Paris Session 2022

Alternative Transformer

A2 PS2 Q2.4

Are there any applications for which alternative transformer technologies are not well suited and what can be done to develop new types of alternative transformer for these applications?

Ahmed Gamil (Germany)

A2 - PS2- Question 2.4

Question 2.4: Are there any applications for which alternative transformer technologies are not well suited and what can be done to develop new types of alternative transformer for these applications?

- Using alternative fluids in transformers, whose properties are different from standard mineral oil do have an impact on the design not only from thermal and dielectric point of view but also by the selection of transformer components and manufacturing process:
  - Components like bushings, OLTC, gaskets, etc. must be checked for compatibility.
  - The different degrees of oxidation lead to different designs concerning the conservator and the type of sealing.
  - With low kinematic viscosity, there is a possibility of reducing the cooling performance to the needed limits, which means less dimensions and less weight.
  - A high kinematic viscosity requires re-engineering of design oil guidance.
  - Different fluids means different values of permittivity, which requires different design of conductor insulation and oil gaps.
  - Some applications, for example; extreme environmental conditions and limited space for a compact design, high fluctuating load-cycle, the selection of oil is limited to less options.

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Question 2.4: What is the impact on the design of a transformer when using alternative fluids like synthetic esters or bio-based hydrocarbon?

Property	Impact on:	Synthetic ester fluid	Bio-based hydrocarbon
		effects	
Thermal expansion	conservator	none	increase volume
Dielectric strength	distance between winding - lead - tank	design adaptions needed	design check, most cases no changes needed
	OLTC, DETC	reduced insulation level	none
Viscosity	cooling, winding	increase size of cooling ducts	none
	cooling, radiators	increase cooler surface	reduce cooler surface
Density	total weight	increase	reduce
Chemical compatibility	gaskets	limited choice of material	none
	bright copper	none	none
	valves, fittings	no mixing of internally used, operating procedures	none
	conservator, sealing	diaphragm or N2 blanket is mandatory	none
Oil handling	degassing machine and pipes	must have dedicated system	can use existing system if flushing
Component interactions	bushing	limited selection, no mixing of internally used	none
	OLTC	current, dielectric deratings, many model restrictions	no dielectric deratings, some model restrictions
	buchholz relay	order with special gaskets	most manufacturers approved, some cases low density means not suitable

Comparing to standard mineral oil, the most important differences are driven by the dielectric strength and viscosity.

Group Discussion Meeting

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Question 2.4: Case study showing the effect of using different alternative fluids

The investigations have shown when using bio-based hydrocarbon fluid a reduction of the cooling system by approx. 20% is possible. In order to validate the design, the max. allowed values for top liquid, average winding and hot spot temperature rise were kept the same. Two identical units were built and tested, one filled with standard mineral oil, the other filled with bio-based hydrocarbon fluid. The results in the test field had confirmed the calculations.

Conclusion:

There is always a possibility to use alternative fluid instead of standard mineral oil, as long as operational safety and reliability requirements of are fulfilled for transformer lifetime.
To overcome the challenge of dealing with new insulation fluid, the research needed must be on the base of transformer practical requirement, not a pure academic one.
The right investment in research will not just lead to cost optimized design, but also a safe one.

Design with 50 MVA-123 kV	Mineral oil (Reference)	Synthetic ester fluid	Bio-based hydrocarbon fluid	Deviation Synthetic ester Fluid-Ref.	Bio-based Fluid-Ref.
Heat expansion coefficient [1/K]	0,00075	0,00078	0,00092	4,00%	22,67%
Density of insulating fluid @ 20°C [kg/m³]	0,870	0,970	0,785	11,49%	-9,77%
Viscosity @ 40°C [mm²/s]	9,30	28,00	3,80	201,08%	-59,14%
Flash point (PM) [°C]	152	260	145	71,05%	-4,61%
Oxidation test IEC_61125	500h; 120°C	164h; 120°C	500h; 120°C	-67,20%	-
Winding weight [kg]	11286	11511	11286	1,95%	0%
Weight of insulating fluid [kg]	16989	18310	14518	7,78%	-14,54%
cooler surface [m²]	552	585	423	5,99%	-23,36%
weight of conservator [kg]	680	750	780	10,29%	14,71%
Top oil rise (measured) [K]	48,1	-	45,0	-	-3,1 K
HS rise (measured) [K]	71,1	-	66,9	-	- 4,2 K