Transformer cooling
Lesson #4
When The Cooling is Not Functioning
Cooling The Life of A transformer

Correct Maintenance will Extend Transformer Life
Anclote generating Plant
Transformer - Components

- Liquid Insulation - *Oil*
  - Provide dielectric strength/medium
  - *Provide a cooling medium*
  - Protects the paper
  - Use as a diagnostic tool to monitor the condition of the paper
Witches Brew

- Paper + H₂O + O₂ + Heat =

  Oil sludge & degraded paper
Cooling System Designations (Liquid Immersed)

• First letter:
  • O for insulating liquid with fire point below 300ºC
  • K for insulating liquid with fire point above 300ºC
  • L for insulating liquid with no measurable fire point

• Second letter:
  • N for natural thermosyphon flow
  • F for forced oil circulation
  • D for directed oil flow

• Third letter:
  • A for air
  • W for water

• Fourth letter:
  • N for natural convection
  • F for forced circulation
Cooling system

• Types of cooling
  • Self cooled (OA), no fans or pumps
  • Forced air (FA), cooling fans
  • Forced oil/Forced air (FOA), fans and pumps

• Example
  • 30/40/50 MVA, OA/FA/FA
  • 300 MVA, FOA, no self-cooled rating
## Cooling System

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<td>OFAF or ODAF</td>
<td>FOA</td>
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Cooling Designations

ONAN = oil natural air natural    OA = Oil to air

ONAF = oil natural air forced    FA = Forced air (one stage of fans)

ONAN/ONAF/ONAF    OA/FA/FA     (two stages of fans)

ONAN/ONAF/OFAF    OA/FA/FOA (two stages of fans one stage of pumps)

ONAN/ODAF    (oil directed)

ONAN/ODAF/ODAF   OA/FOA/FOA (oil directed two stages of pumps)

OFAF or ODAF    FOA (one stage of forced oil and air)
Temperature Measurements

• Transformers have three temperature measurements
  • Top oil temperature
  • Winding temperature
  • Winding temperature rise rating
Top Oil Temperature

- Top oil temperature is a direct measurement of the temperature of the oil near the top of the tank where the oil will be the hottest.
- It is an actual measurement made with a gauge.
Winding Temperature

• Winding temperature is not an actual measurement of winding temperature.
• It is an indirect indication of the hottest spot in the winding based on design calculations.
• Winding temperature is a direct measurement of the temperature of the oil near the top of the tank pulse the additional heat provided by an electric heater.
• The heater is powered by current from the secondary of a Hot Spot current transformer.
• The hot spot CT provides current to the heater based on transformer load.
Winding Temperature

• CT secondary windings are always rated 5 amps with the exception of the HOT SPOT CT.
• The hot spot CT will usually have an odd ratio chosen by the designer to supply the right amount of power to the heater to simulate the calculated hottest spot in the winding.
• Transformers usually have only one winding thermometer but large multi-winding transformers may have several.
Basic Winding Temp. Circuit

- Electric heater
- Hot Oil
- Tank Wall
- Winding Temp.
- Gauge Face
- Transformer Load Current
- Hot Spot CT
More Complex Winding Temp. Circuit

- Electric heater
- Hot Oil
- Tank Wall
- Winding Temp Gauge Face
- Gauge Bulb
- Auto Transformer for Adjusting Heater Current
- CT Shorting SW.
- Hot Spot CT
- Transformer Load Current
Winding Temperature Drawing
Winding Temperature

- Newer transformers with electronic temperature gauges may not use a bulb in the oil at all for winding temperature.
- Winding Temperature calculations can be made using the output from a standard 5 amp CT secondary.
Temperature Rise

• Temperature rise is a value found on the nameplate related to a specific transformer capacity.
• Temperature rise is the average temperature of the winding.
• It is based on the resistance change of the winding measured before and after a heat run in the factory.
• It is a guarantee by the manufacturer that the transformer can carry a specific load without exceeding the given temperature rise (temperature pulse ambient air temperature).
• The maximum air temperature used as a reference is 40°C (104°F).
Temperature Rise

• Example:
  • MVA 15/20/25 Cont. Temp. Rise 55°C
    • Air temp. 20°C load 25 MVA gauge reads ≤ 75°C
    • Air temp. 40°C load 25 MVA gauge reads ≤ 95°C
  • MVA 16.8/22.4/28 Cont. Temp. Rise 65°C
    • Air temp. 20°C load 28 MVA gauge reads ≤ 85°C
    • Air temp. 40°C load 28 MVA gauge reads ≤ 105°C
Heat Transfer Equipment

- Radiators, For ONAN And ONAF Ratings
- Air/Oil Coolers, For ONAF And ODAF Ratings
- Air/Water Coolers, For ONAF And ODAF Ratings
- Fans
- Pumps, One Should Be Cognizant Of Oil Flow Rates And The Effect On Static Electrification
- Selection Of Equipment Can Be Based On Maintenance Performance
Radiator Types

- Tube Type
- Panel Type
- Coolers
Panel Type
Radiators
Panel Type Radiators
Coolers (not radiators)

Coolers will always have forced oil (pumps)
Both new style fans guards and old style fan guards
Oil Pump & Flow Gauge
Oil Gauge With Pump Off
Some Transformers with Radiators Have Forced Oil Pumps
Transformer - Components

- Arrows show flow of Hot Oil
Thermal Design

- Thermal Design Involves Controlling
  - Top Oil Rise
  - Average Winding Rise
  - Winding Hot Spot Rise Over Ambient

- The Applicable Standards Establish The Temperature Rise Limits
  - 60°C For IEC
  - 65°C For ANSI For Top Oil Rise And Average Winding Rise

- Purchaser Can Specify Lower Limits If Desired
Thermal Design

• Methods Of Calculating Are Important
• Top Oil Rise And Average Winding Rise Can Be Measured
• Winding Hot Spot Rise Can Only Be Measured With Sensors Placed In The Winding
• The Vast Majority Of Transformers Are Manufactured Without Hot Spot Sensors, Thus, The Hot Spot Rise Is A Derived Quantity For Most Transformers
Thermal Design

- Hot Spot Temperature Can Be Used To Provide System Operators Guidance In Loading Transformers
- Most Users Do Not Use Data To Dynamically Load Transformers
- Equipment Exists So One Could Do This With The Inclusion Of The Proper Sensors, i.e. Fiber Optic Thermal Sensors
Winding Temperature Procedure