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Question 2.5: There seem to be conflicting opinions concerning the use of some alternative transformer technologies at higher temperatures, especially ester-immersed transformers. What is the experience of using alternative transformer technologies at higher temperatures? What further work is needed on this subject?

Thermal degradation of insulation material is the main influencing factor to determine the transformer lifetime. The heat generated in the winding conductors is transferred to the insulation fluid result in changing the insulation paper properties over time. For the time of using mineral liquids, the main function of High Temperature Insulation Materials (HTIM) is to keep the heat inside the conductor by increasing the current density and at the same time decreasing the rate of degradation. This allows more compact design.

The specified maximum continuous temperature rise limits for transformers with semi hybrid insulation system according to IEC 60076-14 is 60/75/90 for top liquid, average winding, and hot spot temperature rise, respectively. Several case studies have been done investigating the differences between the semi hybrid, mixed hybrid und full hybrid insulation systems.

The most economical solution is in most of the cases was the semi hybrid insulation system by using conventional insulation liquids, as the maximum temperature rise of the liquid is limited to 60 K.

The investigations have shown that the maximum allowed hot spot rise of 100 K of the full hybrid insulation system does not justify the additional material costs, as the cooling system must be designed to a maximum liquid temperature rise of 60 K in both cases.

Table I shows one case study made on this subject using the temperature limits of the semi hybrid insulation system.

Table I

Design with (63MVA-140kV)	Mineral oil (Reference)	Bio based hydrocarbon fluid	Synthetic ester fluid	Deviation Bio based Fluid-Ref.	Deviation Synthetic ester Fluid-Ref.
Core [kg]	23839	23839	24700	0%	3,48%
Winding [kg]	11286	11286	11511	0%	1,95%
Fluid [kg]	11824	11601	15877	-1,92%	25,52%
Temp. gradient [K]	LV: 23,4 HV: 24,3	LV: 21,0 HV: 21,9	LV: 23,5 HV: 24,9	LV: -2,4K HV: -2,4K	LV: +0,1K HV: +0,6K
Top-oil [K] Guar.: 60K	57,9	56,8	57,5	-0,4K	-0,4K
Hot spot [K] Guar.: 90K	89,4	85,3	89,9	-4,1K	+0,5K

During the design process the cooling system and the electrical distances were optimized for each insulation fluid considering the different properties. In each case the no load losses and load losses were kept the same to get a fair comparison between the fluids.

Conclusion:

There is no unique solution which would satisfy the market requirements and offer an optimized design from safety and cost point of view. However, there are a flexibility in technology which always give a chance to reach a comprise between OEM and his client.