A2 - POWER TRANSFORMERS AND REACTORS

PS2: BEYOND THE OIL-IMMERSED TRANSFORMER AND REACTOR

Paper ID: 10437

EXPERIENCE ON DESIGN, MANUFACTURING & TYPE TESTING OF FIRST 420 KV CLASS ESTER FLUID FILLED SHUNT REACTOR

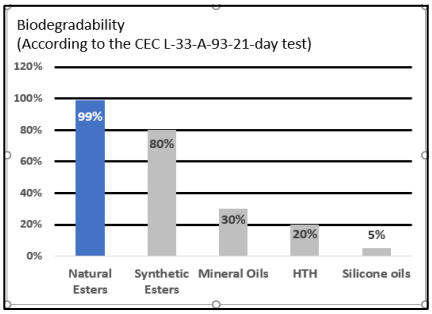
Richik Manas DAS, Gunjan AGRAWAL*, Rajil SRIVASTAVA, A K SINGHAL, Abhay CHOUDHARY

Power Grid Corporation of India Ltd (A Govt. of India Enterprise) INDIA

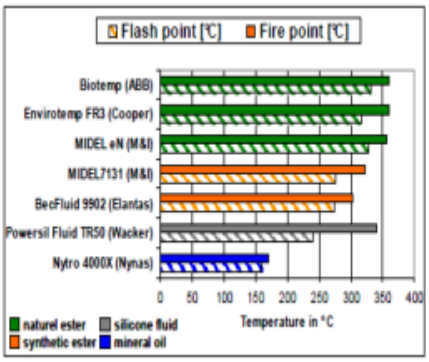
Introduction

Natural & Synthetic Ester fluids are considered as best alternative to Mineral Oil and these fluids are gaining popularity among Utilities and Manufacturers. Both Natural and Synthetic Ester fluids have certain advantages/ disadvantages over one another. Utilities in India and across the globe have gained lot of experience in lower voltage class Transformers on using Natural and Synthetic Ester fluids. However, there has been limited experience available globally regarding use of Ester fluids for higher Voltage class (400kV & above) Transformers & Reactors.

Comparison of biodegradability



Comparison of fire points



POWERGRID initiative.

To gain operational experience of Ester fluid in higher Voltage class Transformers & Reactors, POWERGRID India has taken up a pilot project in which one 400 kV Auto Transformer with Synthetic Ester Fluid and one Shunt Reactor of 420kV class is procured with Natural Ester Fluid.

The experience gained during design, various stages of manufacturing and Type testing of the above Reactor filled with Natural Ester is discussed in details in this paper.

Reactor Technical Data

The finalized Salient technical specification of the reactor filled with natural ester fluid is as follows:

Rated Reactive Power	50 MVAR, 3-Phase
Voltage Rating	420 kV
Rated Frequency	50 Hz
Cooling Type	ONAN
Temperature Rise ºC	Oil: 40 & Winding: 45
Maximum Noise Level	80 dBA
BIL - LI (kVp) SI (kVp) PF (KVrms) PD level @1.58Ur/√3	LI:HV/HVN: 1300/550 SI: HV- 1050 PF: HVN – 230 < 100 pC

Experience and challenges faced in design

The chemical composition of the Natural Ester is considerably different from mineral oils. Therefore, many of the design, manufacturing, handling and maintenance practices used for mineral oil cannot be directly applicable for the Natural ester fluids.

Thermal Design

Oil flow inside the Reactor winding is governed by the temperature difference of Top and bottom and the oil passage provided in winding section as Reactor is ONAN cooled.

Due to higher viscosity, Cooling of about 10-15% enhanced during design stage and radiator pipes of higher diameter (100 NB in comparison to 80 NB used in mineral oil) used to allow more fluid flow through radiators.

Heat transfer coefficient of insulating liquid

It depends upon thermal conductivity, kinematic viscosity, specific heat, density, and coefficient of thermal expansion. The thermal conductivity of ester is higher than the Mineral oil, which improves the cooling performance. Though, the cooler requirement may be slightly reduced for this aspect, the higher cooling was retained, as it is a pilot project being implemented first time.

Thermal Parameters	Natural Ester Fluid (°K)	Mineral oil (°K)
Top oil Rise	33.7	29.5
Winding Rise	36.9	30.2
Winding Gradient	10.0	7.4
Hot Spot Rise	47.0	41.3

Temperature rise for Natural ester is higher than the Mineral oil for the same design with same cooling. Thus, the cooling was enhanced to maintain the similar Temperature rise as in mineral oil.

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Dielectric Design

Due to change of Permittivity and other dielectric parameters of ester fluid and different dielectric behaviors of other insulating items like – paper, pressboard etc., dielectric design was also thoroughly analyzed using 2D FEM softwares for various voltages (i.e. LI, LIC, SI, PF, LTAC etc.) considering the impact of Natural Ester properties i.e. Permittivity, effect of non-homogeneous field, Larger Oil Gaps etc.

Electric field distribution in EHVAC equipment is largely dependent on permittivity of various insulating mediums

Summary of Dielectric Insulation study

Location in the winding assembly	Maximum Electric Field Strength on Copper (kVp/mm)		Maximum Electric Field Strength at oil paper interface (kVp/mm)		Safety Factor	
	MO	NE	MO	NE	MO	NE
Middle Insulation	27.21	34.88	24.78	23.38	1.15	1.18
Top Insulation	4.64	5.06	6.31	5.95	1.45	1.50
Bottom Insulation	3.77	4.83	6.34	5.98	1.30	1.39

Challenge of Stray gassing

Ester fluids have tendency to generate more stray gassing than mineral oils.

At higher temperatures during filtration, Ester fluid release fault gases which may mislead and indicate some fault inside the Reactor i.e. Partial Discharge, thermal fault etc.

To reduce this phenomenon, fluid filling was done at a relatively lower temperature at 60-65 °C .

To increase the rate of impregnation in the insulation and to compensate higher viscosity effect, long hour's oil filtration was carried out.

WG32 of CIGRE, the analytical techniques and interpretation methods for dissolved gases used for mineral oils can be used with some adjustments for non-mineral oils.

Compatibility with materials

- It is very essential to check the compatibility of new type of fluid with the different types of component materials used and surrounded by oil. Materials found compatible with mineral oil found also suitable while using with Natural ester in general.
- Material compatibility tests on gaskets, ceramic spacers, etc. in 420kV class reactor and only those material were used which was found meeting the requirements.
- Buchholz relay, aircell, bushings etc. are also reviewed for their compatibility with natural ester fluid

Experience and challenges faced in manufacturing

Lower Oxidation Stability & Multiple handling of Natural Ester during manufacturing to site commissioning

New set of fluid handling hoses were used. For oil filter machine, old gaskets and filter units were replaced with new sets and proper flushing with ester fluid was done multiple times before usage to ensure no mineral oil should mix with Ester fluid.

Vapor phase drying method was adopted to avoid polymerization of the dielectric fluid

Post VPD treatment, Clamping and fluid filling in the reactor was done under fine vacuum

Nitrogen blanketing was done during dismantling activities to reduce exposure of active part to ambient air.

Since nitrogen was used inside reactor tank, a self-contained breathing apparatus (SCBA) was used during dismantling of bushings and post FAT internal inspection.

Typical SCBA used post FAT internal inspection

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Dispatched with Nitrogen filled at top

To reduce possibility of thin film formation, all the dismantled parts such as conservator, pipes and radiators were pressurized with nitrogen along with provision to check pressure at receipt.

Before dispatching of the unit and accessories 48 hours monitoring was done to check for any pressure drop.

Reactor during transportation

Construction of Breathing System

Aircell type arrangement is adopted along with protection relay (CPR) to reduce the chance of contamination of liquids by exposing them to direct air.

Higher viscosity

To improve the impregnation of the solid insulation, Natural ester fluid was filled under 0.1 torr vacuum.

Impregnation time of 72 Hours was given post processing as compared to 24 Hours for mineral oil.

Pump for Filtration

More filtration time was given considering the reduced efficiency of churning the fluid from tank using same capacity pump (existing facility).

Settling time

The higher viscosity and chance of higher bubble formation in the Natural Ester fluids, settling time before high voltage test increased to nearly three times.

Test Experiences

Reactor was subjected to all the Routine and Type tests as per IEC 60076.

Test results	
Insulation Power Factor of winding	0.247 at 35 °C. (Expected higher value due to polar in nature)
Insulation Resistance	1.6 Giga Ohm (one minute)
Core-Frame-Tank insulation	0.24 to 0.70 GOhm
Partial Discharge	64pC to 77pC at 1.58Ur/√3

CONCLUSION

Sufficient experience is now established in the world for use of Natural ester in distribution transformer and medium voltage transformers. There is a vast potential of this “K Class” liquid in Large Power Transformers and Reactors also as it is ecofriendly and available limited resources of Mineral Oil.

POWERGRID has acquired experience to use this fluid in 50 MVAr, 420 kV class Reactor, which incidentally is the largest rating Reactor tested with Natural Ester (Envirotemp FR3) fluid in the world. Further, one 400kV Transformer with Synthetic Ester is also under advance stage of manufacturing. Once sufficient experience is gained in this voltage class, more number of such Transformers & Reactors shall come in future with Natural Ester Environment friendly fluid.