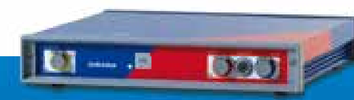
Application

Find the fault

Comprehensive diagnosis of a hydropower generator

Generators are used for generating electrical energy. If they fail, this means a loss of production and therefore a loss of earnings for the operator. Maintenance and diagnostics of the system's functionality both play an important role in avoiding unforeseen failures. Following an extended period of inactivity, electrical diagnostic measurements were performed on an old hydropower generator with a rated voltage of 6400 V and an output power of 5400 kW to secure uninterrupted operation.



DIRANA

- Cuts the typical testing time in half by combining time- and frequency-range methods (PDC and FDS)
- Automatic water content determination without expert knowledge
- Correct wiring thanks to detailed wiring diagrams
- No overestimation of the water content due to unique compensation of aging products

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On generators, the main insulation of the stator winding is only a few millimeters thick. It is kept thin to fit as much copper as possible in the stator slot and to deliver the best possible performance while maintaining its compact outer dimensions. An arc of the main insulation during operation would have fatal consequences. Therefore, inspecting the winding insulation plays a very important role during diagnostic electrical measurements.

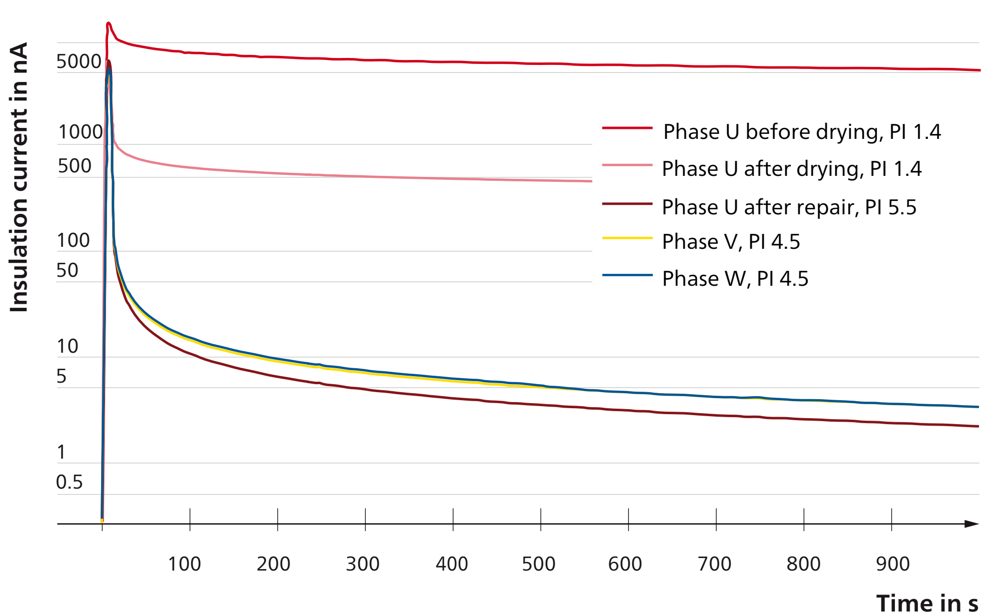
Moisture test

Before high test voltages are applied to the insulation, it is first important to ensure that it is dry. For this purpose, the insulation resistance is measured using DC voltage. If the insulation is in perfect condition, a relatively high current will flow after applying the DC voltage, but then it will drop off sharply. The ratio of the current after one minute to the current after ten minutes is known as the polarization index (PI). The PI is an important indicator for the insulation condition. If it is lower than two, high voltages should not be applied to the winding insulation, as there is a risk of an arc.

DIRANA was first used to measure the insulation currents and the PI. With phase U, after 10 minutes the insulation current was almost 1 000-times higher than with phases V and W. The PI of phase U was just 1.4, whereas the PI of the other phases was around 4.5. The low PI of phase U meant that a more detailed inspection of the insulation was necessary before any high-voltage tests could be performed.

DIRANA: more information in less time

By determining the dielectric response, DIRANA allows for a far more detailed diagnosis of the insulation than could ever be achieved by only using the PI. The dielectric response can be measured over time (PDC - polarization depolarization current) and over frequency (FDS – frequency domain spectroscopy). The PDC method measures the charge and discharge current over time. The FDS ▸



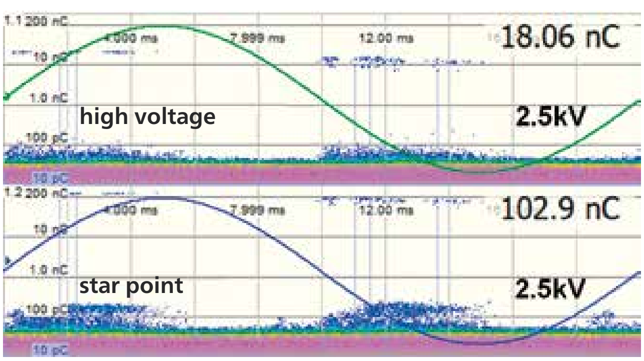
Insulation currents of the phases U, V and W.

method detects the capacitance and dissipation factor over a wide frequency range. DIRANA combines the two methods and thereby cuts the typical testing time in half.

When measuring the dielectric response, the extremely high dissipation factor of phase U with 294% at 10 mHz, compared with about 5% from the two other phases, was particularly striking. The sharp increase in capacitance of phase U from around 100 nF at 50 Hz to 287 nF at 10 mHz was also noticeable immediately.

Potential remedy: drying the windings

Due to the low PI of phase U, the generator's rotor was removed to clean the heavily soiled stator winding. However, when the insulation resistance test was performed again after cleaning, there were no observable improvements. Therefore, the windings were heated and dried using a DC current of around 250 A. When the heating was checked using a thermal image camera, it became clear that certain zones of the winding in phase W were warmer than the rest of the winding.



PD measurement of phase U at 2.5 kV.

PD fault location on the output to the star point.

The winding resistance was then measured using the CPC 100 and a DC current of 100 A. The result indicated that the winding resistance of phase W was about 25% higher than the winding resistance of the other phases. When the winding was inspected, it was determined that various soldered connections in the winding head of phase W were broken. These damaged connections were then resoldered.

In addition to this, the insulation resistance and PI measurements were repeated. At 513 nA after 600 seconds, the insulation current was more than 10-times lower than the value recorded before the drying process. However, the PI of phase U remained the same at the low value of 1.4.

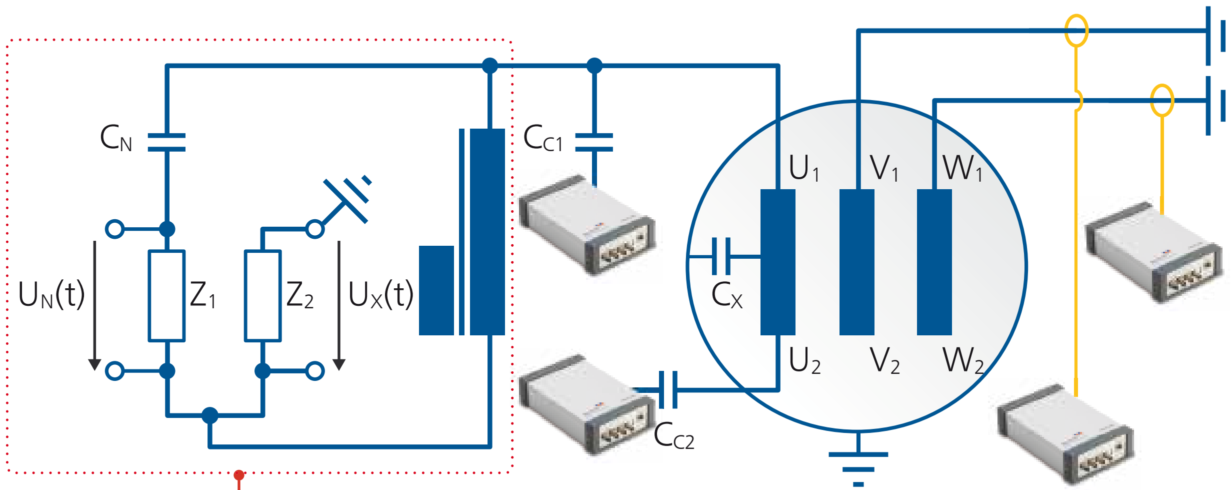
Partial discharge measurement using the MPD 600

A partial discharge measurement was performed to find the fault. One channel of an MPD 600 system was connected to the high-voltage side. Another one was connected to the star point of the U winding.

At a voltage of 2.5 kV, very severe partial discharges of more than 100 nC occurred at the star point. They could be localized acoustically using an ultrasonic detector. The picture on the left shows the fault location: a sharp-edged mounting clamp on the output to the star point.

Repairing the defective winding

However, the actual fault had still not been eliminated, which became obvious when the insulation current measurement was repeated using the DIRANA. Therefore, the windings were tested at their rated voltage (6 400 V). During this test, an arc occurred in phase U after about 10 seconds. The insulation resistance that was measured afterwards was so low that a current of 2 A could be fed into the fault location using the CPC 100. Thereby, the feed point of the current was alternated between the high-voltage side and the star point. The defective rod could be found using a clip-on ammeter. The winding was repaired by disconnecting the defective coil and connecting the ends of the remaining winding to one another. The insulation current was tested again. It was found to be at a similar level with the other two phases. The PI was 5.5 following the repairs, well above the critical value of 2.



Simultaneous capacitance, dissipation factor, and PD measurement using the CPC 100 + CP TD1 and MPD 600.

CPC 100 + CP TD1

- Improved insulation diagnostics thanks to variable frequency testing
- Lightweight and easy to transport thanks to trolley
- Automated testing with testing templates
- Reporting: detailed analyses with trend displays and graphics

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Total testing time following the repairs: 6 minutes

In the final step, all the relevant measurements for commissioning the repaired machine were performed simultaneously. The testing system used for the simultaneous measurement of capacitance, dissipation factor, and partial discharges makes this test extremely efficient. It consists of the CPC 100 universal testing device, together with the CP TD1 capacitance/dissipation factor testing system, and uses CP CR500 compensating reactors for reactive power compensation, and up to four MPD 600 systems, including MCC coupling capacitors and MCT high-frequency converters for partial discharge measurement. The entire test procedure (phase U against phase V, phase W, and stator) took only 6 minutes to complete. Since the test needs to be performed at various voltage levels, the test voltage was increased automatically in 10% steps of the rated voltage up to 120% and then reduced again in steps of 10% back down to zero. All data, such as voltage, current, frequency, capacitance, dissipation factor, and all PD levels and patterns were recorded and saved for all test voltage levels. So the amount of time, that would have been required to record all of this data manually, was reduced dramatically.

Passing these tests successfully demonstrated the machine's operational readiness following its repairs. The hydropower generator was able to be started up again.

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Test & Diagnostics Solutions for Primary Assets