

Transformers for wind turbines are generally hidden away in a green box next to the tower. However, out on the open sea, they tend to be placed in the gondola itself, on the outside of the turbine or even on separate platforms when their role is as a central offshore transformer station for a large wind farm. What most transformers have in common is that they have until now been insulated and cooled using mineral oil. Yet the fact that these insulating fluids are flammable and pose an environmental risk makes it necessary to look for alternatives, especially for use on sensitive sites.

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What's Your Transformer Got in the Tank?

Insulating Fluids Affect the Environmental and Fire Risks of Wind Turbines

Ester-based insulating fluids have comparable performance with mineral oils, are biodegradable, non water-polluting and difficult to ignite. Thirty years after the introduction of these insulating fluids, there are now transformers on the market that can make the most of the capabilities of esters which allow for especially compact designs. So where are they used? In megawatt-class wind turbines.

Environmentally Friendly Energy Using Mineral Oil

The transformer of a 2MW wind turbine contains roughly 1,200 kilograms of fluid. Even in these machines, mineral oil is still seen as the standard solution for transformers that require fluid insulation. It is (still) cheap, tried and tested, and less harmful to health and the environment than the insulating oils based on polychlorinated biphenyls (PCBs), which were banned from use in the 1980s. However, on the most environmentally sensitive sites, which is exactly where most wind turbines are to be found, the dark side of using mineral oil as an insulating fluid becomes apparent. Should it spill out after an accident or a fire, it can lead to extensive environmental damage, including the pollution of drinking water or, in the case of offshore farms, damage to the sea. Removing an oil slick at sea or disposing of contaminated soil is extremely expensive.



Figure 1. Inaccessible to the fire brigades: wind engine on fire. (Courtesy Minimax)



Figure 2. Offshore assembly of wind generators with a crane mounted on a special ship (Courtesy Vestas Central Europe)



Figure 3. Pelamis Wave Power, a pioneer in the use of wave energy, uses ester-filled transformers for its pilot project 'Pelamis' off the Scottish and the Portuguese coasts. (Courtesy Pelamis Wave Power)

The use of mineral oil in transformers not only constitutes an environmental risk, it also represents a safety risk. The fire caused by a transformer in the Swedish nuclear reactor Ringhals in November 2006 was not the first occasion that this had occurred. Mineral oil is highly flammable and is therefore an additional danger. There have been five cases of fire in wind turbines in Schleswig-Holstein (northern

Germany) alone over the past year. A fire in the turbine due to lightning or another cause can bring about explosions in oil-filled transformers, resulting in great damage. Manfred Perkun, a qualified engineer, emphasised in his expert report to the insurance industry that, if there were to be a real emergency, the fire-fighters would only be able to stand and watch one of today's megawatt-class turbines burn, since the

towers are so tall. On offshore farms and other remote sites, a fire in the gondola is virtually equivalent to a write-off anyway; there is almost no chance of extinguishing the fire in such a case. Even limited damage to the transformer itself has a high cost offshore: it is many times more expensive to repair and replace a transformer at sea than on land. An interruption in operations through damage can last for



Figure 6. Extra caution is needed when wind generators are operated close to natural habitats. (Courtesy: Gerlach)



Figure 4. Without contributing to the fire incident, this ester-filled transformer has stood in a veritable bonfire for 70 minutes in the laboratory of the German insurer Allianz. (Courtesy: M&I Materials)



Figure 5. Dutch wind farm transformer

months if, for example, it is necessary to wait for a crane ship. The potential damage is considerable: 'Sometimes 24 hours can mean several thousand euros in lost revenue', says Perkun. Operators are often insured for loss of revenue and fire damage, but there are still the rising insurance contributions, cancelled deliveries and negative headlines.

An Environmentally Friendly and Safe Alternative

Is there an alternative to using flammable and environmentally dangerous mineral oil in transformers? In the wind energy sector, little can be done without using fluids. As the American Council for an Energy-Efficient Economy stated in a study published in 1998, 'currently available liquid-immersed equipment can reach higher efficiencies at lower equipment cost than comparable dry-type equipment'. Moreover, fluid-based transformers generally require less maintenance and are easier to repair if they suffer a technical fault. However, wind turbine operators do have a choice of insulating medium: besides mineral oil, there are also synthetic fluids such as those based on silicone and esters to choose from.

Silicone-based insulating fluids are less flammable, but they stay in the environment for a long period should they leak out. Silicone oil is less than 5% biodegradable within 28 days (OECD Test 301-D).

Ester-based insulating fluids, on the other hand, are proven to be harmless to health and are easily biodegradable. The German Federal Department for the Environment has stated that in its evaluation, MIDEL 7131 (the European market leader's ester-based transformer insulating fluid) poses no risk to water, as it is not poisonous to aquatic organisms and is 71% biodegradable after only 13 days (OECD Test 301-F). A further practical advantage is that no special safety precautions are required for transporting and handling the fluid. These fluids also reduce the need for water protection measures such as double-skinned containers.

The fire point of the ester-based fluid produced by M&I Materials is high, 322°C, and furthermore the liquid heats up very slowly due to its high specific heat capacity and heat conductivity.

Using Synthetic Esters in Old and New Transformers

Mixing synthetic esters and mineral oil is, in general, unproblematic. Lutz Waldig, a process engineer from IsoEst, insists that no modifications in the design or adjustments in the performance of the appliance are necessary when converting a transformer that has previously been using mineral oil. A particularly interesting feature of ester-based fluids in megawatt-class wind turbines is that they allow the construction of extremely

compact transformers. Transformer manufacturers can make the most of the heat conductivity and reliability of the ester-based fluids to design especially light and space-efficient constructions.

What is Their Impact on Cost?

Environmentally friendly alternative insulating fluid is also starting to gain ground in the wind energy sector: several Spanish wind farms are preparing to join the grid, using MIDEL 7131 ester-based insulating fluid inside their transformers.

One reason that synthetic esters have not yet established themselves as the standard solution for insulating transformers is that the fluid is about three to four times more expensive than mineral oil. It is therefore only included in a quotation when it is explicitly mentioned in the call for tender. A standard transformer in a 2MW wind turbine requires some 1,200kg of insulating fluid, which represents a price increase of about 3,600 euros for esters as compared to mineral oil, or only about 0.2% of the entire investment cost for this type of wind turbine. ■

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