EVALUATION OF HEAT DISSIPATION FROM RADIATORS OF TRANSFORMER BY MEASUREMENT AND COMPUTATIONAL FLUID DYNAMICS SIMULATIONS

by

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Agenda

• Background and Motivation
• Objective
• Problem Description
• Experimental Radiator Test Set Up
• Measurement and CFD Analysis Results
• Comparison – Catalogue Data, Measurement and Simulation
• Conclusions
Introduction

➢ Thermal Management is an important aspect for efficient and reliable functioning of transformers.

➢ Radiator-fan constitutes major components of the cooling system

➢ For Optimal Thermal Design Transformer manufacturers are interested to reduce the number of radiators and fans

Thermography image

Transformer winding faults

Transformer failure

Winding failure
Radiator – Heat Dissipation Perspective

A radiator is mechanically a simple object, but from thermo-hydraulic point of view different parameters influence the heat transfer characteristics of the radiator.

- **Air velocity** around the radiator panels, **Temperature difference** oil-air
- **Oil velocity** inside the radiator panels, which depends on:
  - Pump pressure or Thermosyphon pressure:
  - Hydraulic resistance of the radiator panels and hydraulic circuit.
  - Oil distribution over the different radiator panels.
Background and Motivation

Heat dissipation tables are used for selection of radiators which are setup for air natural flow.

Correction factors - overdesign of the cooling system and if not then too high temperature and failures.

For optimal design, accurate heat dissipation from radiators should be known for various cooling configurations.

The best way to collect a trustful data is by measurement on actual radiator test setup.
Objective

1. To **build a flexible test set up** of it’s kind for measurement of different radiator-fan configurations in a controlled conditions

2. **Evaluate heat dissipation** by measurements and Computational Fluid Dynamics simulations

3. **Compare the results** of measurements and simulations with catalogue data of radiator manufacturer
Details of Radiators for Evaluation

- No. of radiators – 4
- No. of fins – 30
- Height – 3m
- Width - 0.52m
- Fin spacing - 50 mm
- Experiments and numerical simulations are performed for radiator number 1 and 2.
Experimental Test Set Up

- An in-house experimental facility.
- A group of 4 radiators mounted on a support structure and connected by pipes.
- Test set up is capable of testing of radiators for all cooling configurations.

- Temperature measurement - K type thermocouples
- Inserted power - Wattmeter
- Flow rate - Oil flow meter

February 22nd - 23rd, 2017, Scope Complex, Lodhi Road, New Delhi, India
Experimental Measurement

- Inlet and outlet temperatures of radiators are recorded by the data acquisition system.
- Data reduction for the calculation of heat dissipation after steady state
  \[ Q = m_{oil} \, c_p \, (T_{in} - T_{out}) \]
- Thermography (using infrared camera) for visualization of temperature distribution over radiators and other parts.
CFD Simulation Details

- **Complete 3D geometry** of the radiator for analysis
- **Hexahedral mesh** for better convergence and accuracy
- Turbulence model - **Shear Stress Transport (SST)**
- Radiation model - **Discrete Transfer Model (DTM)**
- Ambient temperature - **36.4°C**
- Convergence - residuals are below **$10^{-4}$**
A plume of hot air exiting at the top of the radiator.

The radiators work as a kind of open chimney, air is heated up in between the radiator fins and this hot air tends to move upwards due to buoyancy forces.
Heat Flux Distribution

- A red colored footprint of higher heat flux on the surface of the radiators.
- The end fins have higher heat flux than middle fins.
Convection and radiation are comparable for end fins

Total heat dissipation of end fins is 64% more than middle fins

Average heat dissipation per fin is 3.3%: Convection 2.8% and radiation 0.5%.

Convection heat transfer is 84% and radiation 16%
Heat Dissipation Comparison and Remarks

- CFD simulations results are within 5.8% of measurement.
- Manufacturer’s catalogue data is 20.3% and 13.7% higher compared to experimental and numerical results.

If these tables are directly used, trafo manufactures ends up using less radiators for air natural and subsequently it affects forced air cooling.

A Theory is Something Nobody Believes Except the Person Proposing Theory and Experiments are something Everybody Believes Except the Person Doing Experiment - Albert Einstein
Conclusions

- An in-house radiator test set up is built for heat dissipation evaluation of radiators and dataset is generated.
- Results of CFD is in good agreement with measured results.
- Heat dissipation provided in the manufacturer’s catalogue is 20.3% and 13.7% higher compared to experimental and numerical results.
- Actual measured heat dissipation from the radiators for different cooling configurations will help in optimal and efficient design of the cooling system of the transformer.