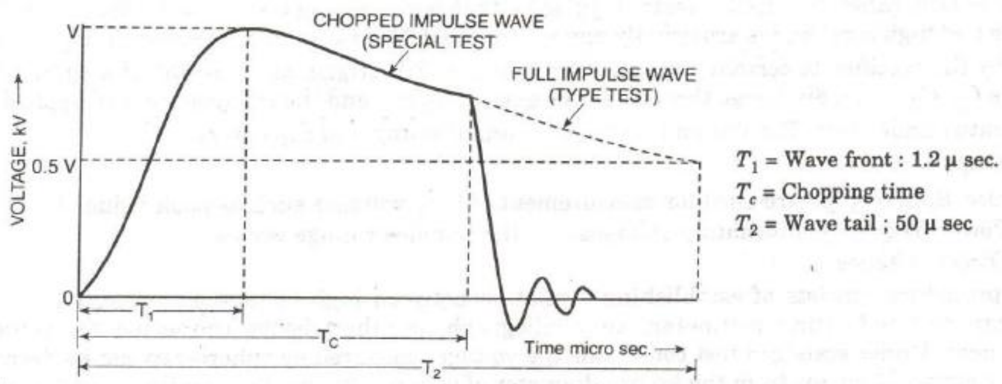


Fig. Q. 499.1. Standard Lightning Impulse Voltage Wave.

Application of Test Voltage

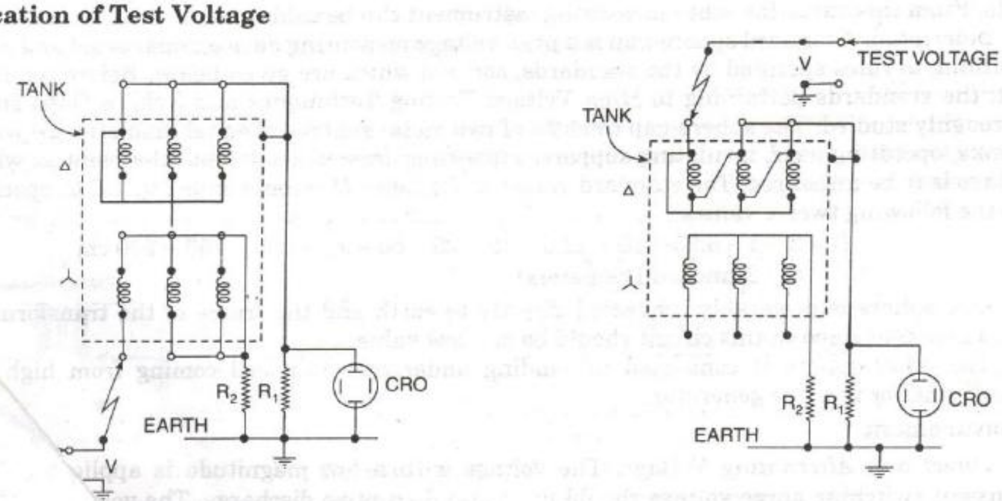


Fig. Q. 499.2. Application of Test Voltage.

so now get added corresponding to the series connection.

Q. 480. Explain the significance of no-load current and no-load losses.

Under no-load condition the transformer takes no load (magnetising) currents. No-load current less than 4% of full load current. Hence I^2R losses (copper losses) are negligible under no-load conditi However, the iron losses (hysteresis losses + eddy current losses) are present during no-load conditio

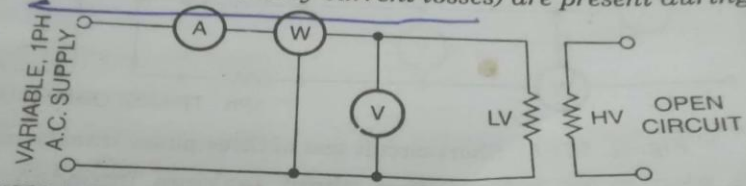


Fig. Q. 480(a). Open-circuit test (no load test) of single-phase transformer.

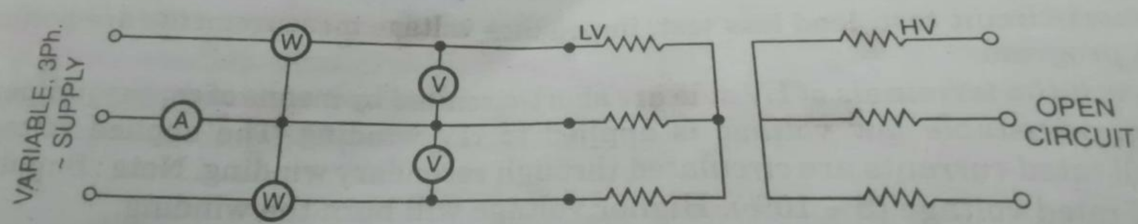


Fig. Q. 480(b). Open-circuit test of three-phase transformer.

No-load test is a routine test and should be performed on every transformer manufactured by a manufacturer before despatch.

No-load test on transformer is performed at normal voltage and normal frequency with HV winding left open. The LV winding is supplied with normal 3-phase rated voltage of rated frequency.

The input power is measured by two-wattmeter method or by three-wattmeters. *The input power gives no-load loss.*

The input current gives no-load current called magnetising current.

The values of no load current and no load losses (iron losses) are useful in evaluating the performance of the transformer. The no load loss is useful in evaluating transformer efficiency.

The defects in magnetic circuit of the transformer cause an increase in the no-load-current and losses and hence, reduce the efficiency of the transformer, and may lead to excessive over heating the reducing in life span.

To check the transformer for such defects, its no load (exciting) current and losses are measured and compared with the design data. For this purpose the no-load loss and exciting-current measurements are carried out. One of the transformer windings (usually the LV) is excited with a 3-phase symmetrical 50 Hz voltage. The voltage is gradually raised from zero to the rated value. The HV winding is left open-circuited. The active power consumed by the transformer is measured by three wattmeter method, line currents are also measured with ammeters.

Q. 481. Explain the significance of the load losses (short-circuit losses) of power transformers and the method of short-circuit test for loss measurement.

If the *secondary winding is short circuited, and rated secondary current is circulated the power input represents total I^2R losses in primary plus secondary windings and also stray losses.*

Short-circuit test at rated current and frequency gives approximately load loss (also called short-circuit loss).

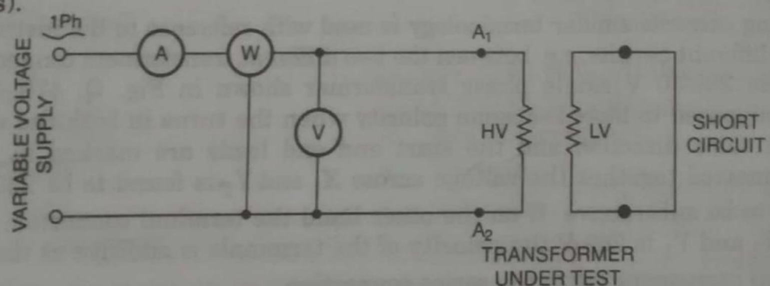


Fig. Q. 481(*a*). Short-circuit test of one phase transformer.

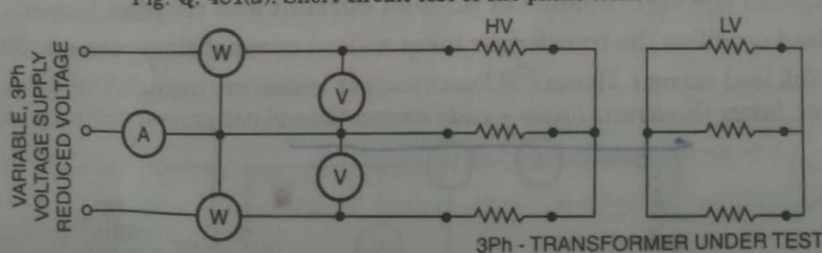


Fig. Q. 481(*b*). Short-circuit test of three phase transformer.

Short-circuit test also gives information about leakage impedance, load losses, impedance voltage of power transformer.

The short-circuit test, load loss test, impedance voltage measurements are performed during a single test program.

In this test the terminals of LV side are short-circuited by means of copper jumpers. Three phase symmetrical adjustable low voltage is applied to HV winding. The applied voltage is gradually increased till rated currents are circulated through secondary winding. Note : Supply voltage is only a fraction of rated voltage (5 – 10%). Higher voltage will burn the winding.