Chapter - 5

Transportation, Erection, Testing and Commissioning

Working Group Members

Mr. S. K. Negi	- GETCO
Mr. Gautam Mazumdar	- CGL
Mr. Umapathi	- Voltech
Mr. Y. V. Joshi	- GETCO
Mr. D. C. Patel	- J. H. Parabia
Mr. N. G. Patel	- GETCO
Ms. Asha Agravatt	- GETCO

CHAPTER - 5

TRANSPORTATION, ERECTION, TESTING AND COMMISSIONING

INTRODUCTION

Considering main objectives of standardisation Manual, this chapter will cover important procedures, check points, flow charts, suggestive tools-tackles, testing formats, etc. which are required for transport, storage, installation & erection, testing and commissioning of power transformer for its good performance during operation.

Transportation and Unloading at site

Power transformers are usually very reliable, but it requires lot of care during all stages of its life & particularly during transportation. If a transformer experiences any mechanical shocks more than suggested “g” level, damage that may occur covers

- Displacement / distortion of windings or core
- Inter turn insulation damage due to movement of active part
- Loosening of winding clamps due to vibration
- Compromise safe clearances between tank & active parts

It is therefore required that transporter should take note of following transport restrictions.

- Axial load distribution
- Brake force distribution between tractor & trailer as per trailer manufacturer’s guide.
- Maintain proper ratio between the gross mass of the trailer and tractor
- Adhere to designated route.
- Avoid travelling during foggy, heavy rain, etc restricting ambient visibility to less than 500 meters.
- Actual survey & planned route
- Permissions

1] Modes of Transport

According to weight of Transformer to be transported, the size & capacity of Trailer, plinth size and mode of transport can be standardised as below.

Sr. No.	Standard Ratings	Approx. Weight in MT	Trailer size (No. of axles)	Mode of Transport
A	**Two Winding Transformers**			
1	132/33 kV, 40/50 MVA	70	6	ROAD
2	220/66 kV, 100 MVA	107	9	ROAD
B	**Auto Transformers**			
1	132/66 kV, 40/50 MVA	60	5	ROAD
2	132/33 kV, 25/31.5 MVA	50	4	ROAD
3	220/132 kV, 100 MVA,	84	7	ROAD
4	220/132 kV, 160 MVA,	83 - 130	7 - 10	ROAD

5	400/220/33 kV, 315 MVA, 3Ø	185 - 230	14 - 18	ROAD
6	400/220/33 kV, 500 MVA, 3Ø	250	19	ROAD / RAIL
7	400/220 kV 167 MVA, 1 Ø	85 - 104	7 - 8	ROAD
8	765/√3 // 400/√3, 333 MVA, 1 Ø	160	13	ROAD / RAIL
9	765/√3 // 400/√3, 500 MVA, 1 Ø	192	15	ROAD / RAIL
C	**Generating Transformers**			
1	15.75/235 kV, 315 MVA 3Ø	190	15	ROAD
2	15.75/420 kV, 315 MVA, 3Ø	230	18	ROAD
3	21/420 kV, 200 MVA, 1Ø	155	12	ROAD
4	21/420 kV, 260 MVA, 1Ø	180	14	ROAD
5	21/420 kV, 333 MVA, 1Ø	220	17	ROAD
6	21/765 kV, 260 MVA, 1Ø	175	14	ROAD / RAIL
7	21/765 kV, 333 MVA, 1Ø	205	16	ROAD / RAIL

** Note: Weights are approximate and may vary from manufacturer to manufacturer*

Mode of transportation may be rail, road or water. Depending on size of transformer, destination, delivery time & route limitations the mode of transportation can be decided.

a) Rail Transport

Where the weight and dimension of main body exceed limits, special well wagons are employed. Detached parts are packed/crated and normally dispatched along with main body of transformer so that all the parts are received at the destination with unit. If the siding facility is not available either at loading or unloading end, mobile cranes or railway cranes can be used for loading into wagons.

b) Road Transport

Multi axle tractor driven, low platform trailers are used for transporting transformers on roads. Transformers may be transported by road, where well developed roads exist & the route conditions permit.

2] Selection of Trailer

Multi axle tractor driven low platform trailers are used for road transport. The tractors are to have adequate hauling capacity and the trailers should have adequate loading capacity. There are two types of trailers available.

i) Low bed Mechanical Articulated Trailer

This is useful for concentrated load like Transformer. The maximum Gross load permissible in Mechanical Articulated trailer is 49 MT (Gross load = Weight of consignment + weight of trailer + weight of pulling unit, tractor)

ii) Hydraulic axle Trailer

Useful for all types of loads including transformers. The maximum Gross load permissible in Hydraulic axle trailer is 18 MT Per axle. Depending upon the weight, the number of axles can be attached one after another. Normally Hydraulic axle unit are available in the combination as a unit of 2 axle, 3 axle, 4 axle, 6 axle and 8 axle (weight of each axle is approx.: 3.5 to 4.5 MT) depending upon Manufacturer. The axle width is generally 3 Mtrs. 1 ½ side axle can also be joined if the width of the consignment is exceeding 4 Mtrs. Total width of the axle in this case will be 4.5 Mtrs.

3] Capacity of Puller

Presently Pullers (figure 5.1) are available to pull loads from 1 to 240 MT.

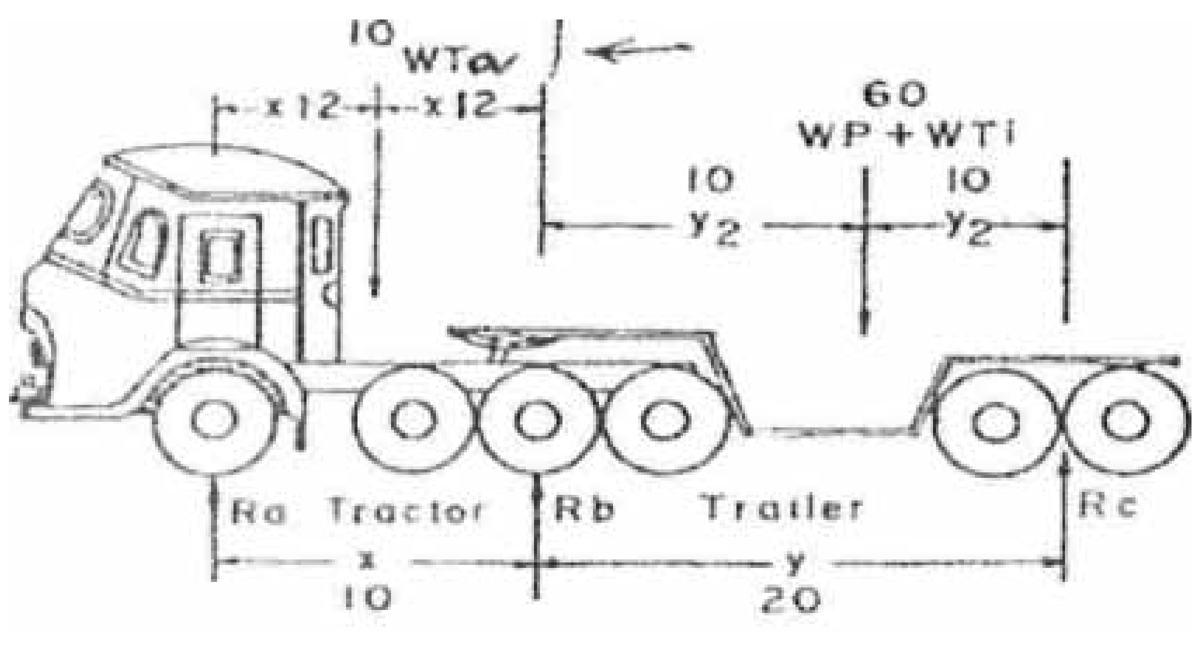


Fig. 5.1

4] No. of Axles

No. of hydraulic axles of any transportable consignment can be determined in the following manner. One puller carried load of the consignment on two hydraulic axles.

Weight of tractor (ra) + trailer (rb)	= X (say, 10 MT)
Weight of Transformer	: (a) e.g. 70 MT
Gross weight permissible per axle	: (b) e.g. 18 MT
Weight of each axle	: (c) e.g. 4.5 MT (standard weight)
Weight of Goods that can be loaded (d)	: (b-c) = (18 MT – 4.5 MT) = 13.5
Hence, for 70 MT Transformer axles to deploy	= {X+(a)}/(d) = {10+70}/13.5 = 5.92

Therefore number of axles which need to be deployed are 6.

In the up gradient of hills or roads extra puller of same rating shall be provided.

In down gradient of ghat section use power brake attached to the hydraulic modular trailer.

5] Route Survey

The route Survey Report is for safe and speedy transport of over dimensional / sophisticated consignments by deployment of well suitable equipment, driver and escorts (both) with professional & technical expertise and their rich experience is the answer of safe and speedy transport.

Based on the dimension and weight of the consignment extensive study is being carried out, first calligraphically wherein most feasible routes for the transportation to the destination site is selected and there after exhaustive field verification are carried out. After collection and compilation of massive data that was collected during the route surveys, only the most feasible route is being selected and detailed report of Survey is being prepared. Efforts to be made for best alternative solution while highlighting the problems that are anticipated for safe and speedy transportation of over dimension / sophisticated consignment

a) Elements of route survey

The road system is examined in detail on the following points:

i. Normally width of the road should be more than 5 m.

ii. Bridges and culverts should have sufficient strength to take the moving load (in this regard, consultation with highway department is necessary)

iii. Hindrance on route like telephone, telegraph, traction and HT/LT wires, avenue trees, sub ways etc are to be assessed.

iv. Sharp bends & road worthiness (i.e. sandy stretches, waterlogged areas, crowded localities like market places, schools and public places)

6] Speed

For the normal running uniform speed of 10 to 20 kmph shall be maintained on good roads. For bad roads it is desirable to run the vehicle at much lower speeds. However, while crossing bridge it shall be 5 kmph. No breaks should be applied during bridge cross over. Movement of other vehicle should be stopped while crossing bridge. Long before the approach to the bridge, the speed should be brought down and the vehicle allowed proceeding over the bridge without creating any impact.

The brake system on the tractor-trailer has to be carefully operated whenever the vehicle is running with load.

7] Night Travel & Halt

Normally night travel is avoided except where it is restricted for heavy vehicles to travel in day time i.e. cities, towns & small villages. Transportation should be avoided during heavy rains also. In the case of night halt or stoppage of the loaded trailer for a fairly long duration the trailer should be supported either by sleepers or providing supporting jacks on all sides thus releasing the load from the tyres. Danger lights should be displayed in the front and rear of the vehicle.

8] Safe movement under O/H lines

The Supervisor should ensure that sufficient line clearance from line conductor to the top most part of transformer and trailer is available as per IE Rules and as per the rating of transmission lines. The transportation during monsoon period should be avoided as far as possible if sufficient clearances are not available. If it is found that the clearances are critical, the hydraulic axle platform can be lowered by 250 to 300 MM as per the provision made in hydraulic axle to avoid any danger of electrical faults.

9] Special spares / tools to be carried during transport

1. Insulated LT wire lifting device
2. Extra tyres
3. Hydraulic Jacks
4. Tools Box
5. Crow bar
6. Tarpaulin
7. Slings for fastening
8. First Aid kit
9. Small Spares
10. Torch
11. Baton sticks
12. Red & Green Flags

10] Crew Size

1. Supervisor - 1 Person
2. Driver - 1 Person
3. Axle operator - 1 Person
4. Helpers - 3 Persons
5. Wire lifting - 3 / 4 Persons.

All above should be equipped with helmet, safety shoes & hand gloves and Supervisor, Axle operator and Driver are with suitable communication facility.

11] Document verification for puller capacity

Registration book issued by RTO department to know the horse power of puller.

12] Movement

A pilot vehicle with all tools and tackles, jacks, sleepers, chequered plates, crowbars, etc., and sufficient trained staff should run in front of the vehicle. Red flags and danger lamps should be exhibited at prominent places to warn traffic on the route.

The branches of avenue trees that are likely to foul the equipment should be cleared while the load is moved. Electric utility power lines likely to foul should be switched off and lifted temporarily / dismantled while the load is moved.

After moving the load for a short distance, tightness of the lashing should be checked.

13] Check Points during Transportation

a) Provide suitable impact recorder which give waveform data and frequency analysis. As per IEEE guide line PC57.150, it is recommended to provide two recorders per transformer to eliminate chances of loss of data due to failure of recorder.

b) Place both the recorders as low as possible and in diagonally opposite positions for best results.

c) Check pressure of dry air or nitrogen as shown below on daily basis. Any loss in pressure shall be made up. For this, Transformer shall be supplied with filled gas cylinder to maintain positive pressure during transportation (figure 5.2).

d) The purity shall be 99.9% for nitrogen gas or dry air conforming to DIN 3188.

e) Weak bridges, if any should be strengthened with the help of highway department.

f) Red flags and danger lamps should be exhibited on the unit.

g) Check tightness of lashing at regular intervals during movement.

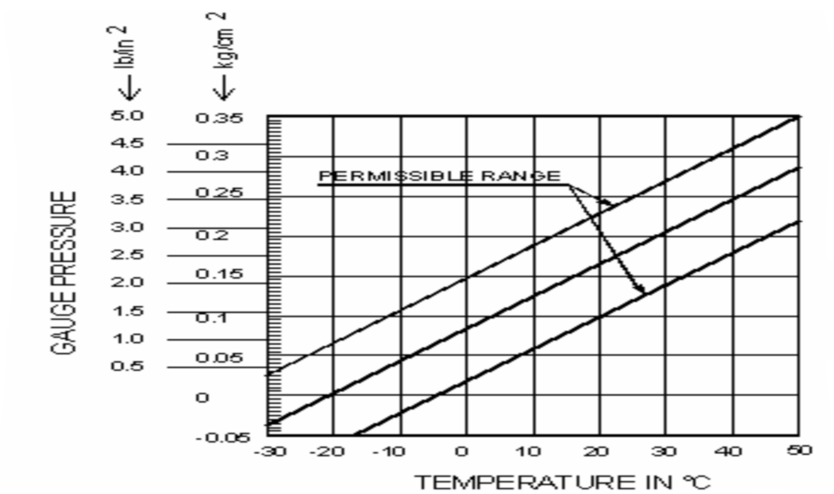


Fig. 5.2:

14] Receipt of Transformer at Site

i. When a transformer arrives at site a careful external inspection must be made of the unit, its cooling system and all sealed components, referring to the general arrangement drawing and the shipping list.

ii. Inspect all packing cases and loose components for damage or missing items.

iii. Check whether the transformer has arrived at site with a positive gas pressure in case of dispatch without oil. In case of dispatch of main body in oil filled condition, check oil level and leakages if any.

iv. Should the transformer arrive at site without pressure (owing to gas leakage), it must be assumed that moisture has entered the tank and that the moisture will have to be driven out. In such cases, the manufacturer's advice must be sought.

v. In case of any oil leakage or damage is discovered, the transportation company, the transport insurer and manufacturer shall be informed immediately.

vi. A record of damage must be prepared in conjunction with other participants and supplier representative. Minor damage which may appear unimportant should also be recorded.

vii. Confirm that case numbers match with the packing list. Check their contents tally with the packing list if the packing case is damaged.

viii. Fill in the check list for external as well as internal inspections.

ix. For oil filled transformers a sample of oil should be taken from the bottom of the tank and tested for BDV and moisture content. If the values do not meet the relevant standards the matter should be taken up with the manufacturer.

x. Down load impacts recorded by impact recorder and analyze the same in consultation with supplier.

15] Unloading of Transformer

All the transformer unloading and handling work should be carried out and supervised by specialized people, following all safety rules and using supporting points indicated on drawing. The use of any other points will result in severe damages to the transformer.

a) The following should be avoided during the unloading process

- The transformer imbalance (Maximum 10 degree)
- Abrupt movements
- Impact against the ground
- Side Impact

The transformer should be unloaded from trailer by using wooden sleepers and rails for dragging the transformer to its plinth.

b) Considerations before unloading

- Availability of access road between unloading point and plinth.
- Ensure overhead crane capacity for weight of main unit.
- Readiness of foundation
- Keep under base of main unit at least 300 – 400 mm above ground level by providing wooden slippers to facilitate jacking.
- Remove lashing before unloading.

c) Unloading from Trailer

i. Unload main unit only on wooden slippers
ii. Jack the transformer at jacking pad only.
iii. Ensure simultaneous operation of all 4 jacks.
iv. Use only haulage lugs for hauling.
v. Ensure capacity of winches and wire ropes to be used for haulage.
vi. Do not use chain pulley block in place of winches.

d) After checking of exact position of transformer, the following sequence should be followed

i Install all wheels to transformer using hydraulic jacks sized for at least 50% of the units weight.

ii Before resting the wheels into groove, make sure all of them properly adjusted.

iii Lower the transformer with the help of the hydraulic jacks until it remains resting on the bottom of the groove. Never allow the transformer to remain inclined.

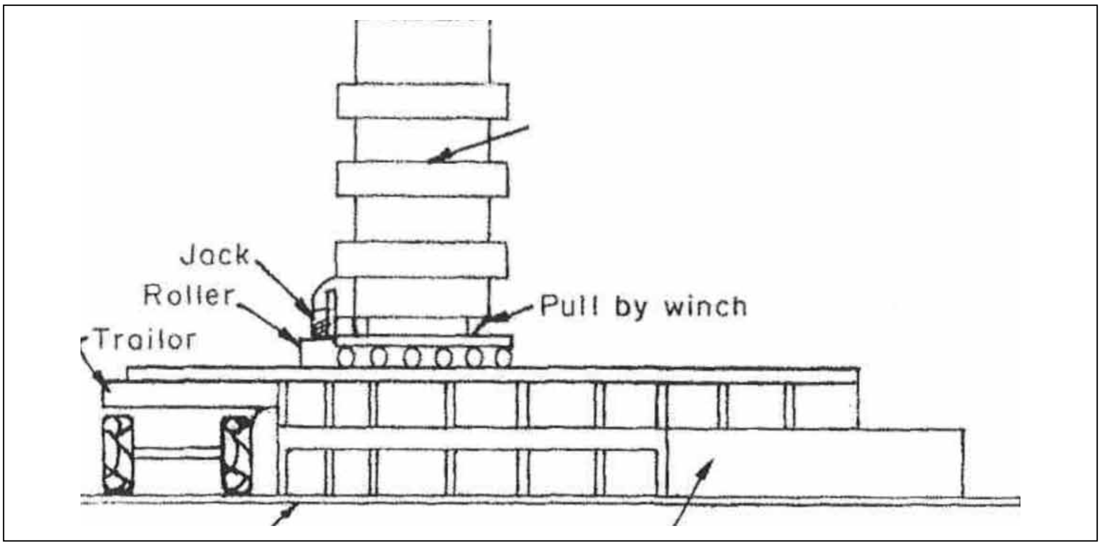


Fig. 5.3:

e) List of major tools for unloading

Sr. No.	Item	Capacity
1	Mobile crane	Min. 110% of weight of transformer
2	Hydraulic Jack	1.5 times weight of transformer
3	Lifting slings	Size of slings to be selected according to weight and angle of lifting
4	Winch machine	115% of weight of transformer divided by 4
5	Wooden sleepers	300 to 400 mm thick
6	Greased steel plates	Adequate numbers
7	Pulleys	115% of weight of transformer divided by 2
8	Oil storage tank	25 kL with motor pump.
9	Oil filter machine /oil purifier	5000 lph
10	Vacuum pump	760 mm of Hg
11	Water proof tarpaulins	30 to 40 M2
12	Flexible hoses for vacuum and oil	10 M long – 4 nos 3 M long – 2 nos
13	Oil test kit	– 100 kV

ERECTION, TESTING AND COMMISSIONING

The complete process of erection from point of dispatch from factory to commissioning is illustrated in the form of flow diagram to follow sequence of activities scrupulously with check points.

1 **Erection**

Erection of power transformer requires great deal of planning and arrangement of resources. It is essential to have erection agency with skilled manpower having experience of EHV class power transformer. Each and every unit is to be treated like a project, so that cost, quality and time are controlled and monitored through a process (Flow chart - see Fig. 5.4). It will ensure that erection activities are carried uninterrupted with safety and without any damage to transformer parts / items.

It is suggested to have kick off meeting (KoM) with following main agenda:

1. Competency of erection agency and their manpower skills.
2. To confirm receipt of transformer as per BOQ in full shape
3. To confirm availability of T&P as per requirement of unit, size and rating. (Refer list as per this manual)
4. To confirm readiness of plinth and radiator foundation as per requirement (Physical check of dimensions)
5. To confirm over head conductor take off or power cable terminations arrangement as the case may be.
6. To confirm safety measures adopted and location hazards, if any.
7. Organization reporting structure, data recording, responsibility and clearances.
8. To confirm insurance, workmen compensation and labor related statutory requirements.
9. Comply to specific requirements agreed in Design Review.

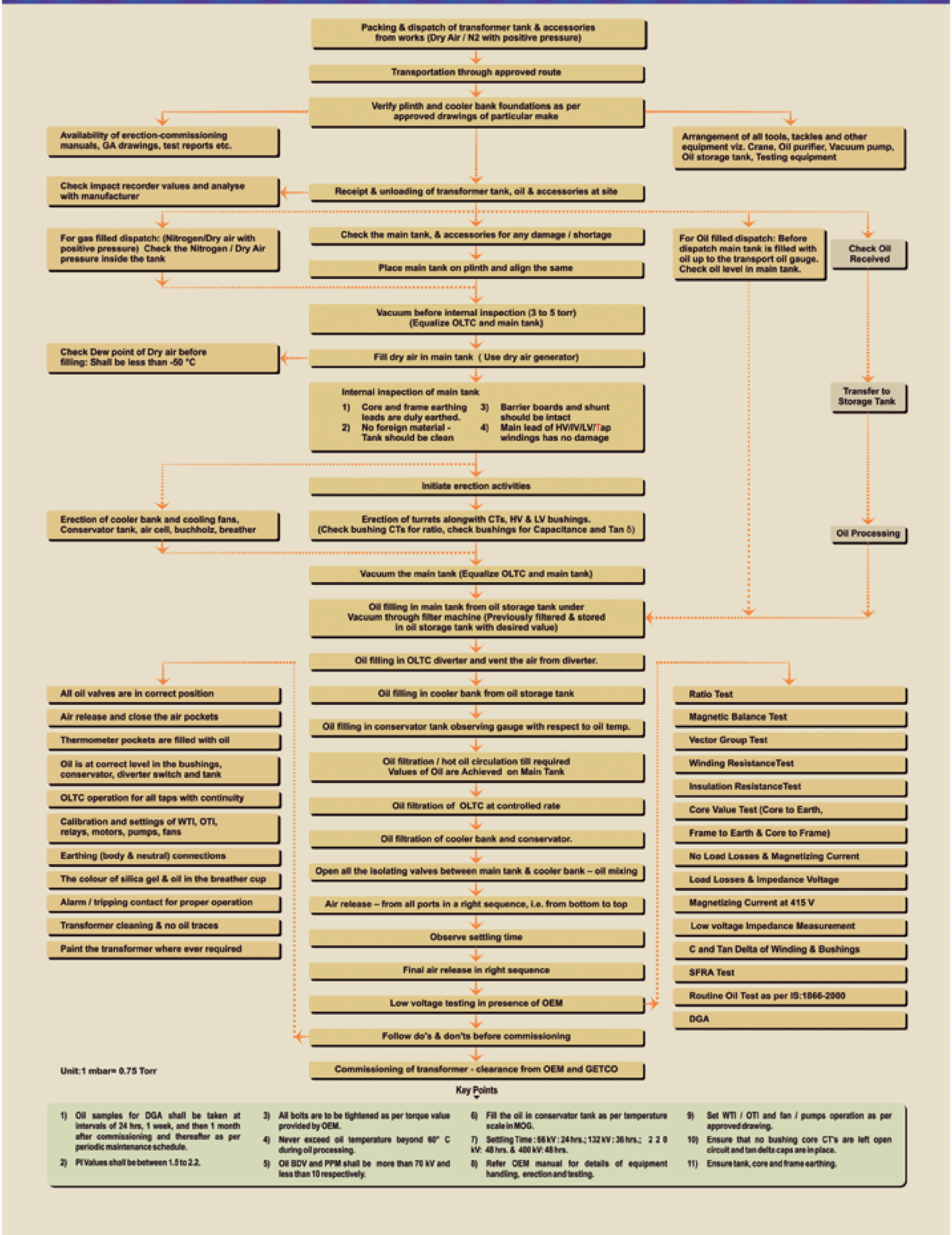
2 **Minimum Tools & Plants and Other Items**

a) **General T&P**

The following tools and plants can be arranged during erection, overhauling activity at site.

Sr. No.	Item	Optimum Quantity Recommended
1	Spanners : a) Double end (size -32) b) Ring (size -32) c) Box/socket type (size 6-36) with a/2" drive complete with ratchet, universal, ordinary handle and extension bar of size 75mm and 150mm	 2 Set 2 Set 2 Set
2	Single end spanners (36,41,46,50,55)	5 Nos.
3	Slugging wrench (32,36,41)	3 Nos.
4	Tubular spanner (size 6-32)	1 Set.
5	Torque wrench (1/2" drive) 5 to 22 kgm	1 No.
6	Adjustable spanner 8" - do - 12" - do - 18" - do - 24"	2 Nos. 2 Nos. 1 No. 1 No.
7	Pipe wrench 12" - do - 18" - do - 24"	1 No. 1 No. 1 No.
8	Spanner for opening transformer butterfly valves (squre)	1 No. for each type of valve
9	Spanner for opening oil drum	2 Nos.
10	Screw Driver a) 10mm (D0 x 400mm (L) b) 10mm (D0 x 300mm (L) c) 8mm x 300mm (L) d) 8mm x 200mm (L) e) 6mm x 250mm (L) Insulated f) 6mm x 200mm (L) Insulated	 2 2 4 4 4 4

FLOW CHART FOR ERECTION OF POWER TRANSFORMER



Sr. No.	Item	Optimum Quantity Recommended
11	Star screw driver (size 1mm to 6mm)	1 Set.
12	Nut driver stet (up to 10 mm)	1 Set.
13	Allen Keys (size 1 mm to 16mm)	1 Set.
14	Cutting pliers insulated - 8" 10"	2 Nos. 2 Nos.
15	Nose pliers insulated - 6" 8" 10"	2 Nos. 2 Nos. 2 Nos.
16	Cir-clip pliers – Internal External	1 No. 1 No.
17	Wire stripper for 2.5 sq. mm	2 Nos.
18	Hammer - ½ kg 2 kg 5 kg	1 No. 1 No. 1 No.
19	a) Teflon mallet (medium size) b) Wooden mallet (medium size)	1 No. 1 No.
20	a) Dot punch b) Hole punch kit up to 32mm	1 No. 1 Set
21	Brass rod (300mm L x 20mm D)	1 No.
22	Files. a) Needle file b) Flat file 12" (rough & smooth) each one c) Half round 8" d) -do- 10" e) Round file 8" f) -do- 10" g) Triangular file 8" (rough & smooth) each one	 1 Set 2 Nos. 1 No. 1 No. 1 No. 1 No. 2 Nos.
23	a) Hacksaw frame - 12" b) Wood saw - 12"	1 No. 1 No.
24	Sheet cutter - 12"	1 No.
25	Scissors - 8"	1 no.
26	Flat Chisel - 8" Round Chisel - 10"	1 No. 1 No.
27	Industrial knife high carbon sheet	1 No.
28	Knife for wire cutting	2 Nos.
29	Measuring tape a) 3 meter (flexi-measure) b) 15 meter (plastic) c) 30 meter (plastic)	 2 Nos. 1 No. 1 No.
30	Steel rule – 30 mm	1 no.
31	Varnier Caliper - 300mm	1 No.
32	Filler gauge - 100mm - 24 blade (metric)	1 No.
33	Tri square 10"	1 No.

Sr. No.	Item	Optimum Quantity Recommended
34	Plumb	1 No.
35	Sprit level	1 No.
36	Bench vice - 8”	1 No.
37	Pipe vice for pipe up to - 2”	1 No.
38	Pipe die set up to -2”	1 Set.
39	Crimping tool a) Hand operated up to 16 sq. mm b) Hydraulic	 1 No. 1 No.
40	Bearing puller - 3 leg (size 300mm)	1 No.
41	Hand operated oil can	1 No.
42	Grease gun (medium size)	1 No.
43	Hand operated oil pump (for oil drums)	1 No.
44	Drilling machine portable (0-13mm) Model WD 34C, Make : Wolf	1 No.
45	Drilling machine heavy duty along with drill chuck, sleeves and arbor Model NW 10, Make : Wolf	1 No.
46	Drill bits : a) size upto 10mm straight shank b) size 12 to 25mm tapper shank	10 Nos. 13 Nos.
47	Hand Grinder (AG-7) Make : Wolf	
48	Bench Grinder, Model TG6-E wheel dia. 150mm	1 No.
49	Vacuum cleaner cum blower with hot air attachment	1 Set
50	Hydraulic jacks (100 t. capacity)	4 Nos.
51	Pulling and lifting machine (Tirfor 5 t. capacity)	2 Nos.
52	Chain pulley block a) 10 T b)1 T	 1 No. 1 No.
53	C-clamps (12”)	6 Nos.
54	D Shackle a) 2 T capacity b) 5 T capacity c) 10 T d) 20 T	 6 Nos. 4 Nos. 4 Nos. 4 Nos.
55	Bull dog clamp heavy duty suitable for 10mm, 12mm wire sling	5 Nos. each
56	Single sheave pulley (a) 1.5 ton (12 mm) (b) 2.5 ton (12 mm)	 1 No. 1 No.
57	Slings. (a) 12mm dia. with standard loop on both ends having 6 mtr. length (b) 12mm dia. with standard loop on both ends having 10 mtr. length (c) 10mm wire rope length (d) 32mm dia. with standard loop on both ends having 10 mtr. length (e) Wire rope slings double legged with ring at one end and hook at other end with 12mm roper of 4 mtr. length	 4 Nos. 2 Nos. 100 mtr 2 Nos. 2 Nos.

Sr. No.	Item	Optimum Quantity Recommended
58	Polypropylene rope a) 6 mm b) 12 mm c) 16 mm	 50 mtr 100 mtr 100 mtr
59	Welding machine with flexible welding cable, insulated electrode holder, protective masc., chisel, chipping hammer, wire brush and leather gloves (model RED-301 of Advani oerlicon Ltd)	1 Set.
60	Brazing, soldering and gas cutting kit	1 Set.
61	Pipe GI or Iron – 25mm and 40mm 50mm dia (1 mtr length each)	3 Nos.

b) **Miscellaneous Items**

Sr. No.	Item	Optimum quantity recommended
1	Torch light (large size)	2 Nos.
2	Emergency light	5 Nos.
3	Flood lights fittings : - Sodium vapor (70 W) - Halogen (500 W)	 5 Nos. 5 Nos.
4	Tarpaulins (large size)	10 Nos.
5	Ladder (Aluminum) (a) Self supporting ladder 1.8 mtr (b) -do- 3.6 mtr (c) extension ladder 4.8 mtr	 2 Nos. 1 No. 2 Nos.
7	Heaters (2.0 kW x 40 Nos.)	2 Sets.
8	Wooden sleepers	50 Nos.
9	U-clamp for connecting OLTC chamber to main tank at the time of vacuum pulling	1 No.
10	Oil sampling bottle	10 Nos.
11	Oil sample flange	2 Nos.
12	Switch boards for extending supply having 15A/5Amp socket, bulb, holder & switch	3 Nos.
13	Earth rods	5 Nos.
14	Fire extinguisher CO_2 (22.5kg) Foam (9kg) Halon (3 kg)	 2 Nos. 2 Nos. 2 Nos.
15	Dry air cylinders	30 Nos.

c) **Special T&P and Instruments**

Sr. No.	ITEM	Quantity.
1	Filter machine 6000 L	1 No.
2	Oil tanks (30 KL capacity)	1 No.
3	Oil hose	100 mtr.
4	Vacuum pump	1
5	Vacuum hose	20 mtr
7	400A switch board for power supply to Filter machine	2 Nos.
8	BDV kit	1 No.
9	5KV/10KV megger	1 No.
10	Tan delta & capacitance kit	1 Set.
11	SFRA kit	1 Set.
12	Ratio meter	1 No.
13	Winding resistance measurement meter with leads	1 No.
14	Multi meter	3 Nos.
15	Clip on meter	1 No.
16	Primary injection kit with leads	1 Set.
17	Variac for 3-phase supply (15 Amp)	1 No.
18	Online PPM Meter	1 No.
19	Dew Point Meter	1 No.
20	Pressure Gauge	2 Nos.
21	Vacuum Gauge	2 Nos.
22	Mobile Crane Hydra	1 No.

3 Safety Measures & Precautions

1. Keep recommended fire extinguishers at site.
2. During hot oil circulation, keep fire extinguisher ready near transformer.
3. Carry out all pre-commissioning Test and final commissioning check as elaborated in this Manual before energizing transformer.
4. Take precaution while handling PRV devices having heavy springs in compression to safeguard person and system.
5. Replace N_2 filled tank by breathable dry air of dew point less than (-40 ^{o}C) at least for 24 hours.
6. Provide adequately rated cables & fuses.
7. Never apply voltage when transformer is under vacuum.

8. Oil spillage shall be inspected regularly and attended if any. Oil shall not be allowed to fall on ground.
9. Keep all combustible items away at safe distance to reduce risk of fire.
10. Welding on oil filled transformer may be avoided or done as per instruction of manufacturer only.
11. All erection personnel must use Personal Protective Equipments like, helmet, safety shoe, boiler suit, etc.
12. No welding work shall be taken up near transformer.
13. Electrical equipment like filter machine, dry air generator etc., must be earthed.
14. First Aid box shall be kept ready at site.
15. Adequate lighting must be available for clear visibility
16. Cordon off the working area, particularly when transformer augmentation work in a switchyard is taken up.
17. All major erection activity like bushing, conservator and radiators must be carried out with crane of adequate capacity and boom size.
18. Never carry out work with unskilled workers.
19. Safety posters, like "No Smoking", "Wear Helmet", etc., must be displayed.
20. Testing circuit and procedures are important to follow as per manual to avoid any induction effect before and after the Test. Approved and tested Earth rods are essential for this purpose.
21. Safety Nodal Officer to make sure that site is cleared on daily basis to prevent fire hazards.

4 Precomissioning Tests:

4.1 Preparation for SAT (Site Acceptance Tests)

- Site study
- Collection of Factory Acceptance Test reports
- Finalization of action plan for carrying out SAT
- Prepare testing program schedule.
- Check whether the transformer under Test had been isolated from other electrical equipments and from induction using earth switch or local earthing arrangement.
- Make the Test procedure
- Make the Test formats
- Get the guidance of Dos and Don'ts from the experts in the field
- Ensure for all safety assessments of Helmets, Gloves and Safety shoes.
- Execute the tests according to the program schedule.
- Compile the Test reports.
- Do analysis of the Test results and ensure for healthiness of transformer.

4.2 Following checks should be carried out before commencing the pre-commissioning Test of the Power Transformer.

- Ensure that Power Transformer and its auxiliaries should be free from visible defects on physical inspection
- Ensure that all fittings should be as per out line General Arrangement Drawing
- Ensure that bushings should be clean and free from physical damages
- Ensure that oil level is correct in all bushings
- Ensure that oil level in Main / OLTC Conservator tank in MOG is as desired.
- Ensure gear box oil level in OLTC
- Ensure that OTI and WTI pockets are filled with transformer oil
- Ensure that cap in the tan delta measurement point in the bushing is grounded
- Ensure unused secondary cores of Bushing CT's, if any, has been shorted
- Ensure CT secondary star point has been formed properly and grounded at one end only as per scheme
- Ensure that Buchholz Relay is correctly mounted with arrow pointing towards conservator
- Ensure all power and control cable terminals are tightened
- Ensure all cables and ferrules are provided with number as per cable schedule
- Ensure that external cabling from junction box to relay / control panel is completed
- Ensure operation of OLTC manually, electrically at local and electrically by RTCC
- Ensure indication of tap position on Diverter switch, Drive mechanism & RTCC are same.
- Ensure working of numerical AVR

4.3 **List of Site Acceptance Tests**

Following pre-commissioning Tests / checks should be carried out:

Sr. No	Test / Checks Name	Testing Equipments
1	SFRA Test	Automatic SFRA kit
2	Capacitance and Tan delta measurement Test	Automatic Capacitance & Tan delta measurement kit
3	Transformer turns ratio Test	Digital Ratio meter
4	Magnetizing current Test	Digital multi meter
5	Magnetic balance Test	Digital multi meter
6	Verification of vector group and polarity test	Digital multi meter
7	Short circuit impedance test	Digital multi meter
8	Measurement of winding resistance test	Digital winding resistance meter

Sr. No	Test / Checks Name	Testing Equipments
9	Winding Insulation Resistance measurement	Digital insulation resistance meter
10	Core Insulation Resistance measurement	Digital insulation resistance meter
11	Oil characteristic test	Oil BDV test kit
12	Tests on bushing CT s	Digital multi meter, CT primary current injection kit, Knee point voltage measurement kit, Insulation resistance tester
13	Operational tests and checks on other equipments	--
14	Measurement of earthing pit resistance	Earth resistance measurement kit
15	Protection and alarms	As per scheme
16	Contact resistance measurement	Contact resistance measurement kit
17	Clearances	Measurement tape/ Automatic Infra red gun
18	Protection relay settings	As per scheme
19	Final documentation review	As per requirement

4.3.1 SFRA Test

(a) Purpose of the test

The transformer is considered to be a complex network of RLC components. The contribution to this complex mesh of RLC circuit are from the resistance of the copper winding, inductance of the winding coils and capacitance from the insulation layers between coils, between winding, between winding and core, between core and tank, between tank and winding etc. (figure 5.5).

(b) Principle of the test

Any form of physical damage to the transformer results in the changes of the RLC network. These changes are looking for and employ frequency response to highlight these small changes in the RLC within the transformer.

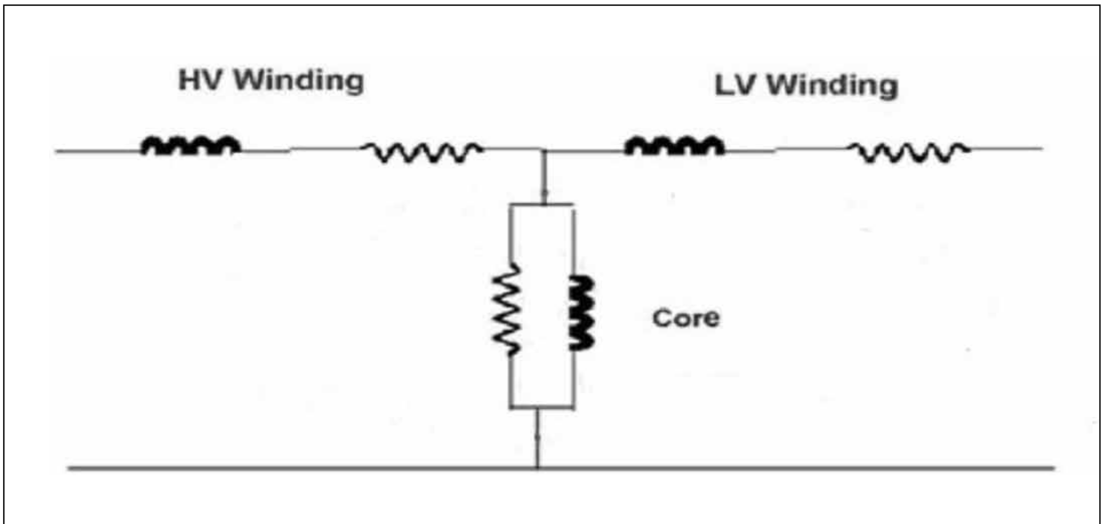


Fig. 5.5:

The test involves measuring the frequency response of each individual winding. The frequency is measured by injecting a sine wave signal with respect to earth at one end of winding to be tested and measuring the signal amplitude there and at other end of winding. The attenuation (in db) of the transmitted signal relative to reference signal at the input terminal is measured over a frequency range from 20 Hz to 2 MHz. SFRA is used to check the eventual change in the internal geometry of the active part of the transformer whether displacement of deformation i.e. the mechanical integrity of the transformer.

Transformers while experiencing severity of short circuit current looses its mechanical property by way of deformation of the winding or core. During pre-commissioning, this test is required to ascertain that Transformer active part has not suffered any severe impact/ jerk during transportation.

(c) Equipments for the test

Automatic SFRA test kit with application software

(d) Circuit for the test (figure 5.6)

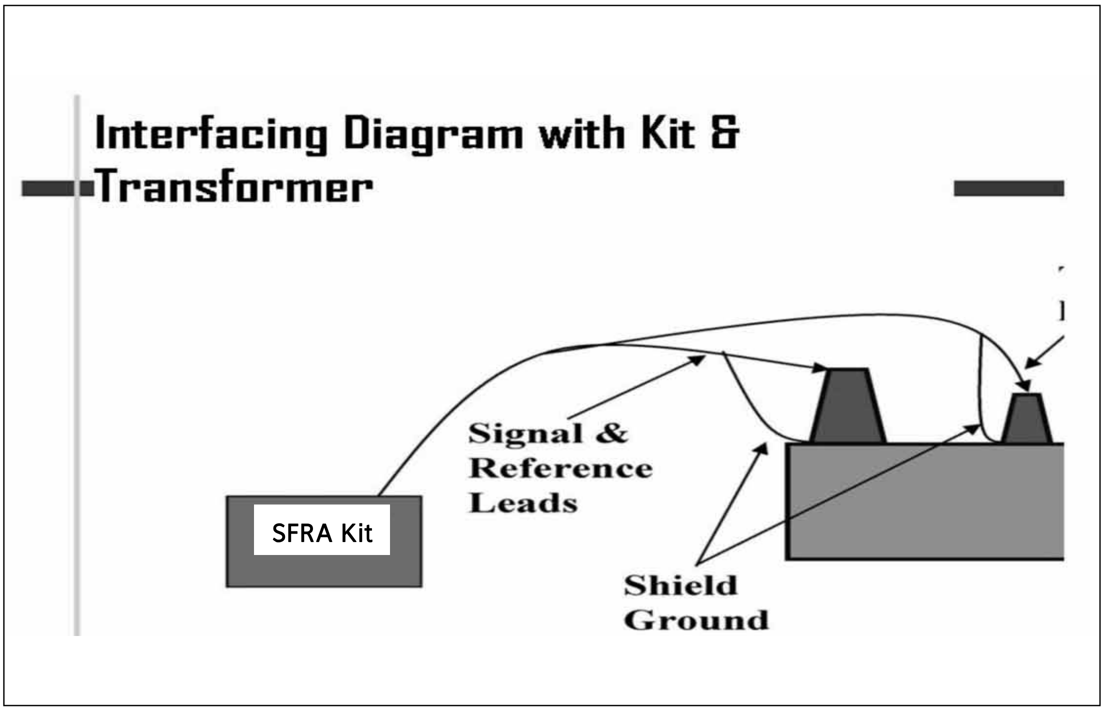


Fig. 5.6:

(e) Procedure for the test

- This test is carried out after completion of all commissioning activities.
- Factory FRA test report in soft form should be available at site.
- FRA signatures will be taken after assembly and oil filling and compared with factory testing to ensure the healthiness of core /coil assembly during transportation.
- Interpretation of test results carried out
- Test results matching with the factory results
- 10 V AC is applied at variable frequency (20Hz to 2 MHz) to the winding for all possible connections of the winding
- These signatures will be the benchmark for future reference.
- The FRA signatures should be analyzed in conjunction with Impact Recorder readings.
- Report of Impact recorder readings is to be obtained from manufacturer.
- It is recommended to follow the standard procedure for the SFRA measurement as per the standard test procedure recommended by the manufacturer.
- It should be done on maximum, normal and minimum tap of the transformer.

Type of connections for the test (figure 5.7) and typical waveform (figure 5.8).

A. **HV Phase to Neutral with LV open**

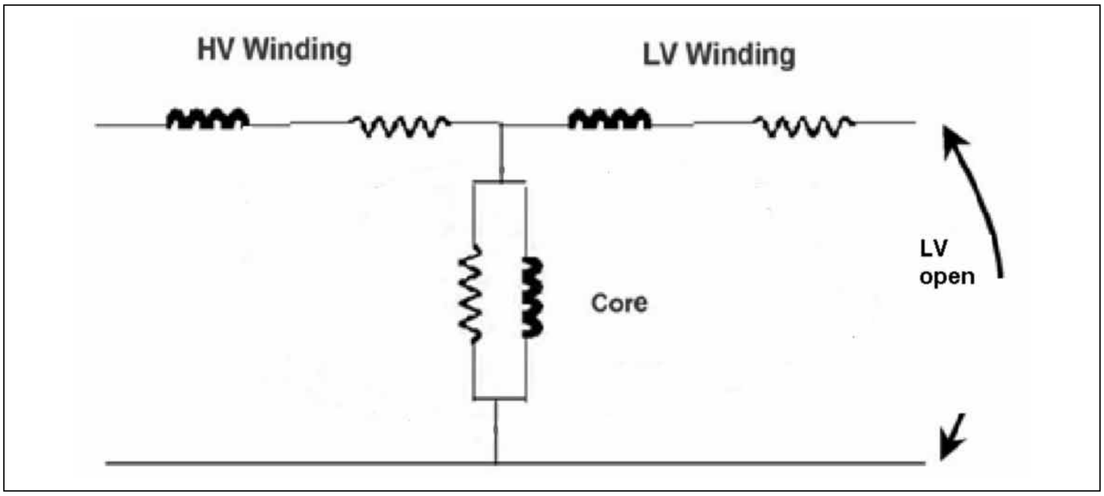


Fig. 5.7:

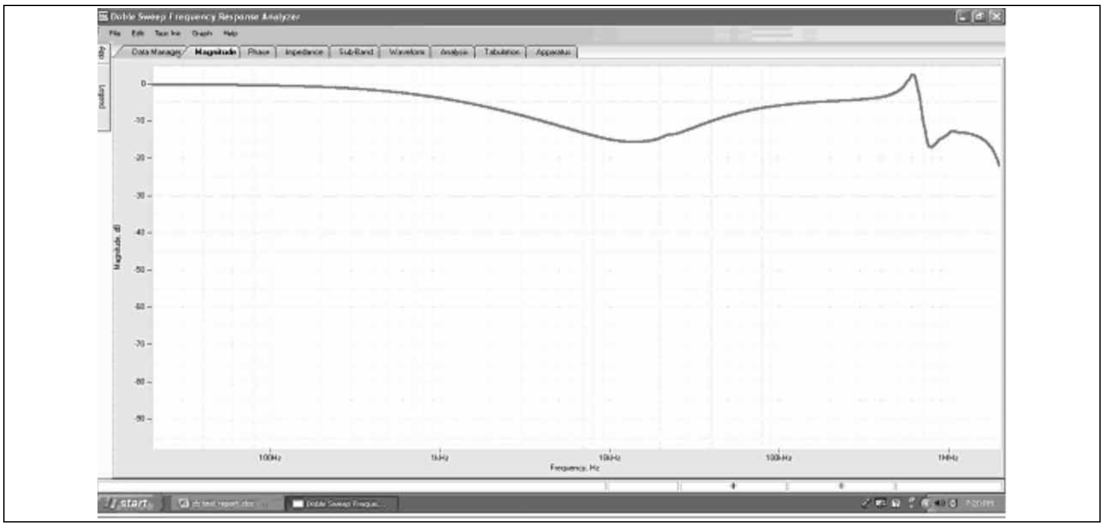


Fig. 5.8:

1. Feed the frequency signal from 20 Hz -2 MHz in the transformer R ph of the HV winding with respect to the neutral (for star winding) and R ph of HV winding with Y ph of HV winding (for delta winding).
2. Both the reference leads should be earthed properly.
3. Keep LV open (including core)
4. Kit will receive the response of the impedance characteristic in the transformer.
5. Response will be plotted in logarithmic scaled graph.
6. Repeat the all procedures for other phases

B. **HV Phase to Neutral with LV shorted**
(Connection see figure 5.9 and typical waveform figure 5.10)

1. Feed the frequency signal from 20 Hz -2 MHz in the transformer R ph of the HV winding with respect to the neutral (for star winding) and R ph of HV winding with Y ph of HV winding (for delta winding).
2. Both the reference leads should be earthed properly.

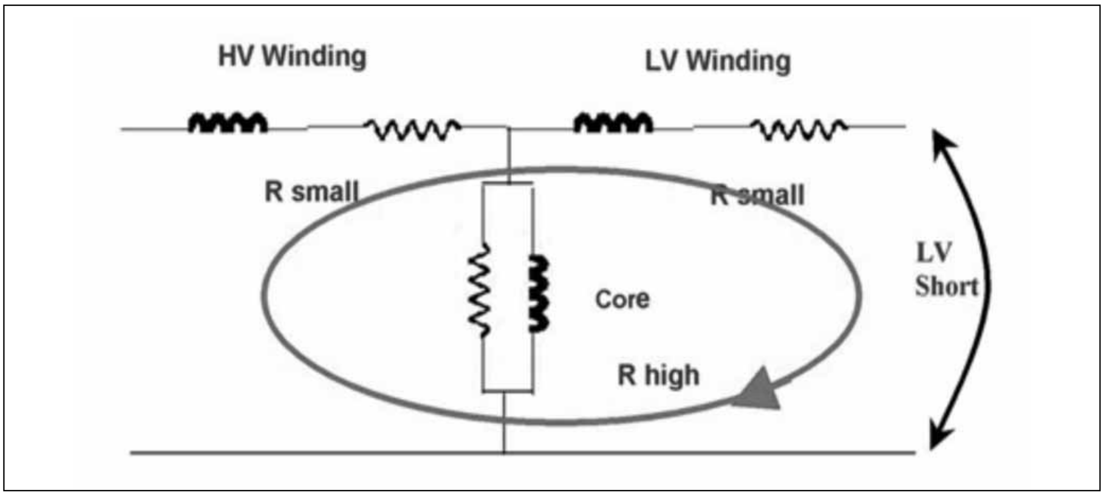


Fig. 5.9:

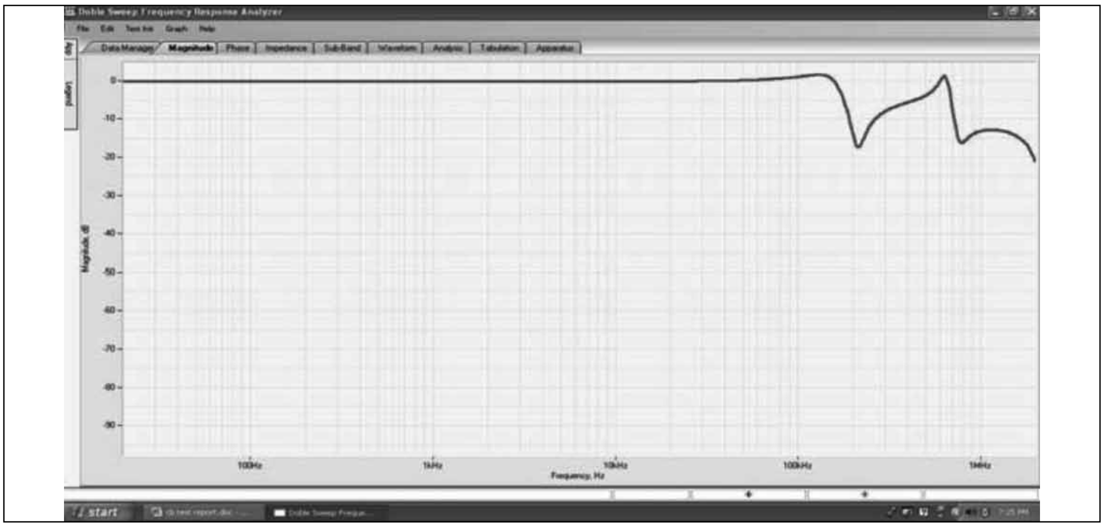


Fig. 5.10:

3. Keep LV winding shorted (core is avoided)
4. Kit will receive the response of the impedance characteristic in the transformer.
5. Response will be plotted in logarithmic scaled graph.
6. Repeat all the procedures for other phases

C. **LV Phase to Neutral with HV open**
(Connection see figure 5.11 and typical waveform figure 5.12)

1. Feed the frequency signal from 20 Hz -2 MHz in the transformer R ph of the LV winding with respect to the neutral (for star winding) and R ph of HV winding with Y ph of LV winding (for delta winding).
2. Both the reference leads should be earthed properly.
3. Keep LV winding open
4. Kit will receive the response of the impedance characteristic in the transformer.
5. Response will be plotted in logarithmic scaled graph.
6. Repeat all the procedures for other phases

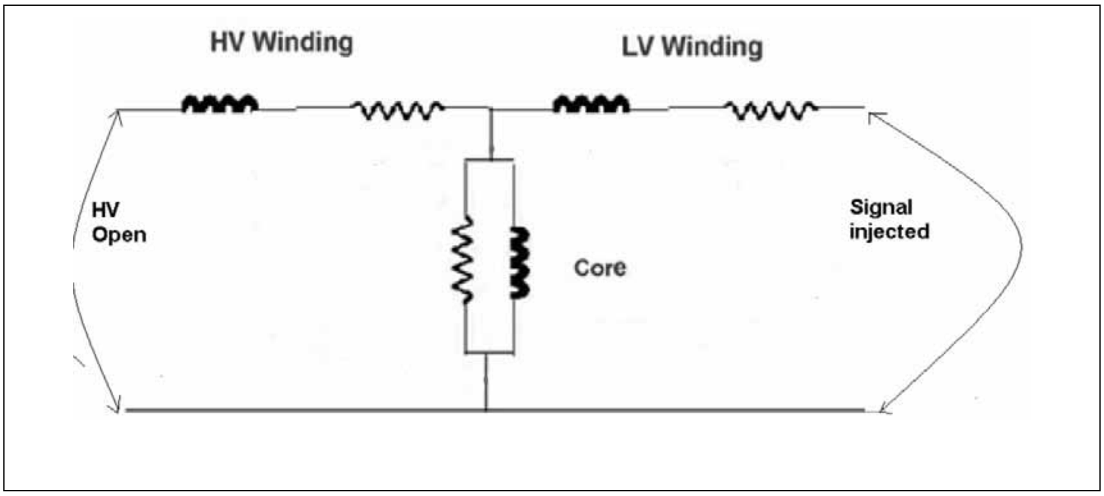


Fig. 5.11:

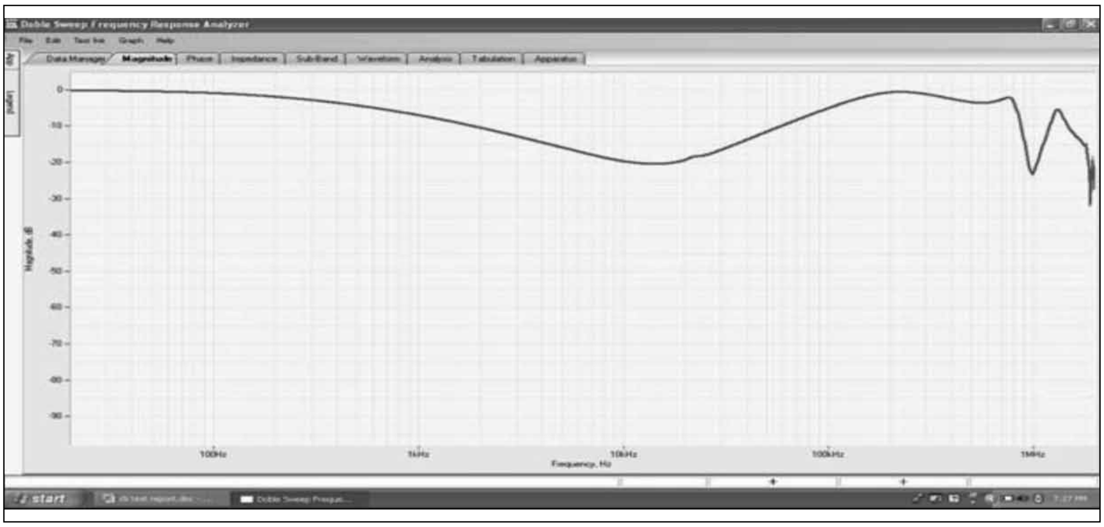


Fig. 5.12:

D. **Between HV and LV winding**

(Connection see figure 5.13 and typical waveform figure 5.14)

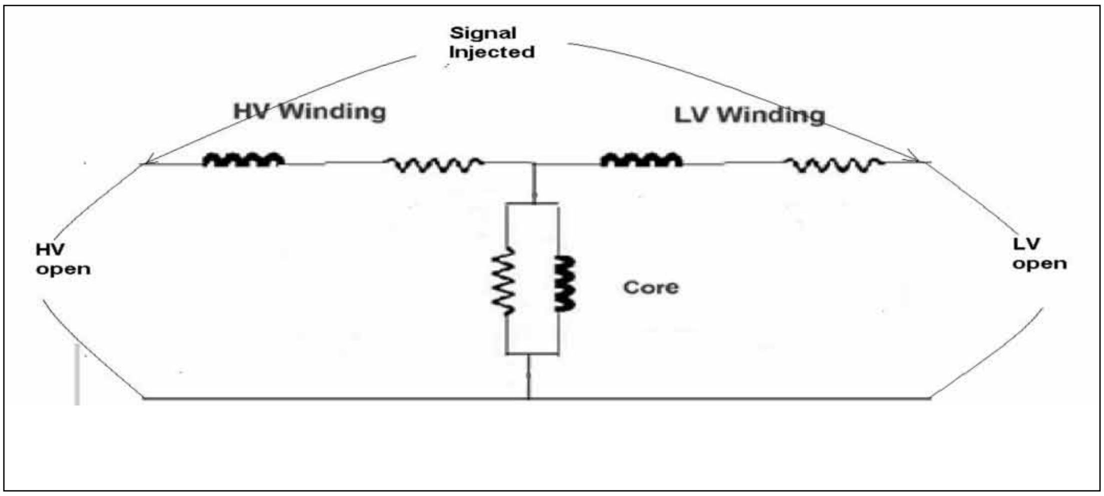


Fig. 5.13:

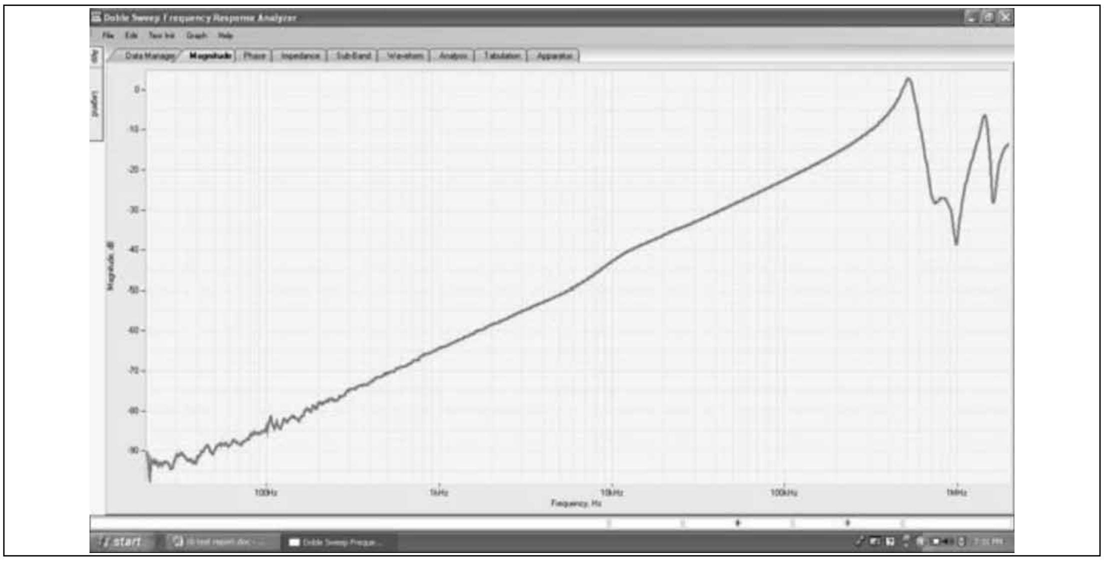


Fig. 5.14:

1. Feed the frequency signal from 20 Hz -2 MHz in the transformer R ph of the HV winding with respect to the LV winding
2. Both the reference leads should be earthed properly.
3. Keep LV winding open
4. Kit will receive the response of the impedance characteristic in the transformer.
5. Response will be plotted in logarithmic scaled graph.
6. Repeat all the procedures for other phases

Maximum possible combinations of connections for SFRA test

Test Type	Test	3 phase	1 phase
Series winding (OC) All other terminals floating	Test 1	H1-X1	H1-X1
	Test 2	H2-X2	
	Test 3	H3-X3	
Common winding (OC) All other terminals floating	Test 4	X1-H0X0	X1-H0X0
	Test 5	X2-H0X0	
	Test 6	X3-H0X0	
Tertiary winding (OC) All other terminals floating	Test 7	Y1-Y3	Y1-Y2 (Y1-Y0)
	Test 8	Y2-Y1	
	Test 9	Y3-Y2	
Short circuit (SC) High (H) to Low (L) Short (X1-X2-X3)	Test 10	H1-H0X0	H1-H0X0 Short (X1-H0X0)
	Test 11	H2-H0X0	
	Test 12	H3-H0X0	
Short circuit (SC) High(H) to tertiary (Y) Short (Y1-Y2-Y3)	Test 13	H1-H0X0	H1-H0X0 Short (Y1-Y2)
	Test 14	H2-H0X0	
	Test 15	H3-H0X0	
Short circuit (SC) Low(L) to tertiary (Y) Short (Y1-Y2-Y3)	Test 16	X1-H0X0	X1-H0X0 Short (Y1-Y2)
	Test 17	X2-H0X0	
	Test 18	X3-H0X0	

e) **Acceptance Criteria**

Test results should match with the factory results

(*In general changes of +/- 3dB*)

If changes are more than limit, it may indicate following faults:	
Frequency Range	**Probable Fault**
5 Hz to 2 KHz	Shorted turns, open circuit, residual magnetism or core movement
50 Hz to 20 KHz	Bulk movement of winding relative to each other
500 Hz to 2 MHz	Deformation within a winding
5 Hz to 10 MHz	Problem with winding leads and/or test lead problem

f) **Format for the test report**

Equipment Detail:

Make	Type	Sr. No.	Range	Cal. Due Date
Close				

1.1 **Low frequency region (20 Hz<1 kHz)**

HV-N side

Tap position	Resonance value in dB (Site)			Resonance value in dB(Factory)			Remarks
	1U-1N	1V-1N	1W-1N	1U-1N	1V-1N	1W-1N	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							

IV-N side

Tap position	Resonance value in dB (Site)			Resonance value in dB(Factory)			Remarks
	2U-2N	2V-2N	2W-2N	2U-2N	2V-2N	2W-2N	
Normal							

LV side

Tap position	Resonance value in dB (Site)			Resonance value in dB (Factory)			Remarks
	3U-3V	3V-3W	3W-3U	3U-3V	3V-3W	3W-3U	
Normal							

1.2 **Medium frequency region (>1 kHz - 100 kHz)**

HV-N side

Tap position	Resonance value in dB (Site)			Resonance value in dB (Factory)			Remarks
	1U-1N	1V-1N	1W-1N	1U-1N	1V-1N	1W-1N	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							

IV-N side

Tap position	Resonance value in dB (Site)			Resonance value in dB (Factory)			Remarks
	2U-2N	2V-2N	2W-2N	2U-2N	2V-2N	2W-2N	
Normal							

LV side

Tap position	Resonance value in dB (Site)			Resonance value in dB (Factory)			Remarks
	3U-3V	3V-3W	3W-3U	3U-3V	3V-3W	3W-3U	
Normal							

1.3 **High frequency region (>101 kHz – 2MHz)**

HV-N side

Tap position	Resonance value in dB (Site)			Resonance value in dB (Factory)			Remarks
	1U-1N	1V-1N	1W-1N	1U-1N	1V-1N	1W-1N	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							

IV-N side

Tap position	Resonance value in dB (Site)			Resonance value in dB (Factory)			Remarks
	2U-2N	2V-2N	2W-2N	2U-2N	2V-2N	2W-2N	
Normal							

LV side

Tap position	Resonance value in dB (Site)			Resonance value in dB (Factory)			Remarks
	3U-3V	3V-3W	3W-3U	3U-3V	3V-3W	3W-3U	
Normal							

4.3.2 Capacitance and Tan Delta Measurement Test

a) Purpose of the test

Dissipation factor / loss factor/ Tan delta is defined as the ratio of resistive components to that of capacitive current flowing in an insulating material. Dissipation factor (tan delta) and capacitance measurement of bushing/winding provides an indication of the quality and soundness of the insulation in the bushing/winding.

Changes in the normal capacitance of an insulator indicate abnormal conditions such as the presence of moisture layer, short -circuits or open circuits in the capacitance network.

b) **Principle of the test**

The capacitance and dissipation/loss factor (Tan δ / Cos ϕ) measurement are made to determine the insulating condition of the transformer's both winding to earth and between the windings, and to form a reference for future measurements during operating the transformer.

There is a small amount of insulating loss in all insulators used in transformer applications at normal operating voltage and frequency. In appropriate insulators, this loss is very small. This loss changes in direct proportion with the "square "of the applied voltage. The insulator and equivalent diagrams are given in figure 5.15.

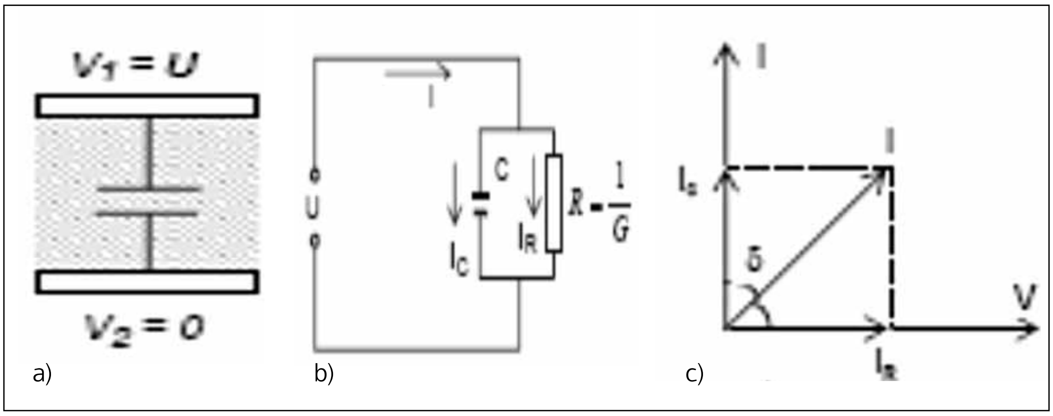


Fig. 5.15:

As seen in figure, the angle delta 'between the total current "Ir" and capacitive current "IC" allows to make evaluation about the loss properties of the insulator.

The loss angle delta, depends heavily on the thick ness of the insulating material and surface condition, structural property of the insulator, type of the material, (humidity, foreign materials/ particles, air gaps, etc. which cause ionization the insulating material).

The conditions which increase the power losses of the insulator also decrease the insulation strength. For this reason, loss angle measurement is a very valuable criterion for evaluating the insulation material at a defined operating frequency. Periodical measurements made during operating are also important to show the general condition of the insulating material. In this way, it is possible to gather information about aging of the solid insulating materials and degradation of the oil.

The active loss of the measurement circuit can be calculated according to below equation:

$P= U. I. Cos\ delta = U^2. C. \omega. tan\ delta$

(It is accepted that in very small angles, Cos delta will be equal to tan delta)

Capacitance, tan delta, active loss and Cos delta can be measured by bridge methods at defined voltages or by a "power factor" (Cos delta) measuring instrument.

The measurement is made between windings and between the windings and the tank. During the test, the temperature of the transformer should also be recorded and corrected in accordance with the reference temperature.

The loss factor depends heavily on temperature. For this reason, in order to make comparisons later, it has to be converted to reference temperature (for example 20 deg reference temperature) by a coefficient.

Correction equation:

$F20 = Ft / K$

F20: loss factor at 20 °C temperature

Ft: loss factor value at t measuring temperature

K: correction factor is given in the table

Correction factor for transformer with mineral oil:

Measurement temperature Deg. C	Correction factor K
10	0.8
15	0.9
20	1
25	1.12
30	1.25
35	1.4
40	1.55
45	1.75
50	1.95
55	2.18
60	2.42
65	2.70
70	3.0

c) **Equipment for the test:**

10 KV or 12 KV fully automatic Capacitance and Tan delta test kit to be used for accurate measurement and repeatability of test results

4.3.2.1 **Transformer winding insulation tests**

a) **Procedure for the test**

1. In a two winding transformer, there are three measurements of capacitance
   i. HV to ground
   ii. LV to ground
   iii. HV to LV
2. These values of capacitance and their respective values of insulation factor (tan delta) are to be measured.
3. All HV line terminals connected together and labeled (H); all LV line terminals connected together and labeled (L); and a connection to a ground terminal, usually connected to transformer tank labeled (G).
4. Leads from the instrument or bridge are connected to one or both terminals and ground.
5. Either grounded specimen measurement of guarded measurements are possible, so that all capacitance values and dissipation factor values can be determined.
6. These measurements are usually made at voltage of 10 kV or less, at power frequency.

b) **Connection diagram**

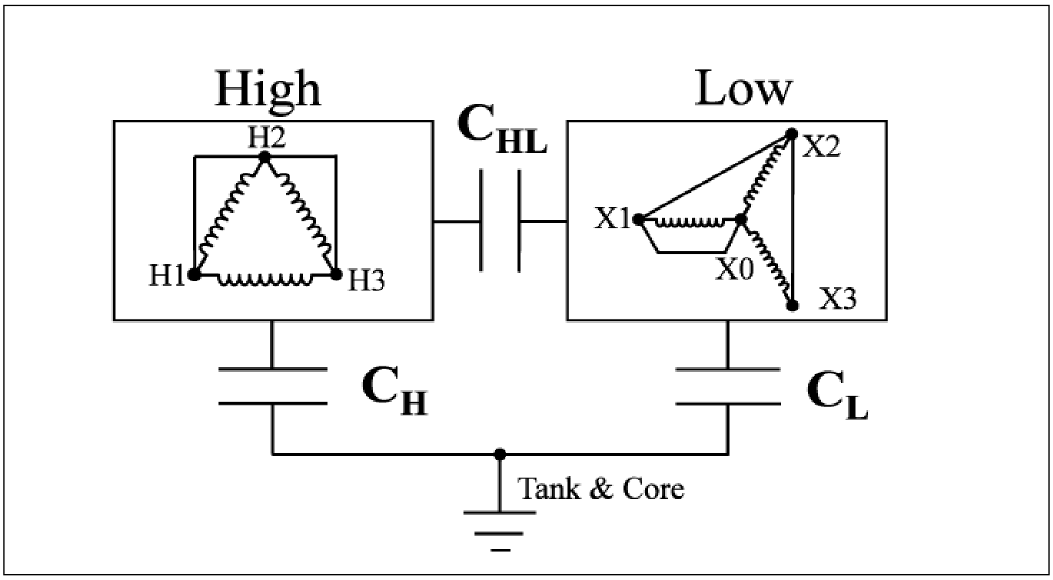


Fig. 5.16:

For tan delta of bushings, connections are to be carried out in UST mode.

For tan delta between windings, connections are to be carried out in UST mode.

For tan delta of windings with earth, connections are to be carried out in GST mode.

(i) **HV winding measurement**

1. Short all the three phases of HV winding and make the zero sequence impedance. In other words, make the current flow only in capacitance region (Omit inductance) in the impedance network of the transformer.

2. Make HV cable connection at HV terminals and LV cable at neutral (ground should be isolated). If it is delta connection then LV cable connection to be made in next phase.

3. Select the test mode GST-G for capacitance measurement in between windings and GST-YG for capacitance measurement in between windings.

3. Apply 10 kV voltage in the stepwise manner and cross check the values in all step voltages.

4. Note the measurement values of applied voltage, leakage current, power factor and dissipation factor, capacitance, humidity and ambient temperature.

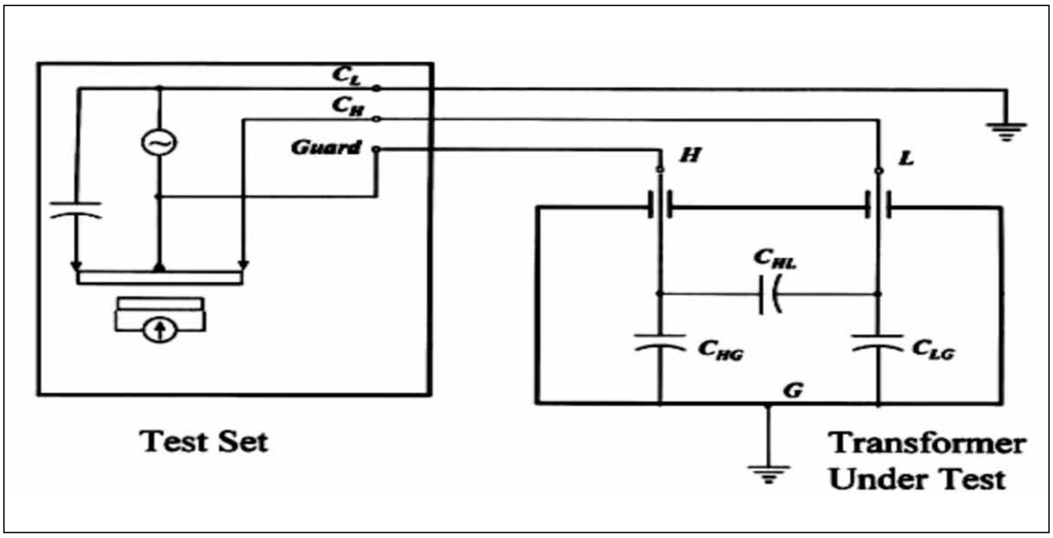


Fig. 5.17:

(ii) **HV-LV connection**

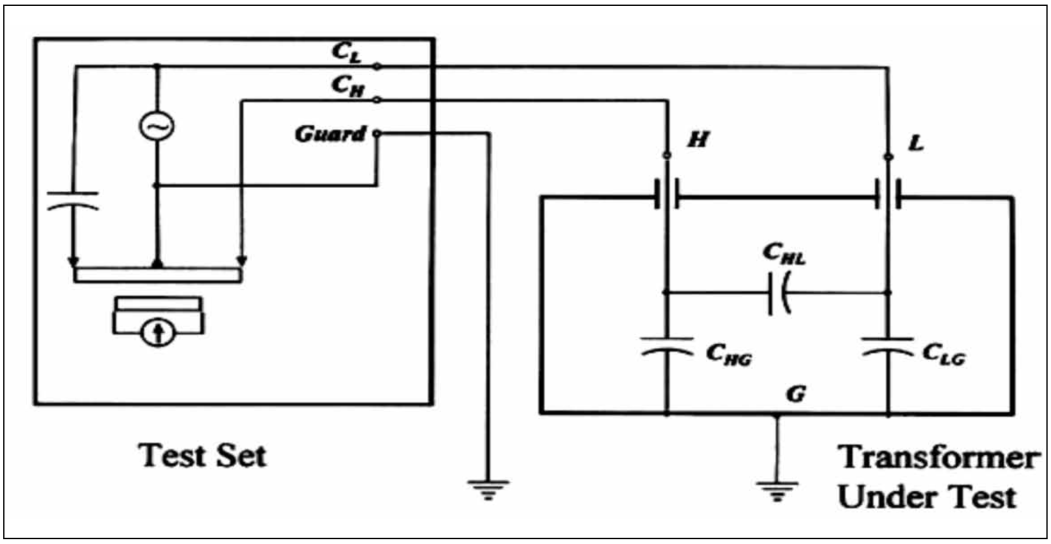


Fig. 5.18:

1. Short all the three phases of HV and LV winding and make the zero sequence impedance. In other words, make the current flow only in capacitance region (Omit inductance) in the impedance network of the transformer.

2. Make HV cable connection at HV terminals and LV cable at LV terminals.

3. Select the test mode UST-YG for capacitance measurement in between tank and winding.
4. Apply 10 kV voltage in the stepwise manner and cross check the values in all step voltages.
5. Connections of the leads to be carried out as per diagram.
6. Note the measurement values of applied voltage, leakage current, power factor and dissipation factor, capacitance, humidity and ambient temperature.

(iii) **LV- Earth connection**

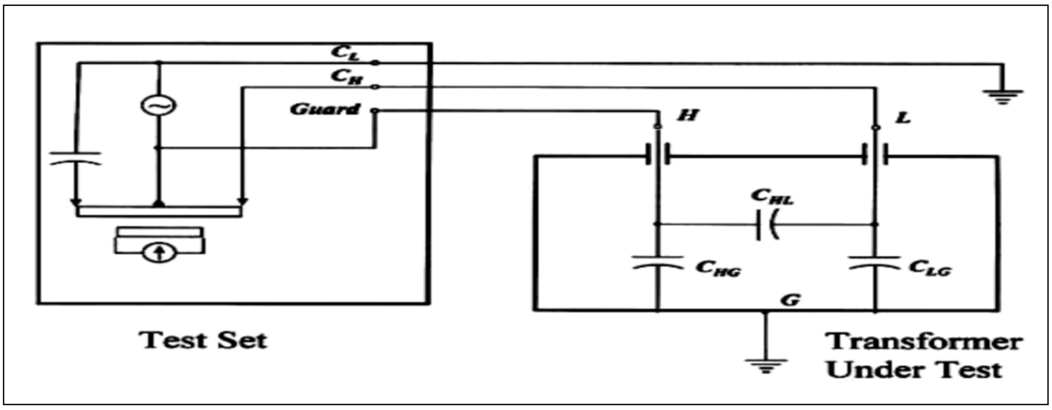


Fig. 5.19:

1. Short all the three phases of LV winding and make the zero sequence impedance. In other words, make the current flow only in capacitance region (Omit inductance) in the impedance network of the transformer.
2. Make HV cable connection at LV terminals and LV cable at Neutral terminals. (Ground should be isolated). If it is delta connection then LV cable connection to be made in next phase.
3. Select the test mode GST-G for capacitance measurement in between windings and GST-YG for capacitance measurement in between windings.
4. Apply 10 kV voltage in the stepwise manner and cross check the values in all step voltages.
5. Connections of the leads to be carried out as per diagram
6. Note the measurement values of applied voltage, leakage current, power factor and dissipation factor, capacitance, humidity and ambient temperature.

(iv) **LV-HV connection**

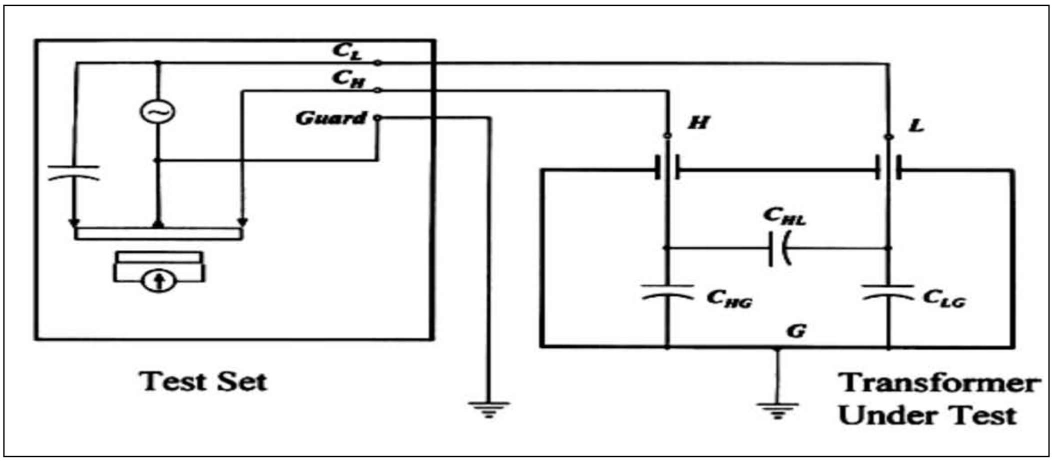


Fig. 5.20:

1. Short the all three phases of LV and HV winding and make the zero sequence impedance. In other words, make the current flow only in capacitance region (Omit inductance) in the impedance network of the transformer.
2. Make HV cable connection at LV terminals and LV cable at HV terminals.
3. Select the test mode UST-YG for capacitance measurement in between tank and windings.
4. Apply 10 kV in the stepwise manner and cross check the values in all step voltages.
5. Connections of the leads to be carried out as per diagram
6. Note the measurement values of applied voltage, leakage current, power factor and dissipation factor, capacitance, humidity and ambient temperature.

4.3.2.2 **Transformer bushing insulation test**

a) **Procedure for the test**

Measurement of C1 Capacitance and Tan delta

1. Connect the crocodile clip of the HV cable to the top terminal of the shorted HV/IV bushings.
2. Unscrew the test tap cover, Insert a pin in the hole of the central test tap stud by pressing the surrounding contact plug in case of 245 kV OIP Bushing and remove the earthing strip from the flange by unscrewing the screw (holding earth strip to the flange body) in case of 420 kV OIP Bushing.
3. Connect the LV cable to the test tap (strip/central stud) of the bushing under test to the kit through a screened cable and earth the flange body.
4. Repeat the test for all Bushings by changing only LV lead connection of the kit to test tap of the Bushing which is to be tested

Measurement of C2 Capacitance and Tan delta

1. HV lead to be connected to the test tap of the bushing under test (if required additional crocodile type clip may be used) and LV of the kit to be connected to the ground. HV of the bushing is to be connected to the Guard terminal of the test kit.
2. Test to be carried out in GSTg mode at 1.0kV.
3. Repeat the test for all Bushings by changing only LV lead connection of the kit to test tap of the Bushing which is to be tested

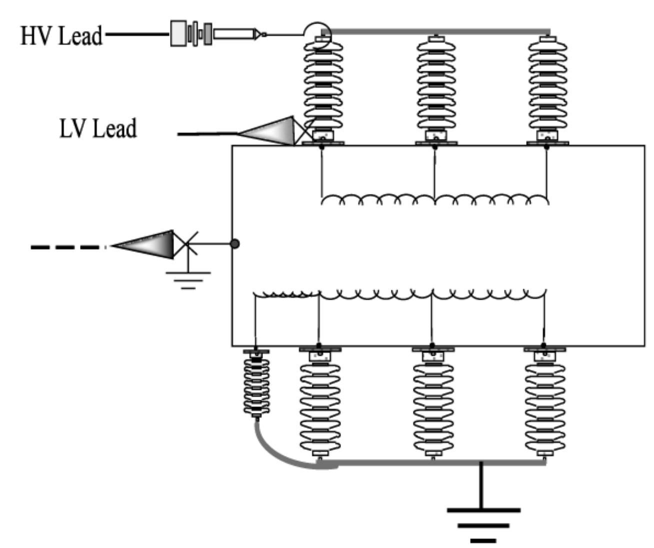


Fig. 5.21:

b) **Format of the Test Report**

Test equipment

Make	Type	Sr. no.	Range	Cal. Due date

c) **Format of the Test Report for Windings**

VOLTAGE	WINDING COMBINATION	TEST MODE	CAPACITANCE		TAN δ		REMARK
			SITE	FACTORY	SITE	FACTORY	
2 KV	HV-IV/ LV	UST					
10 KV							
2 KV	HV-IV/ LV+G	GST					
10 KV							
2 KV	HV-IV/ LV with Guard	GSTg					
10 KV							
2 KV	LV/ HV-IV	UST					
10 KV							
2 KV	LV/ HV-IV+G	GST					
10 KV							
2 KV	LV/ HV-IV with Guard	GSTg					
10 KV							

d) **Format of the Test Report for Bushings (C1)**

VOLTAGE	Bushings/ Make/ Sr. no	TEST MODE	Capacitance C1		TAN δ		REMARK
			SITE	FACTORY	SITE	FACTORY	
2 KV	1U	UST					
10 KV							
2 KV	1V	UST					
10 KV							
2 KV	1W	UST					
10 KV							
2 KV	2U	UST					
10 KV							
2 KV	2V	UST					
10 KV							
2 KV	2W	UST					
10 KV							

e) **Format of the Test Report for Bushings (C2)**

VOLTAGE	Bushings/ Make/ Sr. no.	TEST MODE	Capacitance C2		TAN δ		REMARK
			SITE	FACTORY	SITE	FACTORY	
0.5 KV	1U	GST					
1.0 KV							
0.5 KV	1V	GST					
1.0 KV							
0.5 KV	1W	GST					
1.0 KV							
0.5 KV	2U	GST					
1.0 KV							
0.5 KV	2V	GST					
1.0 KV							
0.5 KV	2W	GST					
1.0 KV							
0.5 KV	3U	GST					
1.0 KV							
0.5 KV	3V	GST					
1.0 KV							
0.5 KV	3W	GST					
1.0 KV							

f) **Acceptance Criteria**

Tan δ for bushing (C1):

Type of bushing	Tan δ (C1)		Capacitance
	% Limit	% Change/annum	% Change/annum
Resin impregnated paper insulated	0.85	+0.04 / -0.04	+1.0 / -1.0
Oil impregnated paper insulated	0.40	+0.02 / -0.06	+1.0 / -1.0

Tan δ for winding – Limit 0.01 (1.0%)

4.3.3 Voltage and Turns Ratio Measurement

4.3.3.1 Voltage Ratio Measurement

a) **Purpose of the test**

To determine

a. Any abnormality in tapings in the winding
b. Any abnormality in the winding
c. Result ensures the inductance property of the transformer

b) **Equipment for the test**

Digital multi meter

c) **Principle for the Test**

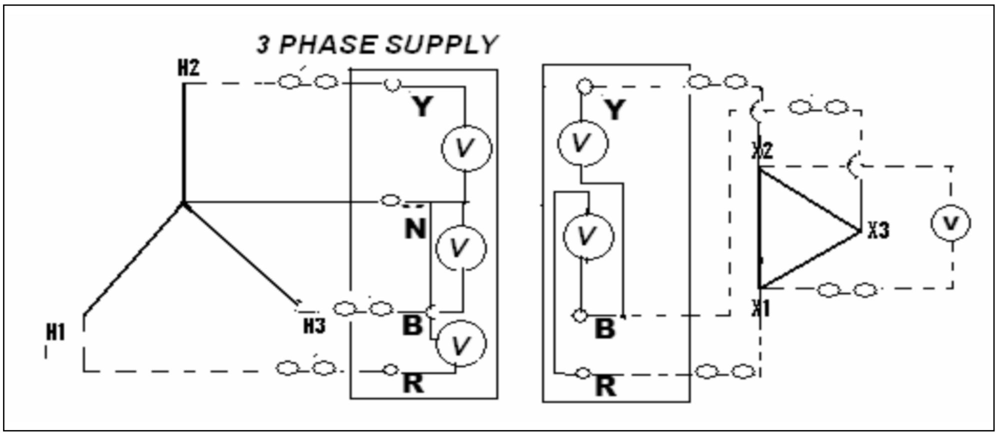


Fig. 5.22:

The total voltage induced into the secondary winding of a transformer is proportional to the number of turns in the primary to the number of turns in the secondary, and by the amount of voltage applied to the primary.

d) **Procedure for the Test**

1. Keep the tap position of the transformer in lowest position and LV in open
2. The voltage should be applied in the high voltage winding in order to avoid unsafe voltage
3. Apply 3 phase 415 V on HV terminals
4. Measure the voltage on each phase (ph-ph) on HV and LV terminals simultaneously.
5. Ratio measurement must be made on all the taps to confirm the proper alignment and operation of the tap changer.
6. Calculate the turns ratio in each tap position of tap: Vp/Vs

e) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

f) **Format of the Test Report**

Ratio HV/IV

Tap no.	Applied HV voltage			Measured LV voltage			Ratio calculated			Ratio actual
	1U-1N	1V-1N	1W-1N	2U-2N	2V-2N	2W-2N	1U-1N/ 2U-2N	1V-1N/ 2V-2N	1W-1N/ 2W-2N	
1										
2										
3										
4										
5										
6										
7										

Tap no.	Applied HV voltage			Measured LV voltage			Ratio calculated			Ratio actual
	1U-1N	1V-1N	1W-1N	2U-2N	2V-2N	2W-2N	1U-1N/ 2U-2N	1V-1N/ 2V-2N	1W-1N/ 2W-2N	
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										

Ratio HV/LV

Tap no.	Applied HV voltage			Measured LV voltage			Ratio calculated			Ratio actual
	1U-1N	1V-1N	1W-1N	3W-3U	3U-3V	3V-3W	1U-1N/ 3W-3U	1V-1N/ 3U-3V	1W-1N/ 3V-3W	
N										

Ratio IV/LV

Tap no.	Applied HV voltage			Measured LV voltage			Ratio calculated			Ratio actual
	2U-2N	2V-2N	2W-2N	3W-3U	3U-3V	3V-3W	2U-2N/ 3W-3U	2V-2N/ 3U-3V	2W-2N/ 3V-3W	
N										

g) **Acceptance Criteria**

The variation of result should be within ± 0.5 % from specified values.

4.3.3.2 **Transformer Turns Ratio Test**

a) **Purpose of the test**

To determine the turns ratio of transformers to identify any abnormality in tap changers/ shorted or open turns etc.

b) **Equipment for the test**

Automatic Transformer turns ratio (TTR) meter

c) **Principle for the test**

The total voltage induced into the secondary winding of a transformer is proportional to the number of turns in the primary to the number of turns in the secondary, and by the amount of voltage applied to the primary.

d) **Procedure for the Test**

1. Connect H1 and H2 leads on HV winding and X1 and X2 leads on LV winding.
2. Apply 110 V AC from the kit.
3. Adjust the phase angle error on zero.
4. Adjust % error knob such that null detector shows zero.
5. Carry out the test for all taps.

e) **Equipment**

Test equipment

Make	Type	Sr. no.	Range	Cal. Due date

f) **Format of the Test Report**

HV/IV

Tap no.	HV Voltage KV	LV Voltage KV	Theoretical ratio	Obtained Ratio Error in %		
				R Ph	Y Ph	B Ph
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						

(b) **HV/LV**

Tap no.	HV Voltage KV	LV Voltage KV	Theoretical ratio	Obtained Ratio Error in %		
				R Ph	Y Ph	B Ph
N						

(c) **IV/LV**

Tap no.	HV Voltage KV	LV Voltage KV	Theoretical ratio	Obtained Ratio Error in %		
				R Ph	Y Ph	B Ph
N						

g) **Acceptance Criteria**

The variation of result should be within ± 0.5 % from specified values.

4.3.4 Magnetizing Current Test

a) **Purpose of the Test**

Excitation/ Magnetizing current test is performed to locate defect in magnetic core structure, shifting of windings, failure in turn to turn insulation or problem in tap changer.

b) **Principle of the Test**

Excitation/ Magnetizing current is the current required to force a given flux through the core. It is the RMS value of the current flowing through a line terminal of a winding when voltage is applied at rated frequency, the other winding being open circuited.

c) **Equipments for the Test**

Digital multi meter

d) **Circuit for the Test**

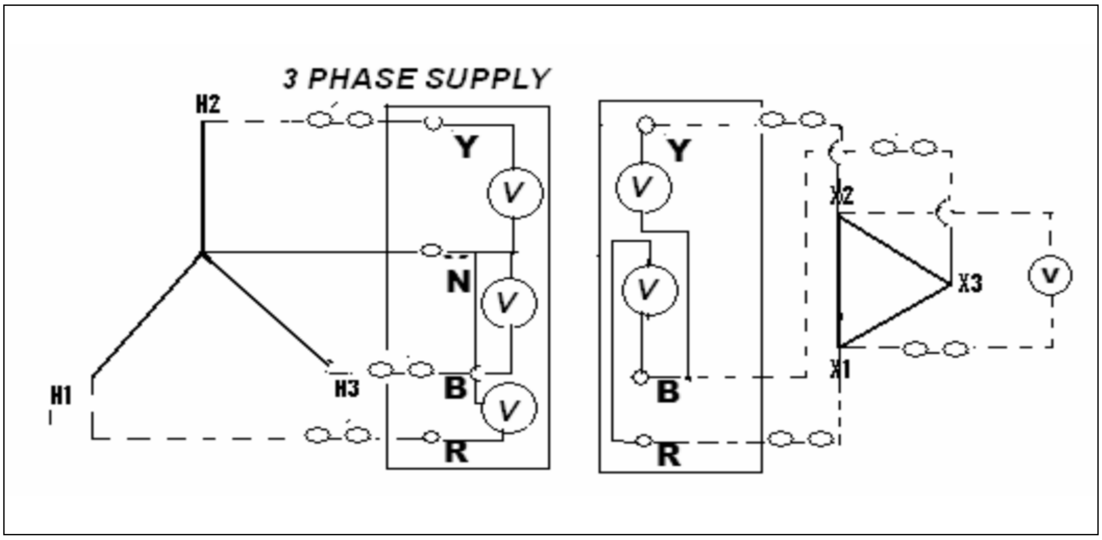


Fig. 5.23:

e) **Procedure for the Test**

1. Apply 3 phase 440 V AC supply on HV terminals and keep LV open.
2. Measure current in all the three phases.
3. Carry out the test on max., normal and min. tap position.
4. Repeat the test for LV side.

f) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

g) **Format of the Test Report**

Magnetizing current from HV

Voltage applied in volts		Current measured in mA Tap 1		Current measured in mA Tap 13		Current measured in mA Tap 17	
1U-1N		1U		1U		1U	
1V-1N		1V		1V		1V	
1W-1N		1W		1W		1W	

Magnetizing current from LV

Voltage applied in volts		Current measured in mA Tap 1		Current measured in mA Tap 13		Current measured in mA Tap 17	
2U-2N		2U		2U		2U	
2V-2N		2V		2V		2V	
2W-2N		2W		2W		2W	

h) **Acceptance Criteria**

- Excitation current < 50 mili-Amperes, then difference between two higher currents should be less than 10%.
- Excitation current > 50 mili-Amperes, then difference between two higher currents should be less than 15 %.
- Value of center leg should not be more than either outside for a three phase reactor.
- Results between similar single phase units should not vary more than 10%.

4.3.5 Magnetic Balance Test

a) **Purpose of the Test**

To check the balance in the magnetic circuit (core balance) in three phase transformers. It verifies core balance.

b) **Principle of the Test**

The voltage should be applied in one phase and measured in the other two phase of the winding. The sharing of the voltage will be maximum in the next phase of the winding (clock wise) more than 60% of the injected voltage and minimum voltage appear in another phase of the winding (clock wise) less than 40% of the injected voltage.

c) **Equipments for the Test**

Digital multi meter

d) **Circuit for the Test**

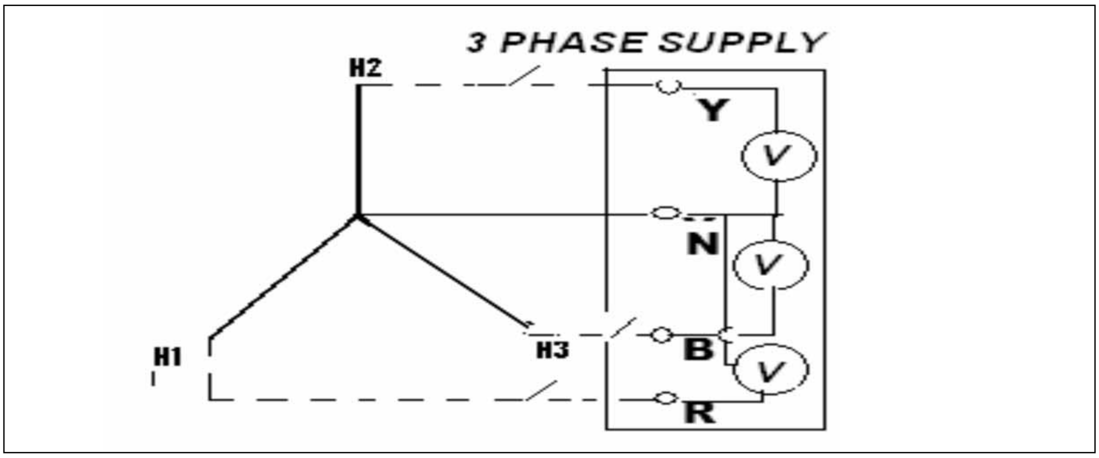


Fig. 5.24:

e) **Procedure for the Test**

1. For delta connected winding, apply 3 phase 440 V between phase to phase of a winding and measure the voltage induced in other two phases of the same winding.
2. For star winding, apply 1 phase 230 V between phase and neutral and measure the voltage induced in other two phases of the same winding.
3. Similarly all the phase should be checked with reference to other two phases

f) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

g) **Format of the Test Report**

HV side (Tap 1)

Voltage applied in volts		Voltage measured at H.V. side		
		1U-1N	1V-1N	1W-1N
1U-1N				
1V-1N				
1W-1N				

HV side (Tap 13)

Voltage applied in volts		Voltage measured at H.V. side		
		1U-1N	1V-1N	1W-1N
1U-1N				
1V-1N				
1W-1N				

HV side (Tap 17)

Voltage applied in volts		Voltage measured at H.V. side		
		1U-1N	1V-1N	1W-1N
1U-1N				
1V-1N				
1W-1N				

IV side (Tap N)

Voltage applied in volts		Voltage measured at H.V. side		
		2U-2N	2V-2N	2W-2N
2U-21N				
21V-2N				
2W-2N				

LV side (Tap N)

Voltage applied in volts		Voltage measured at H.V. side		
		3U-3V	3V-3W	3W-3U
3U-3V				
3V-3W				
3W-3U				

h) **Acceptance Criteria**

- The identical results confirm no damage due to transposition.
- Zero voltage or very negligible voltage induced in any of the other two phases shall be investigated.
- The applied voltage may be expressed as 100% voltage and the induced voltage may be expressed as percentage of the applied voltage. This will help in comparison of the two results when the applied voltages are different.
- The voltage induced in the centre phase shall be 50 to 90% of the applied voltage.
- However, when the centre phase is excited then the voltage induced in the outer phases shall be 30 to 70% of the applied voltage.
- Zero voltage or very negligible voltage induced in the other two windings should be investigated.

4.3.6 Verification of Vector Group and Polarity

a) **Purpose of the Test**

To verify the phase angle relationship in the winding and polarity of transformer

b) **Principle of the Test**

By shorting the R phase of HV and LV terminals, the magnitude of the phases by using the phase angle relationship is obtained

c) **Equipment for the Test**

Digital multi meter

d) **Procedure for the Test**

1. Keep the tap position of transformer at normal
2. Short 1U of HV and 2U of LV
3. Apply 440 V 3 phase supply to HV terminals
4. Measure the voltage across the following terminals as below
5. Make conditions in the way of arithmetical and logical for verifying the phase angle difference

For Yy0 transformer

Rn+Nn=RN

Bb=Yy

By=Yb

For Yna0d11 transformer

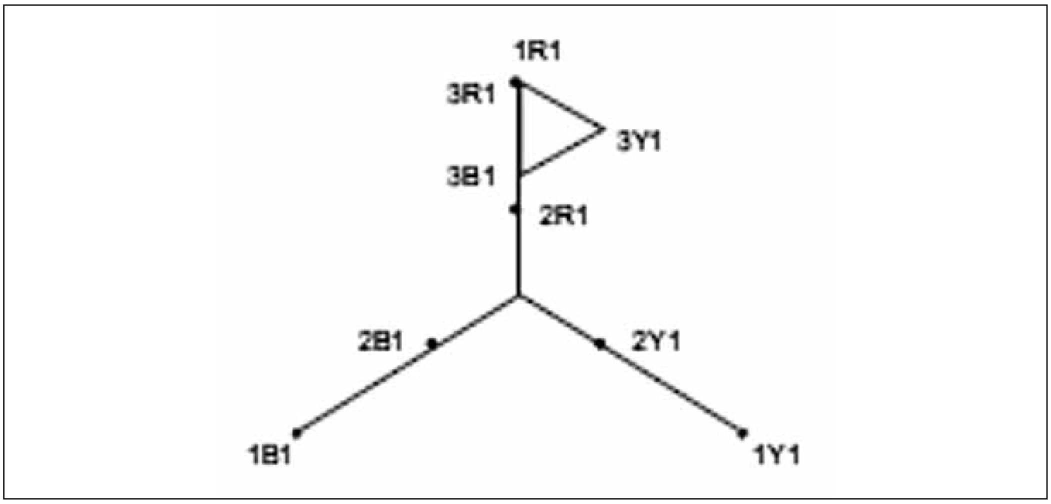


Fig. 5.25:

2R1-N=2Y1-N=2B1-N=Constant

2R1-1B1=3R1-N>3Y1-N>3B1-N

3Y1-1B1>3Y1-1Y1

e) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

f) **Format of the Test Report**

For star /star

Terminal	Voltage measured
Rn	
Nn	
RN	

Terminal	Voltage measured
Bb	
Yy	
By	
bY	

g) **Acceptance Criteria**

Verify that all arithmetical relations are maintained as in the above formula as per the vector group of transformer

4.3.7 Short Circuit Impedance Test

a) **Purpose of the Test**

This test is used to detect winding movement that usually occurs due to heavy fault current or mechanical damage during transportation or installation since dispatch from the factory. It is expressed as a percentage of the rated voltage of former winding. In this case current flowing through secondary is the full load current and is indicative of copper losses.

b) **Principle of the Test**

Rated full load current to flow through this winding when secondary winding is shorted, is known as impedance voltage

c) **Equipment for the Test**

Digital ampere meter

d) **Circuit for the Test**

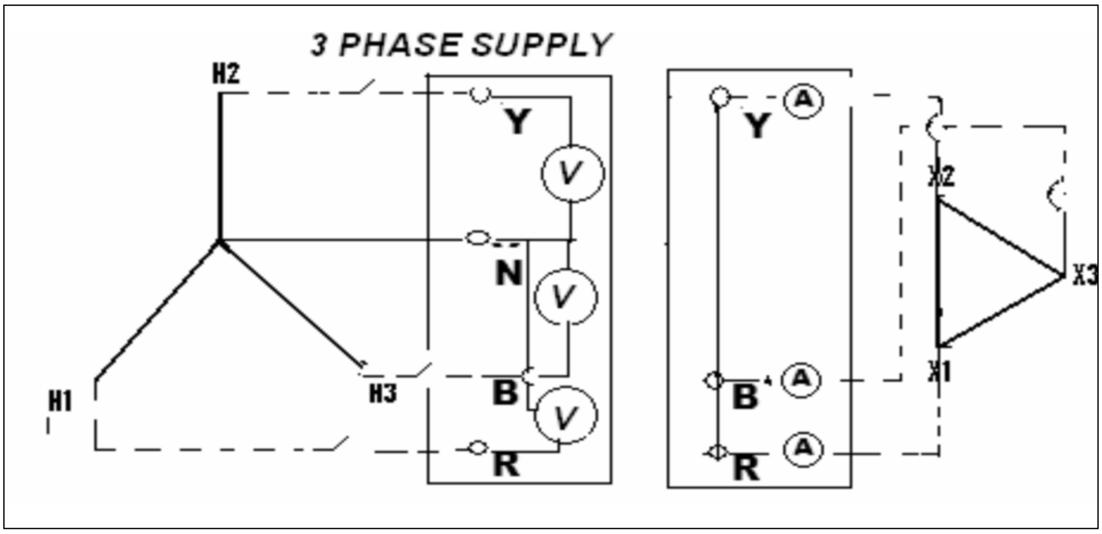


Fig. 5.26:

e) **Procedure for the Test**

1. Connect the 3 ph 440 V supply to the HV winding and short the 3 phase of LV winding.
2. Measure primary voltage and current on HV and LV.
3. Carry out the test on min., normal and max. Tap positions.

f) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

g) **Format of the Test Report**

HV/IV (Tap 1)

Voltage applied		Current measured in Amp				
		H.V. side		L.V. side		IN-n
1U-1V		1U		2U		
1V-1W		1V		2V		
1W-1U		1W		2W		

HV/IV (Tap 13)

Voltage applied		Current measured in Amp				
		H.V. side		L.V. side		IN-n
1U-1V		1U		2U		
1V-1W		1V		2V		
1W-1U		1W		2W		

HV/IV (Tap 17)

Voltage applied		Current measured in Amp				
		H.V. side		L.V. side		IN-n
1U-1V		1U		2U		
1V-1W		1V		2V		
1W-1U		1W		2W		

HV/LV (Tap N)

Voltage applied		Current measured in Amp				
		H.V. side		L.V. side		IN-n
1U-1V		1U		3U		
1V-1W		1V		3V		
1W-1U		1W		3W		

IV/LV (Tap N)

Voltage applied		Current measured in Amp				
		H.V. side		L.V. side		IN-n
2U-2V		2U		3U		
2V-2W		2V		3V		
2W-2U		2W		3W		

Impedance Verification (HV/IV)

Tap no.	Average S/C current on LV side	Average Voltage measured for S/C current on HV side	Impedance voltage	% Impedance voltage
1				
13				
17				

Impedance Verification (HV/LV)

Tap no.	Average S/C current on LV side	Average Voltage measured for S/C current on HV side	Impedance voltage	% Impedance voltage
N				

Impedance Verification (IV/LV)

Tap no.	Average S/C current on LV side	Average Voltage measured for S/C current on HV side	Impedance voltage	% Impedance voltage
N				

h) **Acceptable Criteria**

The measured impedance voltage should be within 3 percent of impedance specified in rating and diagram nameplate of the transformer.

Variation in impedance voltage of more than 3% should be considered significant and further investigated

4.3.8 Measurement of Winding Resistance

a) **Purpose of the Test**

To check for any abnormalities like loose connections, broken strands and high contact resistance in tap changers due to vibrations, fault occurred due to poor design, assembly, handling, poor environment, over loading or poor maintenance and gross difference between the windings and for openness in the connections.

b) **Principle of the Test**

Kelvin bridge technique was adopted in the way of modern digital micro processor method for measuring the winding resistance. Voltage drop is proportional to the winding resistance by injecting the DC current. Voltage drop across the winding terminal in the phase is in the following manner

*U= R*I + (d0/dt); 0-flux*

L= 0/t

When DC current is applied, (d0/dt) =0

*So, U=R*I*

c) **Equipment for the Test**

Automatic winding resistance measurement kit which work on the principle of Kelvin Bridge.

d) **Circuit for the Test**

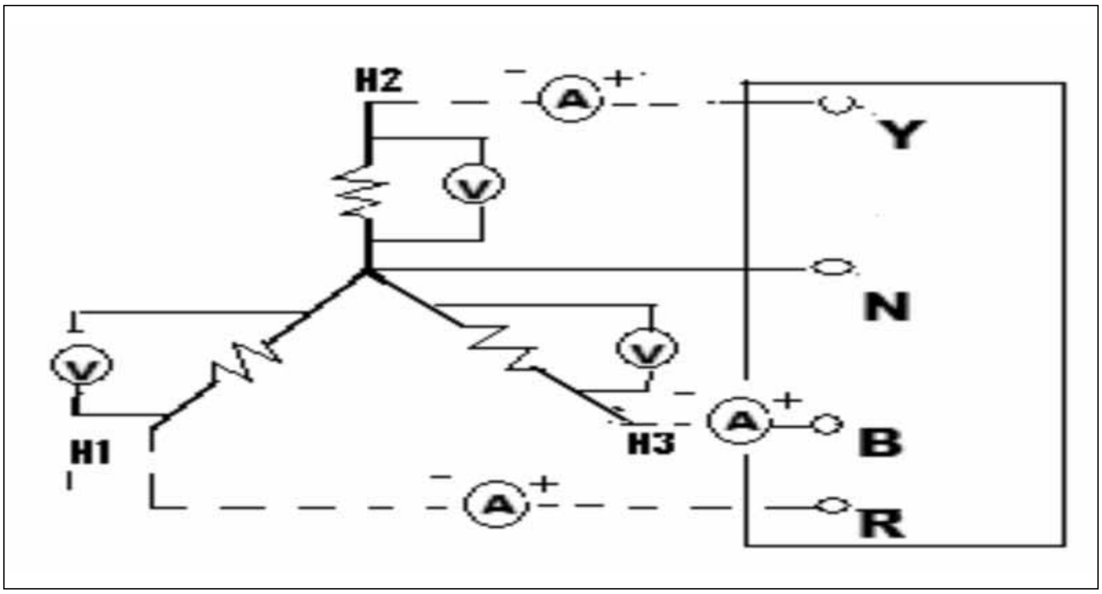


Fig. 5.27:

e) **Procedure for the Test**

1. Connect the current and potential leads to the transformer winding.
2. The potential leads must be connected between the current leads.
3. Do not clip the potential leads to the current leads.
4. Do not use additional extension cable leads.
5. Observe the polarity.
6. Select the test current range, which should be more than 1 % of rated current.
7. Test current should not be more than 10% of rated current.
8. If less than 1%, measured resistance is not consistent.
9. If more than 10%, it could cause erroneous readings due to over heating of the winding.
10. If possible, always inject test current to HV and LV simultaneously (two channel measurement).
11. This will magnetize the core more efficiently and shorten the time to get stable readings.
12. Measure the readings in both positive and negative polarities (tap position in ascending and descending position)
13. During tap changing operation, continuity checks between HV to neutral to be carried out by analog multi meter while changing tap.
14. For delta connected windings, such as tertiary winding of auto-transformers, measurement shall be done between pairs of line terminals and resistance per winding shall be calculated as per the following formula
    a. Resistance per winding = 1.5 x Measured value
15. Take the winding temperature reading while doing the resistance measurement.
16. Calculate the resistance at 75°C as per the following formula
17. R = R (235+75)/(235+t),Where R = Resistance measured at winding temperature t

f) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

g) **Format of the Test Report**

Temperature reading

Temp.- deg C	
OTI	
WTI	

(a) **HV-N**

Tap no.	Winding resistance in mili ohm		
	1U-1N	1V-1N	1W-1N
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			

(b) **IV-N**

Tap no.	Winding resistance in mili ohm		
	2U-N	2V-N	2W-N
N			

(c) **LV**

Tap no.	Winding resistance in mili ohm		
	3U-3V	3V-3W	3W-3U
N			

h) **Acceptance criteria**

All readings should be within +/- 1% of each other.

There should be even increase or decrease of resistance value for the winding having tapping winding for all three phase

4.3.9 **Winding Insulation Resistance Measurement**

a) **Purpose of the Test**

This test reveals the condition of voids in the dielectric insulations like solid insulation in the winding due to heat or moisture, any dampness solubility in the oil, presence of any foreign objects which is having the corrosive characteristic present in the bushing.

b) **Principle of the Test**

If a test voltage ids applied across a piece of insulation, then by measuring the resultant current and applying ohm's law (R=E/I), the resistance of the insulation can be calculated. Effect of temperature in measurement.

For every 10 deg increase in temperature, half the resistance; or for every 10 deg increase in temperature, double the resistance. For example, a 100 Gohm resistance at 20 deg becomes 25 Gohm at 40 deg. Cen.

c) **Equipment for the Test**

Motorized or battery operated insulation tester (0-5 KV range)

d) **Circuit for the Test**

a. **HV/E+LV Shorted**

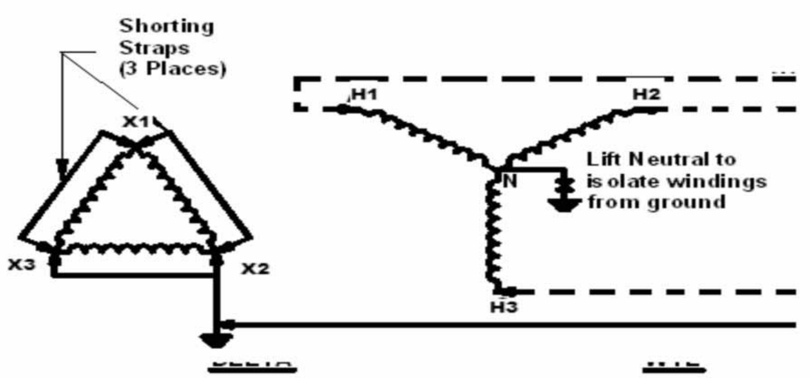


Fig. 5.28:

b. **LV/E + HV Shorted**

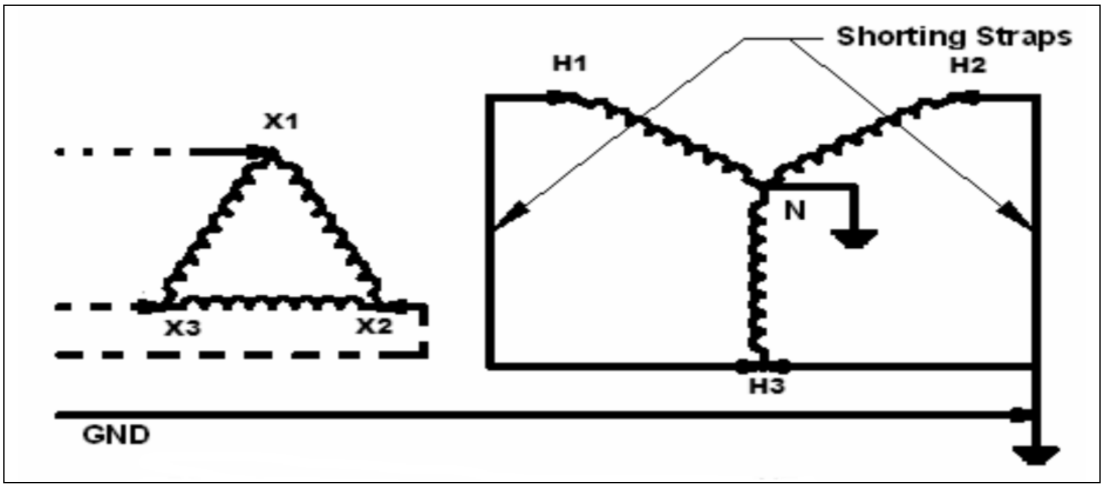


Fig. 5.29:

c. **HV /LV + Ground Open**

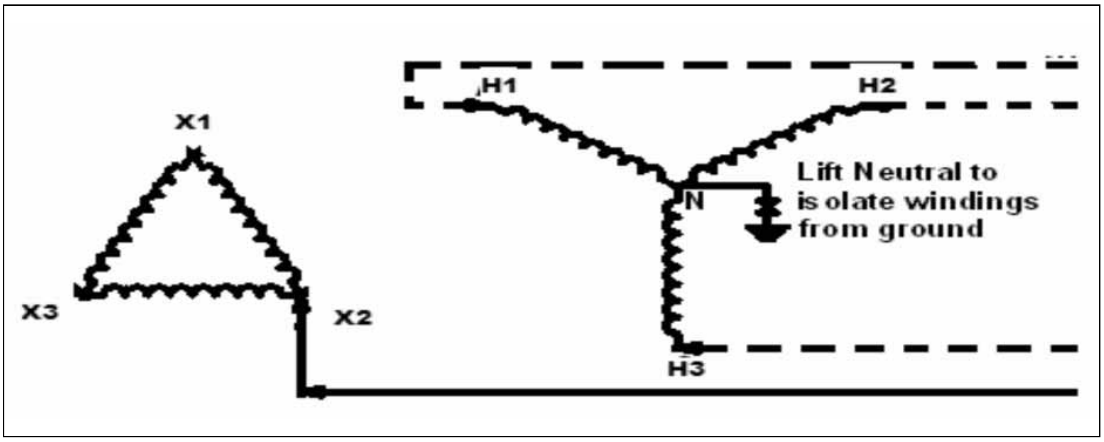


Fig. 5.30:

e) **Procedure for the Test**

1. Connect leads to HV winding and LV winding to measure IR between windings.
2. Apply 5 KV and take measurement at interval of 15 sec, 60 sec and 600 sec
3. Connect leads between winding and earth to measure IR between winding and earth.
4. Keep the other windings shorted and earthed.
5. Repeat the test.

f) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

g) **Format of the Test Report**

Temp.- deg C	
OTI	
WTI	
Amb.	

Conn.	IR value in Mohm			PI=IR at 600 sec/IR at 60 sec
	15 Sec	60 Sec	600 Sec	
HV to E				
LV to E				
HV to LV				

h) **Acceptance Criteria**

Min. insulation values for one minute resistance for transformer

*R=C*E/ (KVA) ^0.5.*

Where,

C=1.5 for oil filled Tr at 20^{o}C.

E= Voltage rating in V (Ph-Ph for delta and Ph-n for Y)

KVA= Rated capacity of the Tr.

As per CBIP guideline, acceptable value is 2 Mega Ohm per KV at 60 ^{o}C

Rated voltage	Recommended accepted limit as a thumb rule as per CBIP guideline Min IR Value for 1 min. at 30 deg
11 KV	300 M Ohm
33 KV	550 M Ohm
66 KV	625 M Ohm
132 KV	700 M Ohm
220 KV	750 M Ohm
400 KV	900 M Ohm

Polarization index insulation condition

PI value	Insulation condition
Less than 1	Wet, Dangerous
1.0-1.1	Poor
1.1-1.25	Fair
1.25-2.0	Good
>2.0	Dry
>3	Not good (Poor impregnation of oil in insulation paper, charging current is still increasing and not steady state)

4.3.10 Core Insulation Test

a) **Purpose of the Test**

To check that core is not earthed other than the specific earth point.

b) **Principle of the Test**

The ground connection terminals for the transformer core are located at top plate of transformer in a box. The terminals are protected by a cover. The terminal box contains a terminal block with three terminals

1. Terminal marked CL is connected to core lamination
2. Terminal marked CC is connected to core clamps
3. Terminal marked G is connected to ground

c) **Equipment for the Test:**

Motorized or battery operated insulation tester (0-5 KV range)

d) **Procedure for the Test:**

1. Shorting link between Core, frame and earth to be removed
2. Apply 2.5 KV and take measurement at interval of 60 sec
3. After completion of Test, provide shorting link between core, frame and earth

e) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

f) **Format for the Test**

Conn.	IR value in Mohm
	60 Sec
CC-CL	
CL-G	
CC-G	

g) **Acceptance Criteria**

IR should be > 1000 MΩ

4.3.11 Oil Characteristisc Test

a) **Purpose of the Test**

To check the electrical, mechanical & chemical property of the oil.

The dielectric break down voltage Test is an important Test to determine the withstanding capacity of any insulating oil. There is a degradation of transformer oil or ingress of moisture and it is necessary to Test the insulating oil periodically.

b) **Equipment for the Test**

Motorized oil BDV Test kit

c) **Procedure for the Test:**

1. Take oil sample from the bottom of the main tank in the oil cup. Always flush drain valve before taking sample
2. Also flush the oil cup
3. Let the bubbles be settled down
4. Carry out the Test and take reading at which oil insulation break down
5. Take 6 readings at time interval of 10 min.
6. Average of the 6 readings is final BDV of oil
7. Oil sample to be collected from bottom of the main tank and to be sent to ERDA to carry out tests as per IS 1866
8. Oil sample to be collected from bottom of the main tank and to be sent to ERDA to carry out tests for DGA

d) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

e) **Format of the Test Report**

BDV

Make	BDV -1	BDV -2	BDV -3	BDV -4	BDV -5	BDV -6	Average
Main tank top							
Main tank bottom							
OLTC tank							

f) **Acceptance Criteria**

Sr. no.	Particular	Accepted norms at the time of first charging	As per Standard
A	Appearance	Clear, free from sediment and suspended matter	Visual
B	BDV (2.5 mm gap)	70 KV for < 72.5 KV	IEC 60156
		80 KV for 72.5 KV to 170 KV	IEC 60156
		90 KV for >170 KV	IEC 60156
C	Water content	20 ppm for <72.5 KV	IEC 60814
		15 ppm for 72.5 KV to 170 KV	IEC 60814
		10 ppm for >170 KV	IEC 60814
D	Acidity	1.2 KOH/g, maximum	IS-1866-2000 IEC 61125 (method C)
E	PCB content	not detectable (less than 2 ppm)	IEC 61619
Sr. no.	Particular	Accepted norms at the time of first charging	As per Standard

F	Resistivity		
	Resistivity at 90 ºC	$6x10^{12}$ Ohm-Cm	IS-1866-2000
G	Tan delta at 90 ºC	0.02 maximum	IEC 60247
H	Interfacial Tension at 27 ºC	0.04 N/m	ISO 6295
I	Flash point	135 ºC	ISO 2719
J	Density at 29.5 ºC	0.89 g/cm^3	ISO 3104
K	Kinetic viscosity at 27ºC	27 cSt	IS-1866-2000
L	Pour point	-30 ºC	IS-1448-P10 ISO 3016
M	Oxidation stability of uninhibited oil		
	1) Neutralization value (Max)	0.1 mg KOH/g	IEC 62021-1/2
	2) Sludge (max)	0.8% by weight	IS-1866-2000
	Additional requirement for inhibited oil	minimum 0.25% maximum 0.40 %	IEC 60666

If BDV value is very low and unacceptable (<30 KV/2.5 mm gap), then it is necessary to dry out & clean the oil till the insulation reaches the satisfactory value.

4.3.12 Tests on Bushing CTs

a) **Purpose of the Test**

These tests are carried out to identify the healthiness of bushing CT s and verifying the measuring and protection systems

b) **Equipment for the Test**

Digital multi meter

Insulation tester

Knee point measurement kit

Current injection kit

c) **Procedure for the Test**

While testing, the other windings on the same phase of the transformer may have to short circuited in order to obtain a stable reading. It is better to demagnetize any CT that is tested by impressing DC voltage across winding.

Rated parameters

CORE	RATIO	CLASS	BURDEN	kpV	PROTECTION / METERING
Core - I					
Core - II					
Core - III					
Core - IV					

A. **Polarity Test**

a) **Purpose of the Test**

The polarity should show in accordance with the terminal markings

b) **Procedure for the Test**

1. The polarity test can be done by inductive kick of direct current
2. In this test, a 1.5 V battery is connected to the primary P1-P2 of CT in such a manner that +ve terminal of batter to be connected to P1 and –ve terminal to be connected to P2.
3 Connect +ve lead of voltmeter in S1 and –ve terminal in S2
4. Close the switch and apply 1.5 V DC, check the deflection
5. It should be in +ve deflection

c) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

d) **Format of the Test Report**

CORE	BETWEEN		HV			
			R - Ø	Y - Ø	B - Ø	N - Ø
Core I	1S1 (+ve)	1S2 (-ve)				
	1S1 (+ve)	1S3 (-ve)				
Core II	2S1 (+ve)	2S2 (-ve)				
	2S1 (+ve)	2S3 (-ve)				
Core III	3S1 (+ve)	3S2 (-ve)				
	3S1 (+ve)	3S3 (-ve)				
Core IV	4S1 (+ve)	4S2 (-ve)				
	4S1 (+ve)	4S3 (-ve)				

CORE	BETWEEN		LV			
			R - Ø	Y - Ø	B - Ø	N - Ø
Core I	1S1 (+ve)	1S2 (-ve)				
	1S1 (+ve)	1S3 (-ve)				
Core II	2S1 (+ve)	2S2 (-ve)				
	2S1 (+ve)	2S3 (-ve)				
Core III	3S1 (+ve)	3S2 (-ve)				
	3S1 (+ve)	3S3 (-ve)				
Core IV	4S1 (+ve)	4S2 (-ve)				
	4S1 (+ve)	4S3 (-ve)				

e) **Acceptance Criteria**

All CT secondary polarity should be as per name plate

B. **Current ratio Test**

a) **Purpose of the Test**

To measure the ratio of a primary to secondary current in the bushing CT and find the current ratio error

b) **Procedure for the Test**

1. Connect the current injection kit to the primary of the bushing CT and measure the current through tong tester having the range of 300A
2. Measure the current through tong tester having the range of 300mA in secondary CT
3. Apply 20% of rated current to he primary side
4. Measure the corresponding primary and secondary current.
5. % error of CT ratio = (Measured current ratio- Theoretical ratio)/Theoretical ratio

c) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

d) **Format of the Test Report**

(a) **HV R**

Core	Terminals	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% of Error
Core I	(1S1 – 1S2)	20%					
	(1S1-1S3)	20%					
Core II	(2S1 – 2S2)	20%					
	(2S1-2S3)	20%					
Core III	(3S1 – 3S2)	20%					
	(3S1-3S3)	20%					
Core IV	(4S1 – 4S2)	20%					
	(4S1-4S3)	20%					

(b) **HV Y**

Core	Terminals	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% of Error
Core I	(1S1 – 1S2)	20%					
	(1S1-1S3)	20%					
Core II	(2S1 – 2S2)	20%					
	(2S1-2S3)	20%					
Core III	(3S1 – 3S2)	20%					
	(3S1-3S3)	20%					
Core IV	(4S1 – 4S2)	20%					
	(4S1-4S3)	20%					

(c) **HV B**

Core	Terminals	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% of Error
Core I	(1S1 – 1S2)	20%					
	(1S1-1S3)	20%					
Core II	(2S1 – 2S2)	20%					
	(2S1-2S3)	20%					
Core III	(3S1 – 3S2)	20%					
	(3S1-3S3)	20%					
Core IV	(4S1 – 4S2)	20%					
	(4S1-4S3)	20%					

(d) **HV N**

Core	Terminals	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% of Error
Core I	(1S1 – 1S2)	20%					
	(1S1-1S3)	20%					
Core II	(2S1 – 2S2)	20%					
	(2S1-2S3)	20%					
Core III	(3S1 – 3S2)	20%					
	(3S1-3S3)	20%					
Core IV	(4S1 – 4S2)	20%					
	(4S1-4S3)	20%					

(e) **IV R**

Core	Terminals	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% of Error
Core I	(1S1 – 1S2)	20%					
	(1S1-1S3)	20%					
Core II	(2S1 – 2S2)	20%					
	(2S1-2S3)	20%					
Core III	(3S1 – 3S2)	20%					
	(3S1-3S3)	20%					
Core IV	(4S1 – 4S2)	20%					
	(4S1-4S3)	20%					

(f) **IV Y**

Core	Terminals	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% of Error
Core I	(1S1 – 1S2)	20%					
	(1S1-1S3)	20%					
Core II	(2S1 – 2S2)	20%					
	(2S1-2S3)	20%					
Core III	(3S1 – 3S2)	20%					
	(3S1-3S3)	20%					
Core IV	(4S1 – 4S2)	20%					
	(4S1-4S3)	20%					

(g) **IV B**

Core	Terminals	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% of Error
Core I	(1S1 – 1S2)	20%					
	(1S1-1S3)	20%					
Core II	(2S1 – 2S2)	20%					
	(2S1-2S3)	20%					
Core III	(3S1 – 3S2)	20%					
	(3S1-3S3)	20%					
Core IV	(4S1 – 4S2)	20%					
	(4S1-4S3)	20%					

(h) **IV N**

Core	Terminals	Primary %	Current Actual	Secondary Current	Theoretical Ratio	Actual Ratio	% of Error
Core I	(1S1 – 1S2)	20%					
	(1S1-1S3)	20%					
Core II	(2S1 – 2S2)	20%					
	(2S1-2S3)	20%					
Core III	(3S1 – 3S2)	20%					
	(3S1-3S3)	20%					
Core IV	(4S1 – 4S2)	20%					
	(4S1-4S3)	20%					

e) **Acceptance Criteria**

Ratio error should match with factory results

C. Excitation Current

a) Purpose of the Test

The magnetization test is conducted in order to see the condition of the turns of the secondary. This test gives the indications regarding the shorting of turns CT secondary winding and to establish CT characteristics as well as capability of CT.

b) Procedure of the test

1. Apply AC voltage to the secondary winding of the CT with primary open circuit
2. Vary the applied voltage from 25% of Vk to 110 % of Vk
3. Measure the current drawn by the winding at each selected value is recorded
4. Verify that, exciting current is less than specified at Vk/2
5. This test should not be performed for metering core
6. If Knee Point Voltage is not mentioned then Knee Point Current may be taken into consideration.

c) Test Equipment

Make	Type	Sr. no.	Range	Cal. Due date

d) Format of the Test Report

i. **HV R**

Voltage		Excitation current	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S3	Core – II 2S1-2S3	Core – III 3S1-3S3	Core – IV 4S1-4S3
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

ii. **HV Y**

Voltage		Excitation current	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S3	Core – II 2S1-2S3	Core – III 3S1-3S3	Core – IV 4S1-4S3
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

iii. **HV B**

Voltage		Excitation current	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S3	Core – II 2S1-2S3	Core – III 3S1-3S3	Core – IV 4S1-4S3
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

iv. **HV N**

Voltage		Excitation current	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S3	Core – II 2S1-2S3	Core – III 3S1-3S3	Core – IV 4S1-4S3
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

v. **IV R**

Voltage		Excitation current	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S3	Core – II 2S1-2S3	Core – III 3S1-3S3	Core – IV 4S1-4S3
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

vi. **IV Y**

Voltage		Excitation current	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S3	Core – II 2S1-2S3	Core – III 3S1-3S3	Core – IV 4S1-4S3
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

vii. **IV B**

Voltage		Excitation current	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S3	Core – II 2S1-2S3	Core – III 3S1-3S3	Core – IV 4S1-4S3
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

viii. **IV N**

Voltage		Excitation current	Current Measurement			
To Be Applied	Actual Value		Core – I 1S1-1S3	Core – II 2S1-2S3	Core – III 3S1-3S3	Core – IV 4S1-4S3
0.25 x KVp		mA				
0.50 x KVp		mA				
0.75 x KVp		mA				
1.00 x KVp		mA				
1.10 x KVp		mA				

e) **Acceptance Criteria**

Excitation current should not be more than specified on name plate.

10 % increase in the voltage from 100 % to 110 %, increase in current should not be more than 50%

D. **Insulation Resistance Measurement**

a) **Purpose of the Test**

To check any shorting of any CT secondary core with earth or between cores

b) **Procedure for the Test**

1. IR measurement secondary core to earth
2. Connect insulation tester leads between CT secondary and earth
3. Apply 500 V DC and measure IR value
4. Carry out test for all cores of all HV and IV CTs
5. IR measurement secondary core to core
6. Connect insulation tester leads between CT secondary cores
7. Apply 500 V DC and measure IR value
8. Carry out test for all combinations of core to core for all HV and IV CTs

c) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

d) **Format of the Test Report**

Measurement Between	Unit	HV			
		R – Ø	Y - Ø	B - Ø	N - Ø
Earth - Core I	M Ω				
Earth - Core II	M Ω				
Earth - Core III	M Ω				
Earth - Core IV	M Ω				

Measurement Between	Unit	IV			
		R – Ø	Y - Ø	B - Ø	N - Ø
Earth - Core I	M Ω				
Earth - Core II	M Ω				
Earth - Core III	M Ω				
Earth - Core IV	M Ω				

Measurement Between	Unit	HV			
		R – Ø	Y - Ø	B - Ø	N - Ø
Core I - Core II	M Ω				
Core I - Core III	M Ω				
Core I - Core IV	M Ω				
Core II - Core III	M Ω				
Core II - Core IV	M Ω				
Core III - Core IV	M Ω				

Measurement Between	Unit	IV			
		R – Ø	Y - Ø	B - Ø	N - Ø
Core I - Core II	M Ω				
Core I - Core III	M Ω				
Core I - Core IV	M Ω				
Core II - Core III	M Ω				
Core II - Core IV	M Ω				
Core III - Core IV	M Ω				

e) **Acceptance Criteria**

Insulation resistance should be more than 50 Mega ohm

E. **Continuity test of Bushing CT secondary winding**

a) **Purpose of the Test**

To check any open of any CT secondary core including pilot wires up to C & R panel

b) **Procedure for the Test**

1. Connect multi meter across each core and check continuity up to Tr MK box and up to remote protection panel end.
2. Carry out test for all cores of all HV and IV CTs

c) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

d) **Format of the Test Report**

Measurement Between	Between Terminal	HV			
		R – Ø	Y - Ø	B - Ø	N - Ø
Core - I	1S1-1S2				
	1S1-1S3				
Core - II	2S1-2S2				
	2S1-2S3				
Core - III	3S1-3S2				
	3S1-3S3				
Core - IV	4S1-4S2				
	4S1-4S3				

Measurement Between	Between Terminal	LV			
		R – Ø	Y - Ø	B - Ø	N - Ø
Core - I	1S1-1S2				
	1S1-1S3				
Core - II	2S1-2S2				
	2S1-2S3				
Core - III	3S1-3S2				
	3S1-3S3				
Core - IV	4S1-4S2				
	4S1-4S3				

e) **Acceptance Criteria**

Continuity test should be OK

F. **Winding resistance measurement of bushing CT secondary winding**

a) **Purpose of the Test**

To check healthiness of winding of CT secondary up to MK Box of Transformer

b) **Procedure for the Test**

1. Connect multi meter across each core and measure winding resistance up to Tr MK box.
2. Carry out test for all cores of all HV and IV CTs

c) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

d) **Format of the Test Report**

Measurement Between	Between Terminal	Unit	HV			
			R – Ø	Y - Ø	B - Ø	N - Ø
Core - I	1S1-1S2	Ω				
	1S1-1S3	Ω				
Core - II	2S1-2S2	Ω				
	2S1-2S3	Ω				
Core - III	3S1-3S2	Ω				
	3S1-3S3	Ω				
Core - IV	4S1-4S2	Ω				
	4S1-4S3	Ω				

Measurement Between	Between Terminal	Unit	LV			
			R – Ø	Y - Ø	B - Ø	N - Ø
Core - I	1S1-1S2	Ω				
	1S1-1S3	Ω				
Core - II	2S1-2S2	Ω				
	2S1-2S3	Ω				
Core - III	3S1-3S2	Ω				
	3S1-3S3	Ω				
Core - IV	4S1-4S2	Ω				
	4S1-4S3	Ω				

e) **Acceptance Criteria**

Winding resistance should be comparable with factory results

4.3.13 Operational Tests and Checks on other Equipments

A. **Temperature Indicators**

The function of temperature indicator is to monitor and control the temperature of oil and winding in the transformer. There are two types of temperature indicators.

1. Winding temperature indicator in each winding
2. Oil temperature indicator

B. **Winding Temperature Indicator**

In WTI the first to check the working of cooler control, alarm and trip signal

a) **Procedure for the Test**

1. Access the local winding temperature indicator and rotate the temperature indicator pointer slowly to the first stage cooling value (65 deg C). Check that the fans of those coolers are working.
2. Continue rotating pointer to second stage cooling value (80 deg C). Check that the fans of those coolers are working
3. Rotating the pointer to alarm value (110 deg C). Check in control room to ensure that alarm signal
4. Rotate the pointer to (125 deg C) trip value. Check in control room to ensure that trip signal has been received.

b) **Procedure calibration of WTI with hot oil**

1. Remove the winding temperature indicator bulb from transformer pocket.
2. Insert the bulb in to calibrated temperature controlled bath. Raise the temperature of the bath in 5 deg C steps and check the response of winding temperature indicator after 10 minutes.
3. This continue up to 30 deg C. Allowable tolerance is =/- 3 deg C.
4. Reduce the temperature of the bath in 5 deg C steps and check corresponding temperature in the indicator after 10 minutes. Allowable tolerance is +/-3 deg C
5. WTI OFAF rating check by using calibrated temperature controlled bath procedure:
6. Remove WTI sensor from transformer lid and put in to calibrated temperature controlled ol bath.
7. Increase temperature of oil bath in 20 deg C steps from 30 deg C up to maximum temperature of 150 deg C.
8. Check and record WTI output readings in milliamps DC against temperature in accordance with table below.

Temperature	mili amps
30	4.0
40	5.3
60	8.0
80	10.7
100	13.3
120	16.0
140	18.7

c) **Procedure for Secondary Injection Test for WTI**

1. First isolate all cooler supplies from WTI
2. Then replace WTI bulb in to calibrated temperature controlled bath and maintain constant temperature of 50 deg C
3. Inject the rated current (4.9A) in to appropriate terminals on winding temperature indication test panel

C. **Oil Temperature Indicators**

a) **Procedure for the Test**

1. Access the local winding temperature indicator and rotate the temperature indicator pointer slowly to the alarm value (95 deg C). Check in control room to ensure that alarm signal.
2. Continue rotating pointer to (110 deg C) trip value. Check in control room to ensure that trip signal has been received.

b) **Procedure for calibration of OTI with hot oil**

1. Remove the oil temperature indicator bulb from transformer pocket.
2. Insert the bulb in to calibrated temperature controlled oil bath.
3. Raise the temperature of the bath in 20 deg C steps and check the response of oil temperature indicator after 10 minutes.
4. This continue up to 120 deg C. Allowable tolerance is =/- 3 deg C.

D. **Operational checks of Magnetic Oil Gauge**

The function of MOG is to indicate the continuous level of oil inside the transformer on a calibrated dial.

The calibrated scale having three markings: Low, 35 deg fill level and High.

It should show 35 deg (normal level) of oil in the tank

E. **Operational checks of Pressure Relief Valve**

Procedure

Check the normality open and normality close contacts by lifting the pressure valve

F. **Tests on OLTC**

1. Conduct the visual inspection of equipment
2. Check the manual operation of all taps (Local)
3. Check complete wiring of the circuit
4. Check the limit switch
5. Check the over load device of driving motor by measuring the current
6. Check the local electrical operation of OLTC
7. Check the remote electrical operation of OLTC
8. Check the status of tap position indicator
9. Check operation of master and follower scheme (Parallel operation)

Sr. no	Description	Status	
		OK	Not OK
1	Visual inspection of equipment		
2	Manual operation of all taps (Local)		
3	Overload device of driving motor		
4	Local operation (Electrical)		
5	Remote operation (Electrical)		
6	Tap position indicator		
7	Check operation with master follower scheme		

G. **Test on Buchholz Relay**

1. Check the normality open and normality close contact by following steps
2. Close the conservator flow valve and tank flow valve which is present in the conservator pipe line
3. Drain the oil which is present in between the two valves
4. Ensure the contact change by using the multi meter in two steps alarm and trip
5. After closing the drain knob in buchholz relay then close the conservator valve first and close tank valve

H. **Cooling System Check**

1. Check all radiator valves are open
2. To check the motor insulation healthiness by doing the IR test
3. To check the excitation current measurement in the motor winding
4. To check the direction of rotation in motor
5. To verify the cooling interlocks

4.3.14 Measurement of Earthing Pit Resistance

a) **Purpose of the Test**

To measure value of earthing pit resistance and verify that, fault current has minimum resistance to ground

b) **Principle of the Test**

There is hand operated D.C.generator. While feeding current to spike, D.C. current is converted into A.C. current by the converter and A.C. current received from spike is again converted in D.C. current by the help of rectifier, while going to generator. A.C. current is fed to the spike driven in earth because there should not be electrolytic effect.

c) **Equipment for the Test**

Earth tester

d) **Circuit for the Test**

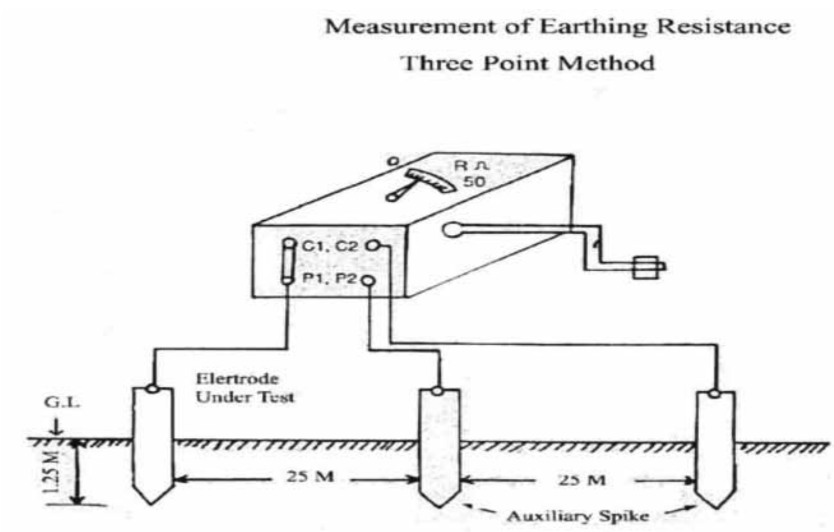


Fig. 5.31:

e) **Procedure for the Test**

1. Earth tester is used for measurement of Earth resistance.
2. For measurement of earth pit resistance, pit earthing connection should be disconnected from main grid.
3. Earth tester terminals C1 & P1 are shorted to each other and connected to the earth electrode (pipe) under test.
4. Terminals P2 & C2 are connected to the two separate spikes driven in earth.
5. These two spikes are kept in same line at the distance of 25 meters and 50 meters due to which there will not be mutual interference in the field of individual spikes.
6. If we rotate generator handle with specific speed we get directly earth resistance on scale.
7. If earth resistance is more, proper treatment is to be given.

f) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

g) **Format of the Test Report**

Earthing Pit Resistance

Pit no	Resistance in ohm
Body earth 1	
Body earth 2	
HV Neutral earth 1	
HV Neutral earth 2	
LV Neutral earth 1	
LV Neutral earth 2	

h) **Acceptance Criteria**

Value of earth pit resistance should be less than or equal to 1 ohm.

4.3.15 Protection and Alarms

Sr. no	Device	Set for		Actual	
		Alarm	Trip	Alarm	Trip
1	Winding temperature high				
2	Oil temperature high				
3	Oil flow failure				
4	Pressure relief valve				
5	Main tank buchholz relay				
6	OLTC buchholz relay				
7	Fan failure				
8	OTI main Tank				
9	WTI main tank				
10	Low oil level				
11	Differential relay				
12	Over load rely				
13	Earth fault relay				
14	Directional over current				
15	Inter trip relay operated				
16	Trip free check				
17	Backup over current				
18	Restricted earth fault				
19	Over flux				

a) **Acceptance Criteria**

Prove the tripping of associated breakers by actual operation of the various devices and relays as per the schemes

4.3.16 Contact Resistance Measurement

a) **Purpose of the Test**

To determine the firmness of torque level in between the bushing jumper and transmission line If torque level is more than or less then the standard position, the heat will dissipated in the joints.

It leads to corrosion in the joints.

b) **Principle of the Test**

Voltage drop is proportional to the contact resistance by injecting the DC current. It depends on the voltage drop across the contact terminal in between the transmission line and the jumper of the bushing.

c) **Procedure**

Direct measurement of resistance by using micro ohm meter

d) **Test Equipment**

Make	Type	Sr. no.	Range	Cal. Due date

e) **Format of the Test Report**

Contact resistance	R ph	Y ph	B ph
Across HV bushing terminal joints			
Across IV bushing terminal joints			
Across LV bushing terminal joints			
Across Neutral connection point			
Across surge arrestor connection			

f) **Acceptance Criteria**

The value of contact resistance should not be more than 5 micro ohm per joint/ connector

4.3.17 Clearances

Check the clearances for live parts

a) **Format of the Test Report**

Particular	Clearance
HV phase to phase	
HV phase to earth	
IV phase to phase	
IV phase to earth	
LV phase to phase	
LV phase to earth	

4.3.18 Protection Relay Settings

Particular	Value
Settings of OTI alarm	
Settings of OTI trip	
Settings of WTI alarm	
Settings of WTI trip	
Settings of start & stop of cooling fan set -1	
Settings of start & stop of cooling fans set-2	

4.3.19 Final Documentation Review

1	Final document of pre commissioning checks reviewed and approved.	YES	NO
2	Documents regarding spares, equipment, O & M manuals etc are available at site for O & M purpose.	YES	NO
3	After modification, if any, as built drawings are available at site		

5 FINAL COMMISSIONING CHECKS

It is important to ensure seamless, full and final integration of power transformer in a substation after commissioning tests specified above. These checks are related to functional and operational conditions within transformer elements as well as external interfaces so that transformer can perform successfully in a transmission system.

1. All the test results of unit are verified and compared with factory results before commissioning.

2. No leakage of oil in any part of unit.

3 Ensure external electrical clearance of conductor jumpers in the switchyard with transformer body, gantry, column, jumpers, fire wall etc.

4. Ensure that tertiary winding terminals are insulated, when they are not used / connected to any system.

5. Ensure earthing of Neutral, main tank body, radiator frame structure, fans and motor.

6. Neutral earthing flat of suitable size must run through support insulator and connected to two separate earthing pits which are in turn connected to main earth mat of switchyard.

7. Ensure that conductor jumpers connected to HV, LV and tertiary terminals are not tight and should have the allowance for contraction. Also ensure that connectors are properly erected with tightness at bushing terminal.

8. Ensure that R.Y.B designated terminals of transformer are matching with R,Y,B buses of switchyards on HV and LV side.

9. Ensure oil level in the Bushings.

10. Ensure continuity of OLTC operation at all taps.

11. In a transformer bank of three single phase units, ensure master- slave OLTC scheme.

12. In a transformer bank of three single phase units, ensure tertiary connection and protection scheme.

13. Ensure oil filling in conservator tank according to temperature scale in MOG and also ensure oil level in pris-matic glass.

14. Ensure that all valves between main tank and radiator banks are opened.

15. Ensure those radiator valves connected to header are open.

16. Ensure that valve to conservator tank via Buchholz relay is open.

17. Ensure physical operation of local protections like Buchholz, PRV, Surge relay of OLTC etc.

18. Ensure OTI and WTI settings of fan & pumps operation, Alarm and Trip as per approved drawings. Fan and pump operation shall be ensured locally and remotely.

19. Review and ensure protection scheme of power transformer with over all protection scheme at remote end in control room.
    - Differential Protection
    - Restricted Earth Fault Protection.
    - Over current and Earth fault protection.
    - Over fluxing Protection.
    - OTI & WTI- alarm and trap
    - RTCC panel interface with protection system
    - Local protection like Buchholz, PRV etc.
    - Integration of on-line condition monitoring equipments.
20. Ensure the common earthing of tank, frame and core provided in transformer.
21. Ensure the shorting of spare cores of bushing CT's.
22. Ensure that cap in the tan delta measurement point in the bushing is put back.
23. Ensure Fire Protection System and oil drain valve operation before charging and commissioning.
24. Oil test results after filtration must be within specified limit.
25. Spares like bushings shall be tested and kept ready before charging and commissioning.
26. Allow minimum period of 24 hrs after filtration for oil temperature to settle down.
27. Ensure release of air from plugs provided on top of main tank, conservator and radiator headers.
28. Take charging clearance certificate from all erection agencies for removal of man, material and T&P from site.
29. Ensure healthiness of Air Cell.
30. Ensure availability of oil in the breather cup in main tank/ OLTC tank.
31. Ensure all rollers are locked with rails.
32. Ensure door seals of Marshalling Box are intact and all cable gland plate's unused holes are sealed.
33. Ensure change over operation of AC supply from source- I to source-II in local master control cubicle.

6 ENERGISATION OF UNIT AND SITE CLOSING

Commissioning of transformer is not complete unless it is put into regular service. Following activities to follow:-

1. Initially charge the transformer under no load and keep it energize for 24 hrs.
2. Gradually load the transformer observing the noise, vibration, temperature rise, oil leakage etc.
3. Check OLTC operation.
4. Carry out Thermo vision scanning of HV/LV terminals and tank body.
5. Carry out DGA test of oil as per schedule given in flow chart of this manual
6. Hand over testing and commissioning records to operation staff along with O&M manual of OEM.
7. Ensure closure of project by clearing site in all respect particularly removal of temporary sheds, T&P, Oil and handing over spares to customer as per contract.