LABORELEC

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DOSSIER ON ELECTRICAL EQUIPMENT

New tightness test on SF6 MV switchgear improves lifecycle calculations

Increased temperature decreases lifecycle

Manufacturers of SF6 MV switchgear have to minimize the leakage rate in order to maximize the lifecycle of their equipment. The Belgian Distribution Network Operators (DNO) however, were concerned that the lifecycle of switchgear might decrease considerably during operation when submitted to high temperatures. At the DNO's request, Laborelec provided experimental evidence based on a cumulative tightness test at high temperatures.

Most of the Ring Main Unit (RMU) and modular types of MV switchgear contain hexafluoride (SF6). The SF6 gas is kept under pressure in a sealed-for-life vessel and serves as an insulating and/or arc-quenching medium. The pressure inside the vessel needs to be maintained within acceptable limits to ensure a lifecycle of at least thirty years. In order to backup this guarantee, manufacturers carry out a routine test at ambient temperature and for a maximum of two hours. Laborelec developed a new testing method, selected a trustworthy measurement tool, and revealed that the lifecycle indeed decreases at high temperatures.

Setting up a new SF6 tightness test

Laborelec decided to put the switchgear in a gas-tight sheath in order to accumulate the leaking gas and measure the leakage rate. Our team first measured the leakage rate at 20°C, before submitting the switchgear to 40°C for 168 hours. Afterwards the temperature was brought down to 20°C and the leakage rate was measured again. The results revealed a significantly higher leakage rate during the measurement.

Selecting the appropriate measuring tool

The tests were conducted at the laboratories of a switchgear manufacturer and in Laborelec's own climatic test station. Two measuring techniques were used: negative ion capture and photo-acoustic spectrometry. The first method turned out to be extremely sensitive to draft, delivering different results when used at different locations. The second technique however, was able to generate reliable results in any environment. Thanks to these tests, Laborelec now has the set-up and the measuring equipment to investigate other switchgear types and advise the DNO on their life expectancy.

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The technical Competence Centre
in energy processes and energy use.
From innovation to operational assistance.

Reinforcing our expertise in electro-technical equipment

Laborelec has greatly improved its expertise in electro-technical equipment over the last three years. We have expanded our staff of specialized engineers and invested in new onsite tools for offline and online measurement. We have also equipped our laboratory with new high-tech equipment for in-depth analysis of electrical performance and composition of materials. In short, we are continuously enhancing our expertise to offer clients high added value in condition monitoring of electro-technical equipment.

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Identifying shorted turns in generator rotors

Online rotor flux measurement proves efficient

Power plant generator rotors must endure severe operating conditions. These can cause interturn short circuits, or shorted turns, which can negatively affect performance. Laborelec now offers a new method to measure and identify shorted turns in generator rotors. This technique can be used online, is easy to install, and available at a limited cost.

During operation, generator rotor windings (or rotor turns) expand and warp, depending on the load. This can damage their insulation and, consequently, generate interturn short circuits. As a result, rotor vibrations, rotor winding temperature increases, field current increases or, in extreme cases, damage to the retaining ring can occur. It is therefore important to monitor rotor shorted turns in order to maintain generator performance.

Online probe measurements

Laborelec's rotor flux monitoring system identifies and locates short circuits between rotor winding turns during generator operation. This is preferable to an offline measurement system, since certain short circuits only appear when the rotor is functioning. The technique provides efficient measurements at a negligible cost compared to the cost of a new winding or generator. The flux probes are installed on the stator, which requires a generator stopping. This installation can, for instance, be done during an overhaul.

Measuring rotor slot leakage flux

The technology measures the leakage flux density specific to each rotor slot. When a rotor has short circuits between turns, the leakage flux of the slots concerned is reduced. By installing a probe opposite the rotor, the flux density can be measured for every slot and transmitted to a PC for analysis. Slots that contain a short circuit can thus be identified.

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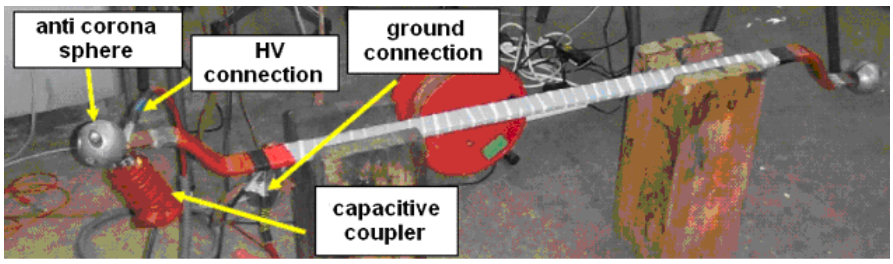
Safe operation ensured for Vaugris power plant

New testing methodology for stator bar insulation provides definitive answer

A stator bar defect at a power plant in Vaugris, France was quickly repaired, enabling resumption of normal operations with minimal downtime. Laborelec's new testing methodology confirmed that the repair guarantees safe operation and that a full rewinding of the stator was not necessary.



Laborelec developed a new methodology for assessing stator bar insulation during a project for Compagnie Nationale du Rhône (CNR). Our team used a series of electrical and material tests to evaluate a stator bar insulation defect on one of the 18.2 MVA generators at the CNR power plant in Vaugris after a quick repair by CEGELEC.

Partial discharges in defective and reference stator bars

First, our team measured the amount of partial discharges on the repaired defective stator bar as well as on a reference bar in perfect condition. Test results revealed a similar low level of partial discharges for the two bars, indicating that the insulation of the defective bar revealed no global ageing degradation.

Material tests confirm local defect

Then Laborelec determined that the defect in the insulating mica and epoxy layers was caused by arcing during the incident, rather than by insulation ageing. Our team conducted a series of material analyses on a sample of the defective bar. The results showed that small parts of the epoxy layer were missing and the mica structure had slightly altered, but only at specific locations in the sample. A local defect was obviously the root cause of the defect in the insulating layer.

New testing methodology

Laborelec's new methodology helps to answer power plant operators' questions on how to deal with stator bar defects. Will the repair ensure safe operation? Or is it necessary to replace all of the stator bars in the generator? The new combination of electrical and material tests provides a definitive answer. Laborelec has in-house skills that can be applied to both small as well as large projects. It is already being used to investigate incidents in larger plants.

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Multidisciplinary investigation of VRLA batteries

Early loss of capacity tackled for Bergum power plant

At the request of Electrabel Nederland, Laborelec investigated the possible causes for the early loss of capacity of Valve Regulated Lead-Acid (VRLA) batteries at the Bergum power plant. Laborelec supplied the operator with operation recommendations after multidisciplinary investigation of the batteries.

Batteries are generally used as power backup for critical applications such as the emergency DC lube oil pumps. The batteries at the Bergum power plant are of the VRLA-type – which are maintenance-free and offer improved safety – and are installed in an air-ventilated electrical room. During its inspection round, the maintenance team had detected an early loss of capacity on some of the VRLA batteries. The operator sent off three batteries to Laborelec – of which one was fully charged – for multidisciplinary investigation of the problem.

Multidisciplinary tests showed no abnormal results

First, Laborelec visually inspected the various parts inside the batteries. The cathode, anode, glass mat layers containing the electrolyte, and welded straps between the parallel plates showed no evidence of degradation. In the second phase, Laborelec measured the DC internal resistance of the fully charged VRLA battery. Internal resistance gives an indication of the electrical condition of the battery. The test showed a deviation of 21%, well within the manufacturer's acceptable limits of 35% deviation.

Finally, Laborelec also ran a series of other physical and chemical tests to determine whether ageing was at the root cause of the problem:

- An X-ray fluorescence test showed no contamination in the composition of any of the elements inside the battery
- An X-ray diffraction analysis proved that the structure of the lead crystals was perfectly normal
- A test with a pH paper strip revealed that the electrolyte in the discharged batteries had turned almost neutral, while the electrolyte in the charged battery was still acid

Recommendations for optimal exploitation

The tests revealed no abnormal results. Therefore Laborelec concluded that the early loss of capacity could have been caused due to an error in the manufacturer's filling process or due to operational conditions. Laborelec supplied Electrabel Nederland with several recommendations for optimal use of the batteries such as more stringent control of the battery's charge-discharge procedure.

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Understanding the degradation mechanisms of cable terminations

Following two successive HV connection failures, Tractebel Engineering called upon Laborelec to analyze a defective cable termination at one of the transformers of the Al Taweelah power plant. Thanks to its vast expertise in cable ageing and materials, Laborelec was able to provide help in understanding degradation mechanisms on the transformer side.

The Al Taweelah combined cycle power plant, located in Abu Dhabi, has a capacity of 1,431 MW. The plant, which is jointly owned by Tractebel and Total, recently experienced two successive cable termination breakdowns on the same transformer. These occurred at the bottom of two 400 kV cable terminations. The root cause was a swelling of the semi-conductor. Observations revealed, however, that the cable terminations on the transformer side had a very different aspect from those on the gas insulation system (GIS) side. For instance, the silver coated top connectors in the transformer terminations were black and brilliant on the GIS side. In addition, a number of other colour changes were observed on certain cable termination components. Laborelec was asked to analyze material samples in order to better understand the ageing mechanisms of these termination parts.

Material analysis reveals chemical reactions

By using several analysis techniques including differential scanning calorimetry, X-ray fluorescence, Fourier transform infrared spectroscopy, and nuclear magnetic resonance, the chemical reactions leading to the degradations were determined. The blackening of the top connector, for example, was due to corrosive sulphur present in the transformer oil. Additional tests revealed that the temperature on the transformer side was slightly higher than on the GIS side, hence explaining why the GIS cable terminations were not affected. Further tests are planned to ensure that similar problems are avoided in the future.

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Cable ageing assessment: indenter proves to be the best tool

Laborelec supports power plants in the screening, selection, and purchase of cable ageing assessment tools. Recently our team selected the indenter as the most suitable tool to meet all of the criteria for Belgium's power plants.

In order to guarantee safe operation, power plants are obliged to evaluate the condition of their cables regularly. This poses a certain challenge. The assessment needs to be done efficiently, minimizing costs and downtime for the plant, but thoroughly, often under the auspices of a controlling body. Therefore Belgian power plants turned to Laborelec to select a tool that enables them to find a good balance between cost and safety. Our team defined a set of criteria for the screening of several assessment tools:

- The measuring method needs to assess ageing in a **non-destructive** way so that cables are not damaged during the examination
- A **portable** tool would enable plant employees to evaluate cables in their operating environment, without having to disconnect them
- The tool has to be **commercially available** so that it can be purchased easily
- **References** were also deemed crucial because of the availability and exchangeability of measurement data

Laborelec's research showed that the indenter best meets all of the criteria. This widely used portable tool determines a cable's state of degradation by pushing in on its surface. A cable's hardness is a perfect ageing marker; the more brittle a cable's jacket, the older the material. The indenter can also be used to assess the ageing of plastic and rubber which makes it useful in the condition monitoring of for instance seals.

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New developments in understanding water tree growth

New equipment for accelerated growth and improved cable analysis

How do water trees grow over time? What is the susceptibility of medium voltage XLPE cables for growing water trees? Answering these questions is essential for managing and maintaining cable networks. To gain better insight into this phenomenon, Laborelec has developed an accelerated water tree growth method in collaboration with the University of Bucharest. It has also acquired additional equipment for its Belgian facilities.

Water trees are produced by water diffusion into the main polyethylene insulation layer of a power cable. They result from the interaction between an electric field, impurities, defects due to cable manufacturing, and the presence of water. This phenomenon is a primary cause of cable breakdowns, which can generate costly power supply interruptions in distribution grids or at major industrial sites. For Laborelec — and for all users of XLPE (cross-linked polyethylene) cables — it is therefore essential to better understand water tree growth.

Accelerated growth generates spectacular results

The most promising method for analyzing water trees is to artificially reproduce the phenomenon using a high frequency, high voltage power source. This enables the acceleration of the process as well as the ability to vary the parameters involved, such as insulation type, environment, and operating conditions. In collaboration with the University of Bucharest, Laborelec has ordered a dedicated power supply unit in the USA, based on specific requirements. Using this equipment, it recently started carrying out accelerated growth tests on real cables (20 kV, 5 kHz). So far the results have been spectacular, with water trees obtained in only seven days in 6 kV cables originating from the Belgian distribution grid. Usually, water trees only appear after twenty to thirty years of service. These encouraging tests on real cables at 5kHz are a world first. The method promises to be extremely useful in timing the replacement and maintenance of existing cables. The technology also presents a potential in terms of resistance tests for new cables.

By accelarating the growth of water trees in laboratories, their evolution can be better understood.

New microscope allows 3D analysis

Laborelec has also acquired important new material for its laboratory in Linkebeek. It is now equipped with a new stereoscopic microscope enabling 400X enlargements as well as 3D views. Laborelec is one of the first to use this tool for this purpose. In addition, Laborelec has purchased a new microtome machine. This high precision equipment is able to precisely cut thin cross sections of cable of 600 microns thick, scratch free. These new tools will help Laborelec make significant advances in this key area of research and improve service to all customers.

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