Advanced Transformer Design Report

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Design Standard: IEC 60076

Project Information

Transformer Type:	Power Transformer
Core Material:	Amorphous Metal
Cooling Type:	Dry Type
Phase Configuration:	Three Phase
Core Shape:	Shell Type
Winding Type:	Helical Winding
Connection Type:	Delta-Wye

Electrical Parameters:

Primary Voltage:	11000.0 V
Secondary Voltage:	433.0 V
Frequency:	50.0 Hz
Power Rating:	2000000.0 VA
Target Efficiency:	95.0%
Regulation:	5.0%
Flux Density:	1.80 T
Current Density:	1.50 A/mm²

Environmental Parameters:

Ambient Temperature:	30.0 °C
Maximum Temperature Rise:	75.0 °C
Altitude:	0.0 m
Harmonic Factor:	1.0

Design Summary

Core Area:	1555.63 cm²
Core Dimensions:	509.2 × 305.5 mm
Window Dimensions:	203.7 × 611.0 mm
Primary Turns:	102
Secondary Turns:	4
Primary Current:	104.97 A
Secondary Current:	2666.74 A
Primary Conductor:	2/0 (69.98 mm²)
Secondary Conductor:	4/0 (1777.83 mm²)
Calculated Efficiency:	99.88%
Total Losses:	2358.43 W
Temperature Rise:	361.0 °C
Hot Spot Temp:	463.2 °C

Core Weight:	1547.1 kg
Copper Weight:	214.0 kg
Total Cost:	$116812.45

Core Design Details

Core Shape:	Shell Type
Material:	Amorphous Metal
Stacking Factor:	0.900
Building Factor:	1.300
Net Core Area:	1555.63 cm^2
Gross Core Area:	1728.48 cm^2
Core Width:	509.2 mm
Core Depth:	305.5 mm
Window Width:	203.7 mm
Yoke Height:	254.6 mm
Window Height:	611.0 mm
Core Volume:	202232.5 cm^3
Core Weight:	1547.1 kg
Flux Density:	1.800 T
Core Loss:	464.12 W

Winding Design Details

Winding Type: Helical Winding

Primary Winding:

Turns:	102
Current:	104.97 A
Conductor Area:	69.9819 mm²
Conductor Type:	2/0 (9.266 mm)
Mean Turn Length:	1.629 m
Resistance:	0.0400 Ohm
Copper Loss:	440.36 W
Eddy Loss:	2.37 W
Skin Depth:	9.348 mm

Winding Configuration:

Turns per Layer	65
Layers	2
Winding Height (mm)	18.404134261751636
Winding Thickness (mm)	9.202067130875818

Secondary Winding:

Turns:	4
Current:	2666.74 A
Conductor Area:	1777.8299 mm²
Conductor Type:	4/0 (11.684 mm)
Mean Turn Length:	1.629 m
Resistance:	0.0001 Ohm
Copper Loss:	462.37 W
Eddy Loss:	425.71 W
Skin Depth:	9.348 mm
Litz Wire:	7 strands of 4/0

Winding Configuration:

Turns per Layer	13
Layers	1
Winding Height (mm)	46.38075261514062
Winding Thickness (mm)	46.38075261514062

Loss Analysis

Primary Copper Loss:	440.36 W
Secondary Copper Loss:	462.37 W
Harmonic Copper Loss:	0.00 W
Total Copper Loss:	902.73 W
Primary Eddy Loss:	2.37 W
Secondary Eddy Loss:	425.71 W
Harmonic Eddy Loss:	428.08 W
Total Eddy Loss:	856.16 W
Core Loss:	464.12 W
Stray Loss:	135.41 W
Total Losses:	2358.43 W

Thermal Analysis

Cooling Type:	Dry Type
Surface Area:	1.307 m^2
Cooling Coefficient:	5.0 $W/m^2°C$
Adjusted Coefficient:	5.0 $W/m^2°C$
Temperature Rise:	361.0 °C
Hot Spot Temperature:	463.2 °C
Ambient Temperature:	30.0 °C
Maximum Allowed Rise:	75.0 °C

Mechanical Design

Enclosure Width (m)	0.66
Enclosure Depth (m)	0.40
Enclosure Height (m)	0.92
Ventilation Area (m²)	1000.00

Dynamic Performance

Reactance:	0.3934 Ohm
Short-Circuit Current:	27961.2 A
Radial Force:	321484248.2 N
Thermal Capacity:	1563656429.0 A²s
Peak Inrush Current:	1.0 A
Inrush Duration:	0.2 cycles

Cost Analysis

Core Weight:	1547.1 kg
Copper Weight:	214.0 kg
Core Cost:	$9282.47
Winding Cost:	$1925.83
Cooling Cost:	$100000.00
Labor Factor:	1.5
Total Cost:	$116812.45

Design Methodology

=== Design Methodology ===

1. Core Dimensions (Shell Type):

Core area: A_c = K*sqrt(P) = 0.9 × sqrt(2000000.0) = 1555.63 cm²

Gross core area: A_g = A_c/k = 1555.63/0.9 = 1728.48 cm²

Core Width (mm): 509.2

Core Depth (mm): 305.5

Window Width (mm): 203.7

Window Height (mm): 611.0

Yoke Height (mm): 254.6

2. Turns Calculation:

Primary turns: N1 = V1/(4.44×f×Bm×Ac) = 11000.0/(4.44×50.0×1.8×1555.63e-4) = 102

Secondary turns: N2 = V2×(1+alpha)/(4.44×f×Bm×Ac) = 433.0×1.05/(4.44×50.0×1.8×1555.63e-4) = 4

3. Current Calculation:

Primary current: I1 = P/V1 = 2000000.0/11000.0 = 104.97 A

Secondary current: I2 = P/V2 = 2000000.0/433.0 = 2666.74 A

4. Conductor Sizing:

Primary conductor area: Aw1 = I1/J = 104.97/1.5 = 69.9819 mm²

Secondary conductor area: Aw2 = I2/J = 2666.74/1.5 = 1777.8299 mm²

Primary wire: 2/0 (9.266 mm)

Secondary wire: 4/0 (11.684 mm)

Secondary requires Litz wire: 7 strands of 4/0

5. Winding Design (Helical Winding):

Primary Winding:

Turns per Layer: 65

Layers: 2

Winding Height (mm): 18.404134261751636

Winding Thickness (mm): 9.202067130875818

Secondary Winding:

Turns per Layer: 13

Layers: 1

Winding Height (mm): 46.38075261514062

Winding Thickness (mm): 46.38075261514062

6. Loss Calculations:

Primary copper loss: 440.36 W

Secondary copper loss: 462.37 W

Harmonic copper loss: 0.00 W

Primary eddy loss: 2.37 W

Secondary eddy loss: 425.71 W

Harmonic eddy loss: 428.08 W

Core loss: 464.12 W

Stray loss: 135.41 W

Total losses: 2358.43 W

7. Thermal Analysis:

Surface area: 1.31 m^2

Cooling coefficient: 5.0 $W/m^2°C$

Temperature rise: 361.0 °C

Hot spot temperature: 463.2 °C

9. Mechanical Design:

Enclosure Width (m): 0.66

Enclosure Depth (m): 0.40

Enclosure Height (m): 0.92

Ventilation Area (m^2): 1000.00

10. Dynamic Performance:

Reactance: 0.3934 Ohm

Short-circuit current: 27961.2 A

Radial force: 321484248.2 N

Thermal capacity: 1563656429.0 A^2s

Peak inrush current: 1.0 A

Inrush duration: 0.2 cycles

11. Cost Estimation:

Core weight: 1547.1 kg

Copper weight: 214.0 kg

Core cost: $9282.47

Winding cost: $1925.83

Cooling cost: $100000.00

Total cost: $116812.45