

Substation Engineering: Transformers (Part 2 of 2)

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Transformers (Part 2 of 2)

- Course: Substation Engineering
- Lecture 8: Transformers (Part 2 of 2)
- Unit 3: Substation Equipment

Agenda

- Importance of Transformer Protection
- Buchholz Relay Operation
- Pressure Relief Valve (PRV)
- Differential Protection
- Temperature Indicators (WTI & OTI)
- Testing and Dissolved Gas Analysis (DGA)

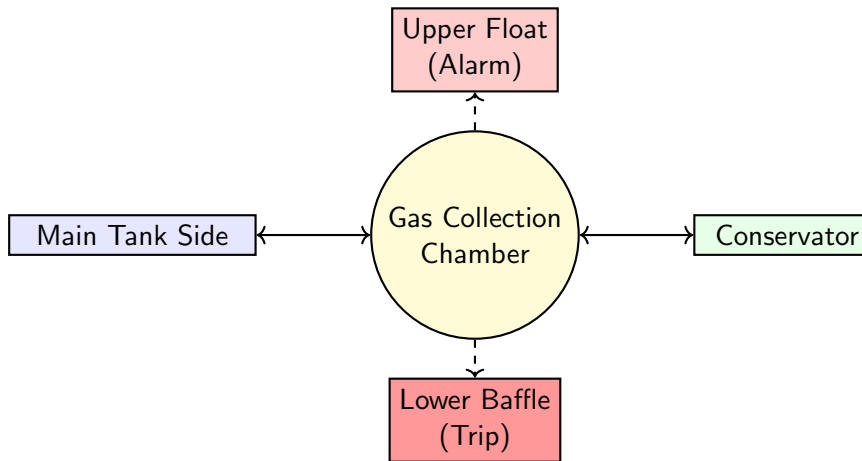
Importance of Transformer Protection

- Transformers are the most expensive assets in a substation.
- Internal faults (e.g., inter-turn short circuits) can lead to catastrophic explosions.
- Protection must be fast to limit damage and secure the grid.
- Involves both Mechanical protections (built onto the transformer) and Electrical protections (relays in control room).

Buchholz Relay Operation

- Gas and oil actuated mechanical relay.
- Installed in the pipe between the main tank and the conservator.
- Minor faults: Generate slow gas bubbles. Gas collects at the top, displacing oil, causing upper float to drop and trigger an ALARM.
- Major faults: Severe arcing causes massive oil surge. Surge pushes the lower flap, triggering a TRIP to the circuit breakers.

Buchholz Relay Mechanism



Pressure Relief Valve (PRV)

- The last line of mechanical defense against explosions.
- Mounted on top of the main tank.
- Spring-loaded diaphragm that pops open when internal pressure exceeds a safe limit.
- Instantly vents oil and gas to the atmosphere, preventing tank rupture.
- Fitted with micro-switches to send a TRIP signal.

Differential Protection Scheme

- Primary electrical protection for the transformer.
- Principle: Current entering the transformer must equal current leaving (adjusted for turns ratio).
- Current Transformers (CTs) on HV and LV sides continuously compare currents.
- If a difference (spill current) is detected, it indicates an internal fault.
- Instantly trips both HV and LV circuit breakers.

Temperature Indicators (WTI & OTI)

- Oil Temperature Indicator (OTI): Measures top oil temperature using a bulb thermometer.
- Winding Temperature Indicator (WTI): Simulates winding hot-spot temperature using a thermal image technique (combines oil temp + load current from a CT).
- Both provide ALARM and TRIP contacts.
- Also used to automatically switch on cooling fans and pumps (ONAF/OFAF).

Transformer Testing (Routine and Type)

- Type Tests: Done on one prototype to verify design (e.g., Lightning Impulse test, Temperature rise test).
- Routine Tests: Done on every unit manufactured.
- Winding Resistance Measurement.
- Insulation Resistance (Megger) and PI.
- Turns Ratio and Vector Group verification.

Factory Acceptance Tests (FAT)

Test	Purpose
Winding Resistance	Detect loose connections or broken strands
Turns Ratio	Verify core and winding turns, OLTC function
Insulation Resistance	Check health of paper and oil insulation
Impulse Test	Verify capability to withstand lightning strikes

Dissolved Gas Analysis (DGA)

- The most powerful predictive maintenance tool.
- Similar to a blood test for a transformer.
- Faults (arcing, overheating) break down oil and paper, creating specific gases.
- Gases dissolve in the oil. Oil samples are analyzed in a lab via Gas Chromatography.
- Key gases: Hydrogen (Arcing), Ethylene (Overheating oil), Carbon Monoxide (Overheating paper).

Maintenance and Oil Filtration

- Periodic checks of silica gel breather.
- Checking for oil leaks at gaskets and valves.
- Cleaning of bushings to prevent external flashovers.
- Oil filtration/centrifuging: Used to remove moisture, dirt, and dissolved gases from oil.
- Prolongs the life of both the oil and the solid insulation.

Key Takeaways

- Buchholz relay detects internal gas generation and oil surges.
- Differential protection provides high-speed electrical fault clearance.
- DGA is a vital predictive tool for assessing internal health.
- Regular maintenance ensures the transformer reaches its design lifespan.

Next Lecture Preview

- Introduction to Isolators (Disconnectors)
- Isolators vs Circuit Breakers
- Construction and Types of Isolators