Substation Engineering: Transformers (Part 1 of 2)

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Transformers (Part 1 of 2)

- Course: Substation Engineering
- Lecture 7: Transformers (Part 1 of 2)
- Unit 3: Substation Equipment

Agenda

- Introduction to Power Transformers
- Core and Winding Construction
- Transformer Vector Groups
- Tap Changing Mechanisms (OLTC)
- Cooling Methods
- Transformer Oil and Conservator

Introduction to Power Transformers

- Primary function: Step-up or step-down voltage levels.
- Operates on the principle of Faraday's Law of Electromagnetic Induction.
- Allows power transmission over long distances at high voltages (low current, low losses).
- Rated in MVA (Megavolt-Amperes) rather than MW.
- Highly efficient machines (often ¿99% efficiency).

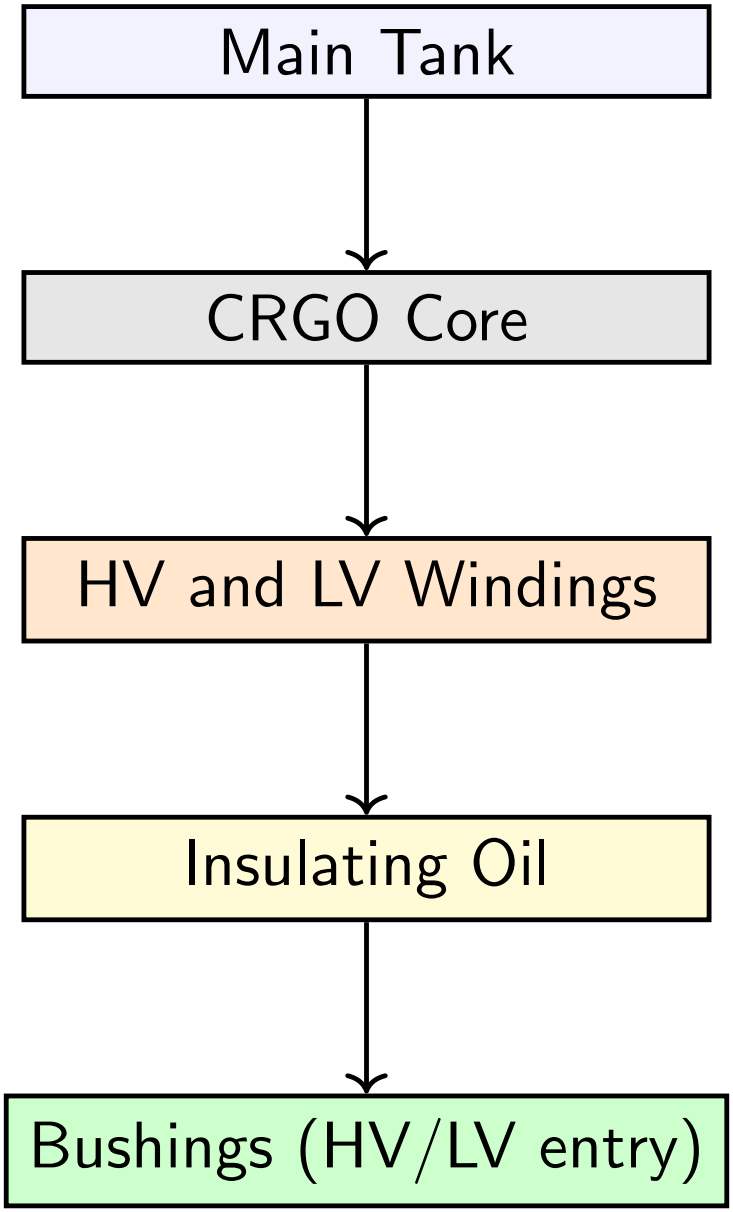
Role in Substations

- Transmission Substations: Step up voltage for grid transmission.
- Distribution Substations: Step down voltage for local distribution networks.
- Interconnecting Substations: Tie together grids operating at different voltage levels (e.g., 400kV to 220kV).
- Often use Auto-transformers for interconnecting closely matched voltage levels.

Core and Winding Construction

- Core: Made of CRGO (Cold Rolled Grain Oriented) silicon steel to minimize eddy currents and hysteresis losses.
- Core Type vs. Shell Type construction.
- Windings: Usually electrolytic copper, insulated with kraft paper.
- LV winding is placed closer to the core, HV winding placed outside to reduce insulation requirement to the core.
- Spacers and barriers ensure cooling ducts for oil flow.

Internal Structure of a Power Transformer



Transformer Vector Groups

- Indicates the phase angle difference between HV and LV windings.
- Standardized using a clock-face notation (e.g., Dyn11).
- D = Delta (HV), y = Star (LV), n = neutral brought out.
- 11 indicates LV leads HV by 30 degrees (clock position 11).
- Crucial for parallel operation; transformers must have compatible vector groups.

Tap Changing Mechanisms

- Used to regulate the output voltage by varying the number of turns in a winding.
- Usually provided on the HV winding (lower current, easier to switch).
- Off-Circuit Tap Changer (OCTC): Can only be operated when transformer is de-energized.
- On-Load Tap Changer (OLTC): Allows tap changing without interrupting the load.
- OLTC requires complex diverter switches and transition resistors.

Cooling Methods

- Transformers generate heat due to copper and iron losses.
- ONAN (Oil Natural Air Natural): Natural convection of oil and air.
- ONAF (Oil Natural Air Forced): Fans blow air across radiators.
- OFAF (Oil Forced Air Forced): Pumps force oil flow, fans force air.
- ODAF (Oil Directed Air Forced): Oil pumped directly into winding ducts.

Comparison of Cooling Classes

Class	Characteristics
ONAN	Base rating, no moving parts, low maintenance
ONAF	$\sim$125% of base rating, requires fans, medium maintenance
OFAF	$\sim$133%+ of base rating, requires pumps and fans, high maintenance
ODWF	Used in hydro plants, very high cooling efficiency

Transformer Oil Properties

- Mineral oil serves dual purposes: Insulation and Cooling.
- High Dielectric Strength (BDV) to prevent internal arcing.
- Low Viscosity to allow free convection and heat transfer.
- High Flash Point to prevent fire hazards.
- Must be free of moisture; even ppm levels of water drastically reduce BDV.

Conservator and Breather System

- Conservator Tank: Allows for expansion and contraction of oil with temperature changes.
- Prevents the main tank from rupturing due to pressure.
- Silica Gel Breather: Attached to the conservator. As oil cools and contracts, air is drawn in.
- Silica gel absorbs moisture from the incoming air.
- Color change (Blue to Pink) indicates silica gel is saturated.

Key Takeaways

- Power transformers step voltages up/down via magnetic induction with high efficiency.
- Vector groups determine phase shifts and are critical for parallel operation.
- OLTC allows voltage regulation under load.
- Oil serves for both insulation and cooling; the conservator manages volume changes.

Next Lecture Preview

- Transformer Protection Systems
- Buchholz Relay operation
- Differential Protection
- Testing and Maintenance Practices