Comparison of the Thermal Performance of Mineral Oil and Natural Ester for Safer Eco-Friendly Power Transformers

A Numerical and Experimental Approach

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Motivation

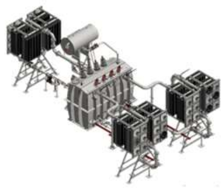
How would a transformer designed for mineral oil would behave with natural ester as insulating fluid?

Should a utility replace fleet by new eco friendly transformers or refurbishing their assets, substituting only the insulating fluid?

Procedure

- ✓ Temperature rise tests run for M.O. (Nynas Nytro Taurus) and repeated for N.E. (Cargill FR3).
- ✓ Different operating conditions (E1 – E5) and winding geometries.
- ✓ Thermal modelling of the windings using Thermal Hydraulic Network Models (FluCORE) and Computational Fluid Dynamics (ANSYS Fluent®).

15 MVA CORE Experimental Setup



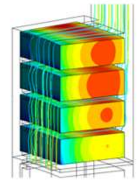
Temperature Rise Tests

6 different windings

Heat Run Tests with different conditions for oil flow rate and heat losses

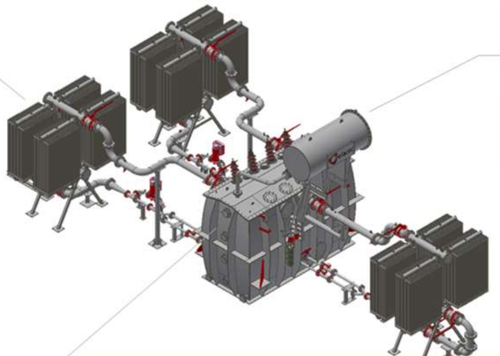
		Heat Losses [kW]		
		220	165	110
Oil Flowrate [m³/h]	90	E1	E2	
	30	E3	E4	E5

CFD simulations



THNM simulations

ODAF Cooling



Tank & Pipes

Windings

Monitoring System

Location of the sensor	Measured property	Sensor
Windings	Temperature	72 Fiber optics
Tank & Pipes	Temperature	17 RTDs PT1000
	Moisture & Temperature	1 Vaisala MMT 162
	Flowrate	6 Ultrassonic flowmeters
	Pressure difference	3 Differencial pressure transmitter

Results & Conclusions

Experimental results

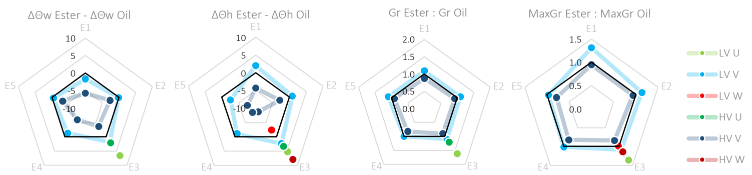
ΔΘw	HS	Gr
⬇ Phase V ⬆ Phase U (E3)	⬇ Phase V ■ For other windings, varies with winding geometry and test conditions ■ HS location can vary with the test conditions and type of fluid	⬇ VHV and WLV windings ⬆ Other windings

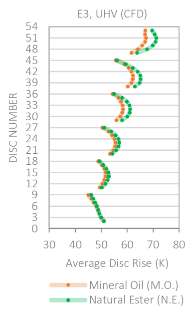
ΔΘw: Average Winding Temperature Rise
HS: Hotspot Temperature Rise
Gr: Winding-to-oil Gradient

⬇ N.E. lower value than M.O.
⬆ N.E. higher value than M.O.
■ Variable value

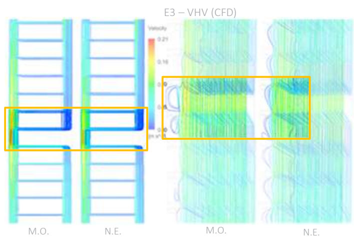
Modeling results

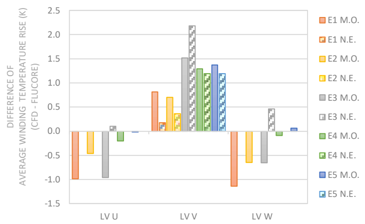
- Average disc temperature rise difference (between M.O. and N.E.) increases vertically along the winding, based on CFD results for E3 UHV.
- CFD fluid path-lines show that, due to its lower viscosity, M.O. is more prone to recirculation zones near flow barriers than N.E.
- The higher viscosity of N.E. helps the flow to be more evenly distributed through the radial channels of each pass, benefiting the cooling performance, uniformizing and maximizing heat transfer from the discs.
- A maximum deviation of 2.2 K in the ΔΘw is obtained, between CFD and FluCORE. This indicates that FluCORE can be used to further investigate the thermal-hydraulic phenomena occurring inside the windings for M.O. and N.E.

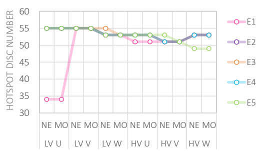




- ✓ The relationship between thermal behavior of the transformer using N.E. or M.O. is not simple - it depends on the operating conditions of the transformer and on the geometry of the windings.
- ✓ These findings are intended to, in one hand, provide insight on the adaptation of transformers design when using N.E. as fluid insulation and, on the other hand, support the utilities on the decisions regarding an eco friendly transformation of their transformer's fleets.







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