

Transformer

1. Electromagnetic Theory

Key concepts:

- EMF Equation: $E = 4.44 f N \Phi$
- Flux density and saturation (1.5–1.7 T)
- Losses: Core (hysteresis, eddy current), Copper ($I^2 R$)
- Leakage reactance and impedance
- Equivalent circuit understanding

2. Thermal Management

- Heat sources: Core & copper losses
- Cooling methods: ONAN, ONAF, OFAF
- Hot spot temperature concept
- Insulation life vs temperature relationship

3. Insulation System

- Oil and paper insulation
- Dielectric strength and testing (BDV, IR, PI)
- Aging factors: heat, moisture, oxygen
- DGA and oil diagnostics

4. Mechanical Integrity

- Short circuit forces (radial and axial)
- Winding stability and clamping
- Failure modes: deformation, displacement

5. Transformer Testing

- Routine tests: ratio, resistance, losses
- Type tests: temperature rise, impulse, short circuit
- Special tests: FRA

6. Transformer Design & Development

Design flow:

- Define rating (MVA, voltage, frequency)
- Core design (flux density selection)
- Winding design (turns, conductor size)
- Leakage reactance optimization
- Thermal and cooling design
- Insulation coordination
- Mechanical strength validation

7. Engineering Calculations & Simulation

- Electromagnetic simulation (ANSYS Maxwell)
- Thermal analysis (ANSYS Fluent, COMSOL)
- Mechanical stress simulation (ANSYS Mechanical)
- Design validation loop