Natural ester oils: a promising solution

Natural esters—commonly called “vegetable oils”—represent a credible option as a “green” insulating liquid in power transformers. They provide definite environmental and safety gains. Research, though, continues, as we need to reach the same level of knowledge and understanding as we presently have for mineral oil.

Fears over looming shortages of petroleum-based oil have focused the industry’s attention on renewable alternatives. The T&D sector has re-discovered the benefits of natural ester oils (those extracted from rapeseed, soya and sunflower). Originally, windings were immersed in vegetable oil before the introduction of petroleum products at the beginning of the 20th century. We are now witnessing an increasing trend in their use in distribution transformers (DT). The big challenge is to extend the use of natural ester oils to high voltage power transformers (PT) where electrical and thermal stresses are much more pronounced. Today, only about 100 PT are insulated and cooled by vegetable oil, but research is going strong in order to ensure high reliability in service. “Alstom Grid is participating in a whole series of research projects at several European universities,” says Christophe Perrier, Research Engineer of the Power Transformer Technology and Innovation Center.

Natural ester oils have excellent green credentials. With their high flash and fire points, the fire hazard is significantly reduced. They are biodegradable and have low or no toxicity, so spillages have practically no impact on the environment. In addition, vegetable oils extend the service life of the composite transformer insulation system utilizing oil-impregnated cellulosic materials. “Technically speaking, natural ester oils really come into their own with their high water solubility—20 to 30 times higher than that of mineral oil at the ambient temperature, before saturation,” says Perrier. As the cellulose-based solid insulation is highly hygroscopic, a related advantage is that the oil draws moisture out and absorbs it, thus keeping the insulating material dry and extending its life span.
Interrelated advantages and drawbacks

Technologically, the minimum set of properties to be checked to evaluate any transformer oil includes dielectric strength, heat transfer efficiency and ageing stability. "Vegetable oils are equivalent to mineral oils under AC voltage conditions, and the dielectric strength of paper impregnated with vegetable oil is broadly the same as that of paper impregnated with mineral oil," says Perrier. More in-depth investigations are ongoing to determine dielectric strength under lightning impulse conditions, more particularly through the study of electric streamer generation and propagation. Vegetable oils also conduct heat more effectively thanks to their higher thermal conductivity. However, they have higher viscosity, which impacts the coolant velocity through the transformer active part and consequently may affect the overall heat transfer performance. This aspect is effectively controlled by transformer designers through an optimum choice of the oil pumps in the forced oil cooling circuit.

One of the biggest technical challenges is to reduce the pour point (the temperature at which the oil does not flow), which is presently a limiting factor for the minimum restart temperature of transformers from the cold condition. Two options are possible, either to act directly on the oil chemistry or to optimize the energizing procedure. The very biodegradability that makes vegetable oils an environmentally attractive prospect also influences their ageing stability. It makes them slightly more prone to oxidation, causing them to age faster. Nevertheless, this minor issue can be mitigated by the combined action of vegetable oil suppliers and transformer manufacturers (see sidebar).

A cry for standards

While there are data and international standards galore for mineral oils, there are as yet no IEC standards addressing the composition or testing of the natural ester oils with their different chemical composition. This lack of standards could be seen as one of the limiting factors with regard to the initial rate of implementation of vegetable oils in PT. "Insulating oil in PT is like blood in humans," says Perrier. "It can tell you about the state of their health if you have access to effective means for dissolved gas in oil analysis and diagnostics." Developing such capability is exactly what the industry is doing, with Alstom Grid in the forefront. With such credentials Alstom Grid is actively dealing with all environmental challenges.

THE CASE FOR STANDARDS

Natural ester oils are fully biodegradable, which makes them more sensitive to oxidation than petroleum-based oils. Vegetable oil suppliers therefore add oxidation inhibitor packages (at low concentrations to remain in a green product classification) and transformer manufactures propose sealed systems. Even better, Alstom Grid has patented a hermetically sealed design for PT. To date, the difficulty is that no international standards govern additive content and oxidation stability tests for natural esters.

Alstom Grid participates actively in IEC and CIGRE working groups (WG) dedicated to the subject of vegetable oils.

- IEC TC 14 is developing an international standard as well as oxidation stability tests dedicated to natural ester oil applications. The final draft is expected soon.
- CIGRE WG A2–35 is establishing the state of the art of alternative liquids and especially ester oils. The final technical brochure is planned for this year.

Meanwhile research teams are running accelerated ageing tests on DT filled with different ester oils. The performance of each oil type is monitored at regular intervals with a view to collecting data for further development.