Test case: cold start-up validation of transformer pumps using a large climatic test chamber

The new trend in the installation of wind turbines is the choice of remote areas, where wind conditions are very often optimal leading to new investments for the implementation of wind energy parks. On the other hand, such locations have to deal with extreme inhospitable climatic conditions: extreme cold and/ or hot temperatures, strong winds and gusts, high humidity, ice and/or snow, salty environment (in case of the offshore market). These harsh locations form a huge challenge for the machine itself and maintenance and repair work in such circumstances can be challenging. In some cases, repair work has to be postponed because of bad environmental conditions and thereby noticeably affects the turbine availability and its business case.

This is the reason why wind turbines and components need to be designed and validated as capable of surviving and operating in such extreme conditions. OEM's and component suppliers are more and more aware of the need to perform advanced validation tests in order to substantiate confidence in its designs, and to increase the reliability and robustness of their products in such inhospitable environments.

EFAFLU is a Portuguese company entirely dedicated to the development, manufacture, marketing, technical support and after-sales service of pumps, pumping systems and fans. With the increase in the demand of wind turbine installation in harsh environments, EFAFLU saw the need to validate one of its leading product's typology, oil pumps for transformers, performing cold start-up tests in extreme cold temperatures. For this, EFAFLU teamed up with Sirris/OWI-Lab.

Sirris/OWI-Lab is specialized in testing and verification of wind turbine components and full integrated systems, such as gearboxes, generators, liquid filled and cast resin transformers, power converters, hydraulic systems, etc. in extreme climatic conditions. This is thanks to its own climatic test chamber, one of the largest in Europe, which has a temperature range from -60°C to +60°C. A specific focus of the climatic test lab is in to test cold-start-up sequences, cold climate / winterization effects, and icing conditions on large electro-mechanical equipment.

The wind turbine transformers are an essential component in the energy transmission chain from wind to grid. It steps up the output voltage (low) from the generator to the distribution grid level (high). This critical component needs to operate correctly and, moreover, failure or damage have to be avoided in order to guarantee a continuous distribution. Generally, these transformers are cooled with oil. The oil,

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besides providing the cooling during the transformer operation, acts as an electrical insulator to minimize losses and to protect the system.

There is a pump in the oil circuit: its function is to circulate the oil in the transformer, in order to avoid hot or cold spots and to pump the oil into the heat exchanger. Here it is further cooled down and pumped again in to the transformer. Thus, the oil pump plays an important role in the entire chain, and failure or malfunction is not an option.

Transformers can be found in different locations in a wind turbine: in the nacelle, inside the tower, on a platform, inside the wind turbine at the entrance or outside the wind turbine near the entrance. In particular, one of the trends is indeed to place them inside the tower: the design of these transformers has been revised to allow the installation, which is done by entering the tower from the door at the base, a relatively narrow opening. Nevertheless, since the power conversion has to be the same compared to the traditional design for the same application, outside installation, the 'slender' design brings different challenges in terms of reliability, e.g. cooling during operation; and the oil pump becomes a more

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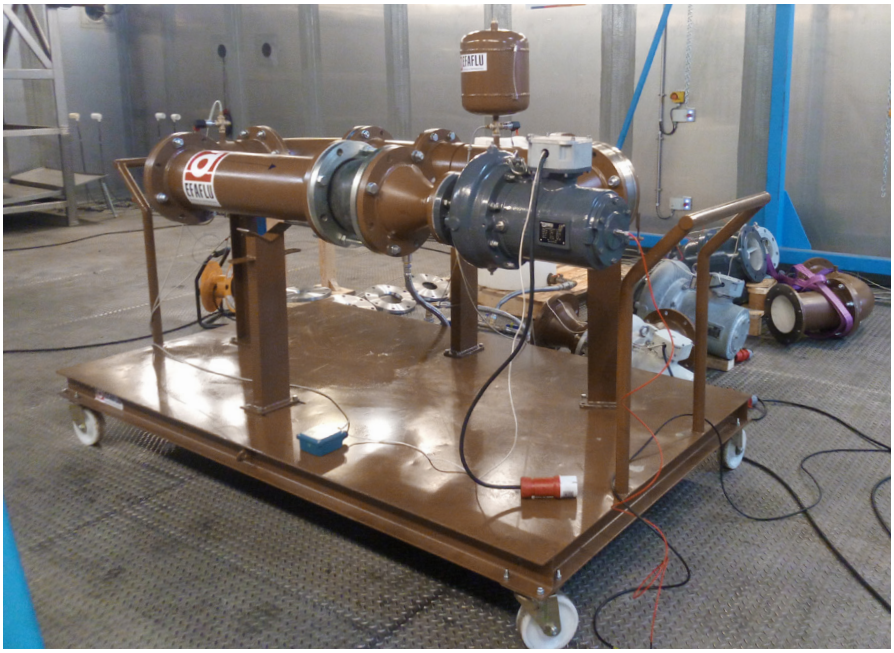
critical element as well.

There are potential risks, which lead to failures during the start-up of the pumps in extreme cold temperatures, listed here below:

- The viscosity of the oil increases due to the extreme cold temperature, adding exceptional loads on the pump
- The rotating elements in the pump can be at risk because of insufficient lubrication and/ or the differential thermal expansion of the sub-components
- The motor of the pump can experience overheating problems caused by high current demand during the cold start-up
- The low temperatures affect other materials (plastics, metals, rubbers) and can cause brittle fracture of the sub-components, gaskets, cables, etc.

According to EN 50216-7 standard: 'Power transformer and reactor fittings; Part 7: Electric pumps for transformer oil', pumps are required to perform a cold start-up test at -25°C. During the test, the pump shall reach full running speed following the conditions of minimum voltage, with oil at the minimum temperature and without overheating of the motor or other adverse observations.

Besides the standard specifications, the intention of EFAFLU was to extend the standard requirements to a more severe scenario of -45°C, the main driver being the installation of wind farms in locations with extreme climate, such as Russia, Canada, etc. where robustness and reliability is critical not only during operations but also for the more complex maintenance activities due to the harsh environment.



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A tailor-made test setup was designed and implemented by EFAFLU. It is able to accommodate different types of pumps and sensors for measurements at specific locations, in the form of a closed loop piping system, with a changeable orifice plate to adjust the load for the different pumps models. This is in order to mimic the functional behavior of the pump in the transformer setting.

The test setup was placed in the Sirris/ OWI-Lab climate chamber, and equipped with temperature sensors, to measure the oil temperature at the inlet and outlet of the pump, and the temperature of the motor winding, pressure sensors, an inductive sensor for the motor speed, a current sensor to monitor the peak current during the start-up and a voltage sensor to measure the condition of minimum voltage at the start-up. 2 types of pumps were tested, for a total of 5 different models. In particular 3 end-suction pumps and 2 in-line pumps, with nominal diameters from 100mm to 200mm and power ranging from 1.1kW to 7.5kW.

For each pump under test, a dedicated orifice plate was installed in the test setup to create the correct load due to the oil flow. The temperature in the chamber has been lowered until the oil temperature was stable at -45°C. Then, the cold start-up of the pump was performed, measuring the quantities listed above.

Having completed all the tests successfully, a full report for each pump was undertaken. The report contains a full explanation of the test, test schemes, values recorded during the cooling and during the cold start-up test, results and conclusions. EFAFLU decided to enclose the report from Sirris/OWI-Lab among the documentation on the pumps as an approval for applications in cold climates, as a proof for the customer: the OEMs, transformer suppliers, etc. that the product can survive and operate at -45°C.

This test case shows that the validation in a controlled environment of systems and components that have to be installed in areas where extreme conditions represent a risk of potential failures is crucial to guarantee the correct operation of the component and to assess the design choices which influence the functionality and more over the lifetime of the part.

Sirris/OWI-Lab climate chamber

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