Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
	2. No of turns / disc	100%	As per approved drawings / Factory drawing	As per Factory drawing	--	P	V
	3. Dimensional checks i) Outer diameter ii) Inner diameter iii) Unshrunk height iv) Radial thickness	100%	As per approved drawings / Factory drawing	As per Factory drawing	--	P	V
	4. Brazing procedure and brazer's qualification	--	Customer approval	As per approval	-	P	V
	5. Visual inspection of brazed joints	100%	As per brazing procedure	As per approval	-	P	V
	6. Visual check for transposition	100%	As per design drawings	As per design	-	P	V
	7. Visual check for terminal marking & length	100%	As per design drawings	As per design	-	P	V
	8. Insulation arrangement including end insulation	100%	As per design drawings	As per design	-	P	V
	9. Lead & coil identification & marking	100%	As per design drawings	As per design	-	P	V
	10. Continuity test (testing of winding continuity/ brazing test)	100%	--	No breaking of continuity	-	P	V
	11. Coil clamping for shrinking & shrunk coil height and clamping force	100%	As per design drawings	As per design		P	V
	12. Check arrangement of fiber optic sensor (FOS) (if applicable)	100%	As per design drawings	As per design		P	V
	13. Inter-turn Insulation	100%	As per design drawings	As per design	-	P	V
IV	**Core Coil Assembly**						
	1. Visual Check of level of bottom yoke (bearing beam)	100%	--	As per design	-	P	W
	2. Visual Check assembly of the magnetic shields (if applicable)		--	As per design	-	P	W
	3. Visual Check strip barrier assembly on all limbs		--	As per design	-	P	W
	4. Visual Check position of lead take out of HV		--	As per design	-	P	W
	5. Visual Check clamping of upper yoke		--	As per design	-	P	W
	6. Visual Check torque/ pressure of tensile bolt		--	As per design	-	P	W
	7. Visual Check insulation resistance between cooling duct by 500 V megger		--	As per design	-	P	W
	8. Check IR between core and frame at 2 kV by Megger.		--	As per design	-	P	W

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Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
	Check of insulation resistance between CC-CL, CC-Yoke Bolt, CL-Yoke Bolt-2kV Megger						
	9. Visual check for inter-coil insulation		--	As per design	-	P	W
	10. Lead & coil identification & marking		--	As per design	-	P	W
	11. Brazing / Crimping of Joints		--	Shall be smooth and no sharped age	-	P	W
	12. Visual check for completeness, cleanliness, clearance of live parts, absence of sharp edges, placement of lead support assembly		--	Complete assembly shall be free from dust / particles	-	P	V
	13. Ratio test		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	14. Magnetic balance test		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	15. Magnetizing current test, polarity & vector group		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	16. Alignment of Spacers/Blocks		--	Aligned	-	P	V
	17. HV test		Manufacturer's standard	10kV for 1 min withstand	-	P	W
V	**DRYING OF ACTIVE PART: Vapor Phase Drying (VPD) Validation**						
	1. Check of temp of Evaporator 2. Check temp of Main heating 3. Check temp of Sprayed Kerosene 4. Check Vacuum Pressure (mbar) of VPD 5. Check Vacuum Pressure (mbar) of Fine vacuum 6. Check Water Extraction (g / Hr / Ton of Insulation) / Process Termination parameters 7. Check total process time (Hrs.) 8. Check Oil characteristics before impregnation a. Electric strength b. Water content c. Tan delta at 90^{0}C d. Resistivity at 90^{0}C(For Information) e. IFT at room temperature	100%	Manufacturer's standards/drawings /checklist	Manufacturer's standards/drawings/ checklist Graph of Vacuum Vs Time and Temperature Vs time to be submitted for review As per Annexure-L of the document	-	P	V
VI	**Connections and checks before tanking**						
	1. OLTC fitting & connections	100%	Manufacturer standard	Manufacturer standard	--	P	---
	2. Check for cable sizes	100%	As per design drawings	As per design	--	P	V

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Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
	3. Check for clearance from tank walls	100%	As per design drawings	As per design	--	P	V
	4. Visual checks for crimped joint	100%	--	Shall be smooth and no sharped age	--	P	V
	5. Visual checks for bushing CT assembly tightness	100%	--	Assembly tightness	--	P	V
	6. Ratio test	100%	As per IS 2026 / IEC 60076	Tolerance as per standards	--	P	V
VII	**Tank**						
	1. Thickness of walls	100%	As per approved drawings	As per approved drawings	--	P	V
	2. Dimensions	100%	As per approved drawings	As per approved drawings	--	P	V
	3. Visual internal Inspection	100%	As per approved drawings	As per approved drawings		P	V
	4. Pressure test	100%	As per specification	To withstand, permanent deflection shall not exceed as per specification	--	P	W
	5. Vacuum test	100%	As per specification	To withstand, permanent deflection shall not exceed as per specification	--	P	W
VIII	**Opening, Tanking and Oil filling**						
	1. Drying	100%	Manufacturer standard	Low voltage tan delta and PI values shall be checked periodically and after achieving the satisfactory values the process will be declared complete	--	P	
	2. Checks for complete tightness before taking (a) Tightness of all joints / screws (b) Application of thread locking adhesive (c) Padding of top yoke (d) Pressing of active parts (e) Fitting of wall shunts & packing (f) Electrical clearance of core/coil assembly after completion of terminal gear connections.	100%	Manufacturer standard	As per design	--	P	
	3. Cleanliness of tank before tanking	100%	Manufacturer standard	Shall be clean.	--	P	---
	4. Tanking of active parts and check for clearance including clearance of the leads from tank walls & Core/frame earthing.	100%	As per design drawings	As per design	--	P	V
	5. 2kV HV test between (a) Core & end frame	100%	As per specification	To withstand 2kV for 1 min	--	P	V

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Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
	(b) Core & yoke bolts (c) End frame and yoke bolts						
	6. Check for oil quality before impregnation	100%	As per specification	As per specification	--	P	V
	7. Proper scarfing of insulation during tapping of terminal gear joints, position of leads.	100%	Manufacturer standard	Manufacturer standard		P	V
	8. Oil filling & Air release	100%	Manufacturer standard	Manufacturer standard	--	P	---
	9. Impregnation process	100%	Manufacturer standard	Sufficient impregnation time shall be given before conducting the electrical test on the transformer	--	P	---

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	**Customer**
A.	**Acceptance Tests**		100%	Specification IS: 2026 IEC 60076 other applicable standard			
	1.	Appearance, construction and dimension check as assembled for testing			As per approved drawings	P	W
	2.	Check validity of calibration of all test equipment and measuring instruments (e.g. HV test equipment, Loss measurement kit, Partial Discharge kit, impulse units etc.)			As per Specification/ IS: 2026/ IEC 60076/ other applicable standard	-	V
	3.	Measurement of winding resistance at all taps				P	W
	4.	Measurement of voltage ratio at all taps				P	W
	5.	Check of phase displacement and vector group				P	W
	6.	Measurement of no-load loss and current measurement at 90%, 100% & 110% of rated voltage and rated frequency				P	W
	7.	Magnetic balance test (for three phase Transformer only) and measurement of magnetizing current				P	W
	8.	Short Circuit Impedance and load loss measurement at principal tap and extreme taps				P	W
	9.	Measurement of insulation resistance (IR) & Polarization Index (PI)				P	W
	10.	Measurement of insulation power factor and capacitance between winding to earth and between windings				P	W
	11.	Measurement of insulation power factor and capacitance of bushings				P	W
	12.	Tan delta of bushing at variable frequency (Dielectric frequency response)				P	W
	13.	Full wave lightning impulse test for the line terminals (LI) (for 72.5kV< Um≤170 kV)				P	W

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
	14.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformers with Um>170 kV)				P	W
	15.	Switching impulse test for the line terminal (SI) (for transformers with Um>170 kV)				P	W
	16.	Applied voltage test (AV)				P	W
	17.	Line Terminal AC withstand voltage test (LTAC) (for transformer with 72.5 kV< Um ≤170 kV)				P	W
	18.	Induced voltage withstand test (IVW) (for transformers with Um ≤170 kV)				P	W
	19.	Induced voltage test with PD measurement (IVPD)				P	W
	20.	Test on On-load tap changer (Ten complete cycle before LV test) and other tests such as One complete operating cycle at 85 % of auxiliary supply voltage ,one complete operating cycle with Transformer energized at rated voltage and frequency at no load .Ten tap change operation with +/- 2 steps of principal tap with as far as possible the rated current of Transformer with one winding short circuited etc. as per IS 2026				P	W
	21.	Measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment.				P	W
	22.	Check of core and frame insulation				P	W
	23.	Leak testing with pressure for liquid immersed transformers (tightness test)				P	W
	24.	Measurement of no load current & Short circuit Impedance with 415 V, 50 Hz AC.				P	W
	25.	Frequency Response analysis after completion of test for max, min &				P	W

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
		normal tap (Soft copy of test report to be submitted to site along with test reports)					
	26.	High voltage withstand test on auxiliary equipment and wiring after assembly				P	W
	27.	Tank vacuum test (at tank supplier premises during tank manufacturing)				P	W
	28.	Tank pressure test (at tank supplier premises during tank manufacturing)				P	W
	29.	Check of the ratio and polarity of built-in current transformers				P	W
	30.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)				P	W
B.	**Type Tests/Special test**		One from Lot	Specification/ IS:2026 / IEC 60076/other applicable standard	Specification/ IS:2026 / IEC 60076/other applicable standard		
	1.	Measurement of transferred surge on Tertiary due to HV lightning impulse (if applicable)				P	W
	2.	Measurement of transferred surge on Tertiary due to HV switching impulse (if applicable)				P	W
	3.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformer with Um≤170 kV)				P	W
	4.	Lightning impulse test for the neutral terminals (LIN)					
	5.	Switching impulse test for the line terminal (SI) (applicable for Um>72.5 kV & ≤170 kV)				P	W
	6.	Temperature rise test				P	W
	7.	Measurement of Zero seq. reactance (for three phase Transformer only)				P	W
	8.	Measurement of harmonic level in no load current				P	W
	9.	Determination of sound level				P	W

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
	10.	Measurement of power taken by fans and liquid pump motors (not applicable for ONAN)					
	11.	Short circuit withstand capability test (Dynamic)				P	W

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Typical example for calculation of flux density, core quantity, no-load loss and weight of copper

Calculation of flux density, core quantity, no-load loss and weight of copper for a specific transformer has been given below. Similar calculations for any rating of transformer can be carried out and relevant data may be obtained from the manufacturer.
Example: 75 MVA, 220/11, YNd11, 3 Phase, Power transformer,
Tap Range: -2.5% to +7.5% , Off-circuit Switch (Linear) connection

Measured data of core step width and thickness:

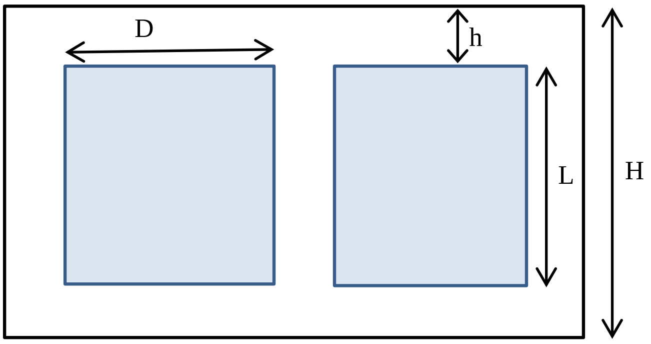
STEP NO.	WIDTH	THICKNESS	THICKNESS	AREA OF STEP	AREA OF STEP	SUM OF STEP AREA
	(mm)	(mm)	(mm)	(mm^2)	(mm^2)	(mm^2)
1	260	8.25	8.25	2145.00	2145.00	4290.00
2	300	8.41	8.41	2523.00	2523.00	5046.00
3	320	8.17	8.17	2614.40	2614.40	5228.80
4	360	8.48	8.48	3052.80	3052.80	6105.60
5	380	8.52	8.52	3237.60	3237.60	6475.20
6	400	8.45	8.45	3380.00	3380.00	6760.00
7	440	8.42	8.42	3704.80	3704.80	7409.60
8	460	14.4	14.4	6624.00	6624.00	13248.00
9	500	10.05	10.05	5025.00	5025.00	10050.00
10	520	19.06	19.06	9911.20	9911.20	19822.40
11	560	25.43	25.43	14240.80	14240.80	28481.60
12	600	14.5	14.5	8700.00	8700.00	17400.00
13	620	15.5	15.5	9610.00	9610.00	19220.00
14	640	15.79	15.79	10105.60	10105.60	20211.20
15	660	19.1	19.1	12606.00	12606.00	25212.00
16	680	23.2	23.2	15776.00	15776.00	31552.00
17	700	23.07	23.07	16149.00	16149.00	32298.00
18	720	40.05	40.05	28836.00	28836.00	57672.00
19	740	71.67	71.67	53035.80	53035.80	106071.60
				GROSS AREA (mm^2):		**422554.00**
Stacking Factor = 0.96 to 0.97						
NET CORE AREA (A)=Gross Area x Stacking factor= 422554 x 0.96 mm^2 = 4056.52 cm^2						

CALCULATION OF FLUX DENSITY:

Phase voltage = 4.44 f x B_{max} x A x N x 10^{-4}
Where,

Phase voltage = 11 kV
Frequency (f) =50 Hz
A= 4056.52 cm^2
N= No. of turns on 11 kV side =72
Maximum flux density, B_{max} = (11000)/(4.44*50*4056.52*72*10^{-4}) = 1.696 T

CALCULATION OF WEIGHT OF CORE:



Net core area (A) = 4056.52 cm^2
Window height (L) = 2000 mm
Yoke height (h) =740 mm
Core Height (H) = L+ 2 x h= 2000 + (2 x 740)=3480 mm
Window width (D) =810 mm
Limb Pitch = D+h = 810+740 = 1550 mm

There are 3 core heights and 4 window widths

Hence, total periphery of the core = 3H+4D = (3x3480) +(4x810)
= 13680 mm =1368 cm

Weight of the core
= Total periphery of the core x Cross-section area of core x Density of CRGO steel
=1368.0 x 4056.52 x 7.65 x 10^{-3}
= **42452.3 kg**

Guaranteed weight as per GTP= 42000 kg

Average Core Lamination Thickness =0.23 mm
Cooling duct thickness measured =4.24 mm

CALCULATION OF NO LOAD LOSS FROM SUPPLIER'S LOSS CURVES:

Weight of core lamination = **42452.3 kg**

Flux density at normal tap at 100% rated voltage=1.696 T

Referring to supplier's curves for core losses against working flux density
The value of watts/kg at 1.7 Tesla. = 0.78 approx

No load loss = Core weight x Watts/kg at 1.7 Tesla x Building Factor x 10^{-3} kW
= 42452.3 x 0.78 x 1.11x 10^{-3}= 36.755 kW
(Where the value of building factor taken is 1.11)

Guaranteed No Load Loss = 39.0kW

Calculated No load loss < (Guaranteed loss figure)

<u>Estimation of copper quantity during stage Inspection</u>

A. Weight of bare copper by ID/OD METHOD

	Periphery (P) (mm)	**Outer Dia (OD) =P/3.14 (mm)**	**Radial depth (RD) (mm)**	**Mean Dia (OD-RD) (mm)**
LV Winding	**3035**	966.1	**77.60**	888.5
HV Winding	**4585**	1459.5	**169.50**	1290.0
Regulating (Tap) Winding	**4585**	1459.5	**169.50**	1290.0

No. of Turns:
LV Winding: 72 HV Winding: 811 Tap Winding : 84

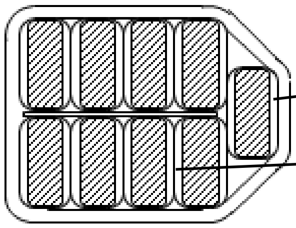
Type of Conductor in LV winding – Continuously Transposed Cable (CTC)
No. of Coils in LV Winding =1
No. of Cables parallel in LV Winding =2
No. of strands per cable in LV Winding = 77

Type of Conductor in HV winding – Twin Paper Insulated Copper Conductor (TPICC)
No. of Coils parallel in HV Winding =2
No. of Cables per turn in HV Winding =2
No. of strands per cable in HV Winding =2

Type of Conductor in Tap winding – Paper Insulated Copper Conductor (PICC)
No. of Coils parallel in Tap Winding =2
No. of Cables per turn in Tap Winding =3
No. of strands per cable in Tap Winding =1

No. of phases = 3

Measured Strand dimension
Size of LV strand **=** 5.067 x 1.929 mm (with 0.1 mm enamel and 0.04 mm epoxy)
So bare size of LV strand = (5.067-0.1) x (1.929 -0.14*****) mm (* Low chip epoxy used)
= 4.967 x 1.789 mm



Bare Size of HV strand = 9.880 x 1.792 mm
Bare Size of Tap strand = 7.845x 3.012 mm
Area of each LV Cable = Strand area x No of strands/Cable
= [(4.967x1.789)-0.363)] x 77 = 656.27 mm^2
Area of each HV Cable = Strand area x No of strands/Cable
= [(9.88x1.792)-0.363)] x 2 = 34.68 mm^2
Area of each Tap Cable = Strand area x No of strands/Cable
= [(7.845x3.012)-0.55] x 1 = 23.08 mm^2

Bare Cu Weight of LV winding
= 3 x π x Mean Diameter x No. of Turns x Area of cable x No. of cables per turn x Cu Density
= 3 x 3.142 x 888.5 x 72 x 656.27 x 2 x 8.89x 10^{-6} = 7036 kg

Bare Cu Weight of HV winding
= 3 x π x Mean Diameter x No. of Turns x Area of cable x No. of cables per turn x Cu Density x No. of parallel Coils
= 3 x 3.142 x 1290 x 811 x 34.68 x 2 x 8.89x 10^{-6}x 2= 12161 kg

Bare Cu Weight of Tap winding
= 3 x π x Mean Diameter x No. of Turns x Area of cable x No. of cables per turn x Cu Density x No. of parallel Coils
= 3 x 3.142 x 1290 x 84 x 23.08 x 3 x 8.89x 10^{-6}x 2= 1258 kg

Total Bare Copper weight = 7036+12161+1258 = 20455 kg

B. WEIGHT OF BARE COPPER BY PER UNIT LENGTH METHOD

Measured bare cable Cu weight of LV winding per 650 mm = 3718 gm
bare cable Cu weight of LV winding per unit length = 5720 gm/meter

Measured bare cable Cu weight of HV winding per 595 mm = 184 gm
bare cable Cu weight of HV winding per unit length = 309.3 gm/meter

Measured bare cable Cu weight of Tap winding per 745 mm = 160 gm
bare cable Cu weight of Tap winding per unit length = 214.8 gm/meter

Bare Cu Weight of LV winding
= 3 x π x Mean Diameter x No. of Turns x No. of cables per turn x weight of unit length
= 3x 3.142x888.5x72x 2 x5720 x 10^{-6} = 6898 kg

Bare Cu Weight of HV winding

= 3 x π x Mean Diameter x No. of Turns x No. of cables per turn x weight of unit length x No. of parallel Coils

= 3x3.142x1290x811x2x309.3x2x 10^{-6} = 12200 kg

Bare Cu Weight of Tap winding

= 3 x π x Mean Diameter x No. of Turns x No. of cables per turn x weight of unit length x No. of parallel Coils

= 3 x3.142 x 1290x 84 x 3 x 214.8 x2x 10^{-6} = 1316 kg

Total Bare Copper weight = 6898+12200+1316 = 20414 kg

C. WEIGHT OF BARE COPPER BY RESISTANCE METHOD

Measured Ambient temperature = 31 ^{o}C

Measured Resistance of each strand of LV = 0.42760 ohm

Measured Resistance of each LV cable = 0.42760/77

= 0.005553ohm

Measured Resistance per strand of each HV coil (46 disc from HV center)

= 3.121 ohm

Measured Resistance per strand of each HV coil (Last 4 disc of HV bottom)

= 0.26834 ohm

So Total Measured Resistance per Stand of each HV coil (50 disc from HV centre)

= 3.121 + 0.26834

=3.38934 ohm

So Total Measured Resistance per Cable of each HV coil (50 disc from HV centre)

= 3.38934/2 = 1.69467 ohm

Measured Resistance per cable of each Tap coil (2 disc of Tap coil) = 0.067465 ohm

So, Total Measured Resistance per cable of each Tap coil (8 disc of Tap coil)

= 0.067465 x 8/2 =0.26986

Resistivity (ρ) of Copper (at 20 ^{o}C) = 0.017241 ohms- mm^{2}/meter

Resistance Conversion factor at 20 ^{o}C = (235+20)/(235+31)= 0.95865

Resistance of LV Winding at 20 ^{o}C = Resistance of LV Winding x Resistance Conversion factor

= 0.005553 x 0.95865 = 0.005324 ohm

Resistance per cable of each HV coil at 20 ^{o}C = Resistance of HV cable x Resistance Conversion factor

=1.69467 x 0.95865 =1.6246 ohm

Resistance per cable of each Tap coil at 20 ^{o}C = Resistance of Tap cable x Resistance Conversion factor

= 0.26986 x 0.95865

= 0.2587 ohm

R = ρ (L/A)

ρ : Resistivity, L : Length in Meters, A : Area of conductors in mm^{2}

Length of each LV cable = (R x A)/ ρ **=** 0.005324x 656.27/ 0.017241
= 202.27 x10^3 mm
Length of each HV cable = 1.6246 x 34.68/ 0.017241
= 3267.86 x10^3 mm
Length of each Tap cable = 0.2587 x 23.08/ 0.017241
= 346.31 x10^3 mm

Bare Cu Weight of LV winding
= 3 x length of per cable x area of each cable x no. of parallel cables x Cu density
= 3 x 202.27 x10^3 x 656.27 x 2 x 8.89x 10^{-6}
= 7081 kg

Bare Cu Weight of HV winding
= 3 x length of per cable x area of all parallel conductors x Cu density x No. of parallel Coils
= 3 x 3267.86 x10^3 x 34.68 x 2 x 8.89x 10^{-6} x 2
= 12090 kg

Bare Cu Weight of Tap winding
= 3 x length of per cable x area of all parallel conductors x Cu density x No. of parallel Coils
= 3 x 346.31 x 10^3 x 23.08 x 3 x 8.89x 10^{-6} x 2
= 1279 kg

Total Bare Copper weight = 7081+12090+1279= 20450 kg

D. CURRENT DENSITY CALCULATION:

LV winding:
Current = 2272.73 A; Conductor area = 656.27x2= 1312.54 mm^2
Current density = 2272.73 / 1312.54 = 1.73 A/mm^2

HV winding: (Minimum Tap)
Current = 201.88 A; Conductor area = 34.68 x2x2= 138.72 mm^2
Current density = 201.88 / 138.92 = 1.46 A/mm^2

Tap Winding: **(Minimum Tap)**
Current = 201.88 A; Conductor area = 23.08 x3x2= 138.48 mm^2
Current density = 201.88 / 138.92 = 1.46 A/mm^2

BASIC MANUFACTURING FACILITY & MANUFACTURING ENVIRONMENT

Customer/Purchaser always desires that transformer manufactured and delivered is of good quality and must perform trouble free service for its “Specified Design Life”. The consistency in quality of material used & manufacturing process are main cause for variation in quality of transformer. It is also equally very important that transformer is manufactured in a clean dust free and humidity controlled environment. Any compromise on this aspect will have adverse effect in expected design life of transformer, however good is the quality of material used. A broad list of facilities the transformer manufacturers should have are given below:

Basic manufacturing facility

Following manufacturing facility should be available for use with transformer manufacturer:

1. EOT Crane for main manufacturing bay and other shops (With Load Cell).
2. Vapor Phase Drying Oven (adequately sized to accommodate offered transformer and have facility to record temperature, vacuum, moisture etc.)
3. Air Casters for material handling
4. Core cutting line (if applicable)
5. Vacuum auto claves
6. Air oven
7. Adjustable Horizontal and vertical winding machine
8. Winding Mandrels
9. Hydraulic Press
10. Brazing equipment
11. Mechanical platform
12. Tools and fixtures
13. Mechanical power press
14. Welding machines
15. Crimping tools
16. Faraday’s cage
17. Motor Generator Set/ Static Power System Set

18. Testing transformer
19. Capacitor bank
20. Impulse voltage generator
21. Capacitance & Tan delta bridge
22. Power Analyser
23. Current & Voltage transformer
24. Partial Discharge (PD) measuring kit (for all manufacturers) & PD Diagnostic Kit (for 400 kV & above voltage class Transformer manufacturer)
25. Temperature data logger
26. Noise measurement kit
27. Thermo vision camera
28. Loss measurement kit
29. Insulation tester
30. Winding resistance meter
31. Turn ratio meter
32. Transformer oil test lab
33. Dissolved Gas Analysis (DGA) test kit
34. Sweep Frequency Response Analyser (SFRA) kit
35. Frequency Domain Spectroscopy (FDS) kit
36. **NABL Accredited laboratory for testing**
37. Oil Storage tanks
38. Oil filter plant with requisite level of vacuum and filter
39. Tensometer for Oil Surface tension
40. Particle Count Kit (for 400 kV & above Transformer)
41. Multimeters

Manufacturing environment (Clean, dust free and humidity controlled environment)

A. Transformer must be manufactured in a bay having positive pressure w.r.t. external environment. Winding shall be manufactured in an clean, dust free and humidity controlled environment. The dust particle shall be monitored regularly in the manufacturing areas. Further, there shall be positive atmospheric pressure, clean, dust free and humidity controlled environment for following:

1. Insulation storage
2. Core storage
3. Glue stacking area
4. Core cutting line
5. Winding manufacturing bay
6. Core building area
7. Core coil assembly area
8. Testing lab
9. Packing & dispatch area

B. Following accessories to be kept in clean and covered location:

1. Piping
2. Radiator
3. Tank
4. Bushing (as per manufacturer's guideline)
5. Marshalling box
6. Turret
7. Conservator
8. Insulating oil

Annexure- H

List of drawings/documents to be submitted by the manufacturer

1.0 Each drawing shall be identified by a drawing number and each subsequent resubmission/revision or addition to the drawing shall be identified by a revision number. All drawings shall be thoroughly checked for accuracy & completeness and signed. Any mistakes or errors in drawings shall not form a basis for seeking extension of delivery period.

2.0 In addition to any other drawings which the manufacturer may like to supply, the following drawings/ calculations/ documents/ catalogues shall be submitted in hard and soft copy:

(a) Guaranteed Technical Particulars (GTPs) and other Technical particulars

(b) Rating and Diagram Plate giving details of terminal marking and connection diagram

(c) General Arrangement (GA) drawing (as built drawing) of transformer showing Plan, Elevation, End view (left side & right side view looking from HV side) and 3D view identifying various fittings & accessories, dimensions, weight, clearances, quantity of insulating oil, centre of gravity etc.

(d) View showing maximum lifting height of core-coil assembly and maximum clearance over tank top required for taking out the bushing.

(e) List of all accessories, description, make, weight and quantity

(f) Bill of Materials (BoM) with description, make & quantity

(g) Foundation Plan showing Rail gauge, fixing details of foundation bolts, clamping arrangement to restrict movement during earthquake & location of jacking pads and loading details

(h) Bushing Drawing showing dimensions, electrical & mechanical characteristics, mounting details and test tap details (as applicable)

- i) HV Bushing
- ii) LV (or LV1/LV2)Bushing
- iii) Tertiary Bushing
- iv) Neutral Bushing

(i) Transport Dimension Drawing indicating transport weight, transport condition (oil filled/ gas filled), lifting bollards, jacking pads, pulling eyes, quantity and location of impact recorder etc.

(j) General Arrangement Drawing of Cooler Control Cabinet, Marshalling box

(k) General Arrangement Drawing of RTCC panel (if applicable)

(l) GA drawing for Junction Box (if applicable)

(m) GA drawing for Cable Box (if applicable)

(n) Cooler Control Scheme: Schematic wiring diagram of cooling arrangement along with write up on scheme

(o) Tap Changer Control Scheme (if applicable): Schematic wiring diagram of OLTC along with write up on scheme

(p) Mounting Arrangement and wiring diagram of remote WTI along with write up.

(q) Alarm/Trip Indication Scheme

(r) Valve Schedule Plate drawing showing all valves, air vents, drain plugs etc. with type, size, material and quantity of valves

(s) Technical literature of all fittings and accessories

(t) Calculation in support of thermal withstand capability of transformer due to short circuit

(u) Calculation of hot spot temperature

(v) Value of air core reactance with a typical write-up of calculation

(w) Magnetisation Characteristics of bushing CTs and neutral CTs

(x) Hysteresis Characteristics of iron core

(y) Over fluxing withstand duration curve

(z) Typical heating and cooling curves

(aa) Drawing showing winding arrangement & geometrical sequence w.r.t core with winding ID/OD, height & separation distance between windings etc.

(bb) Twin bi-directional roller assembly drawing

(cc) Oil Flow Diagram

(dd) List of spares

(ee) Connection diagram of all protective devices to marshalling box showing physical location

(ff) Insulating oil storage tank drawing

(gg) Oil sampling Bottle details

(hh) Customer inspection schedule

(ii) Test procedure of transformer

(jj) Manufacturer Quality Program (MQP) and Field Quality Plan (FQP) (kk) Field Welding Schedule for field welding activities (if applicable)

(ll) Type test reports

(mm) O&M manual (hard copy and soft copy) of transformer inter-alia including instructions for Aircell, Oil filling, Bushing removal and Core Coil Assembly un-tanking etc.

Annexure – I

SCOPE OF DESIGN REVIEW

Sr. No.	Description
1.	Core and Magnetic Design
2.	Inrush-current characteristics while charging
3.	Winding and winding clamping arrangements
4.	Characteristics of insulation paper
5.	Typical data and parameters mentioned in GTP
6.	Short-circuit withstand capability including thermal stress / withstand capability for 2 seconds
7.	Thermal design including review of localized potentially hot area
8.	Structural design
9.	Cooling design
10.	Overload capability
11.	Calculations of losses, flux density, core quantity etc.
12.	Calculations of hot spot temperature
13.	Eddy current losses
14.	Seismic design, as applicable
15.	Insulation co-ordination
16.	Tank and accessories
17.	Bushings
18.	Mechanical layout design including lead routing and bushing termination
19.	Tapping design (as applicable)
20.	Protective devices
21.	Number, locations and operating pressure of PRD
22.	Location, Operating features and size of Sudden Pressure Relay/ Rapid Pressure Rise Relay
23.	Radiators, Fans and Pumps (as applicable)
24.	Sensors and protective devices– its location, fitment, securing and level of redundancy
25.	Oil and oil preservation system
26.	Corrosion protection

27.	Electrical and physical Interfaces with substation
28.	Earthing (Internal & External)
29.	Processing and assembly
30.	Testing capabilities
31.	Inspection and test plan
32.	Transport and storage
33.	Sensitivity of design to specified parameters
34.	Acoustic Noise
35.	Spares, inter-changeability and standardization
36.	Maintainability
37.	Conservator capacity calculation
38.	Winding Clamping arrangement details with provisions for taking it "in or out of tank"
39.	Conductor insulation paper details
40.	Location and numbers of Optical temperature sensors (if provided)
41.	The design of all current connections
42.	Location & size of the Valves
43.	Manufacturing facilities and manufacturing environment (clean, dust free, humidity controlled environment) as per Annexure G

Annexure-J

CRITERIA FOR SELECTION OF SIMILAR REFERENCE TRANSFORMER FOR DYNAMIC SHORT CIRCUIT WITHSTAND TEST

A transformer is considered similar to another transformer taken as a reference if it has the following characteristics in common with the latter:

- Same type of operation, for example generator step-up unit, distribution, interconnection transformer;
- Same conceptual design, for example dry type, oil-immersed type, core type with concentric windings, sandwich type, shell type, circular coils, non-circular coils;
- Same arrangement and geometrical sequence of the main windings;
- Same type of winding conductors, for example aluminium, aluminium alloy, annealed or work-hardened copper, metal foil, wire, flat conductor, continuously transposed conductors and epoxy bonding, if used;
- Same type of main windings, for example helical-, disc-, layer-type, pancake coils;
- **Absorbed power at short circuit (rated power/per unit short-circuit impedance) between 70% and 130% of that relating to the reference transformer;**
- Axial forces and winding stresses occurring at short circuit not exceeding 120 % of those relating to the reference transformer;
- Same manufacturing processes;
- Same clamping and winding support arrangement.

(**Note:-**A format for comparison of characteristics as given above of successfully type tested reference transformer and of transformer short circuit strength of which shall be evaluated (offered transformer) has been provided below. Data of a typical sample reference transformer has been filled for reference and guidance of utility to compare a Short Circuit tested transformer with the offered transformer in order to verify the similarity criteria.)

DATE :	**Format for determining similar reference transformer for short Circuit withstand Strength**	**Manufacturer NAME**
DOC No.:		
Page: -- of --		

		Details of offered transformer short circuit strength of which is being evaluated	**Details of SC tested transformer**	**Is characteristic similar ?**	**Reference document /Remarks if any**
General Information					
	Customer and Purchase Order No.:				
	Project Name:				
	Transformer General Rating Description (MVA, Voltage Ratio, tested short circuit current):		**315MVA, 400/220/33KV AUTOTRANSFORMER, 3 phases, --kA**		

	Unit number/ Serial no:				
	Short circuit test laboratory detail:	-NA-	KEMA, Netherland		
	Short circuit test report reference No. & Date:	-NA-			
Characteristics as per IEC 60076-5 :2006					
1	**Type of Transformer based on operation:** *e.g. Generator Step up unit; Distribution; Interconnecting; Auto; Station auxiliary etc.*		**AUTO transformer**	**Yes/No**	Reference: 1. *Rating & Diagram plate 2. Approved GTP
2	**Factory of production, material used (Material of conductor, cellulose insulating material, oil, grade of CRGO material), and as built Drawing**				Reference: Short circuit test report
3	**Tested Short Circuit Current and duration of Dynamic short circuit current (250ms / 500ms)**				Reference: Short circuit test report along with as built drawing

<table>
<tr><td>4</td><td>Conceptual design
e.g. Dry / oil-immersed type ; Core type with concentric windings / sandwich type, shell type, Circular coils / non-circular coils</td><td></td><td>OIL-IMMERSED, CORE TYPE, CONCENTRIC WINDINGS, CIRCULAR COILS</td><td>Yes/No</td><td>Reference:
1. Rating & Diagram plate
2. Approved GTP</td></tr>
<tr><td>5</td><td>Arrangement and geometrical sequence of main windings
e.g.; Core-LV-HV-T</td><td></td><td>CORE - LV (TER) – REG – IV - HV</td><td>Yes/No</td><td>Reference:
1. Winding assembly drawing in Short circuit test report if available
2. *Or Representative Coil assembly drawing reference</td></tr>
<tr><td>6</td><td>Type of conductors for each winding
e.g aluminium / aluminium alloy, annealed or work-hardened Copper; metal foil / wire / flat conductor / Continuously Transposed conductor; Epoxy bonding (Yes/No); work hardened Proof stress (min) N/mm²</td><td></td><td><table><tr><td></td><td>LV</td><td>Tap</td><td>IV</td><td>HV</td></tr><tr><td>Conductor</td><td>COPPER</td><td>COPPER</td><td>COPPER</td><td>COPPER</td></tr><tr><td>Type</td><td>CTC</td><td>CTC</td><td>CTC</td><td>CTC</td></tr><tr><td>Epoxy coated</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr><tr><td>Proof stress N/mm (min)</td><td></td><td></td><td></td><td></td></tr></table></td><td>Yes/No</td><td>Reference:
1. *Test Certificates submitted by the conductor Vendor for each winding
2. Approved GTP</td></tr>
<tr><td>7</td><td>Type of each windings</td><td></td><td><table><tr><td>Winding</td><td>LV</td><td>Tap</td><td>IV</td><td>HV</td></tr></table></td><td>Yes/No</td><td>Reference:
1. In case Short ckt. test report is inclusive of detail on</td></tr>
</table>