A high voltage withstand test, in particular DC on XLPE cables is likely to lead to their destruction. Similarly AC tests at low frequency (VLF tests) are of themselves not necessarily indicative of the health of a cable. There are plenty of instances where a break down occurred not long after a loss angle test. Monitored withstand testing (MWT) as described here, on the other hand, has excellent predictive capability and the testing methods do not compromise the cables under test. In combination with partial discharge testing, a very powerful piece of testing apparatus is created.

The disadvantages of simple cable testing can be summarised as follows:

- No estimate of the cable quality can be made before the full test voltage is applied
- The duration of the test cannot be adapted to the condition of the cable
- No estimate can be made of how well the cable passed the test nor whether the cable will fail within an hour or in ten years

Combining VLF cable testing and VLF tan-delta diagnostics can avoid these limitations. The essence of the test is two stages:

- "ramp-up" and
- "MWT" or "hold" stage

VLF (Very Low Frequency) was introduced to test the insulation of medium voltage underground cables after new installations, after repairs or as a routine measure at regular intervals. In XLPE cables, DC testing can induce trapped space charges in the polymeric material sometimes causing breakdown shortly after de-energising the cable. This behavioural pattern was observed in medium voltage cables failures. Voltage withstand testing of itself does little more than provide a pass or fail without any indication as to how long the cable is likely to remain serviceable. The combination loss angle (tan δ) and partial discharge test offers a predictive test as to the long term reliability or otherwise of the cable being examined. The phasor diagram (figure 1) shows the combination of conductive insulation leakage and the capacitive displacement current. As the conductive component increases, tan δ increases.

The measurement of loss angle at 0.5, 1.0 and 1.5 of rated voltage provides good information. A high mean value of tan δ very likely indicates the presence of water trees. Note: in combination with partial discharge, any resultant electrical trees will show up. A continual increase in tan δ (Δ tan δ) with increase in test voltage is an indicator of partial discharges. On the other hand a negative Δ tan δ can be indicative of vaporisation at terminations.

The advantage of a ramp-up stage is that a cable is not immediately stressed beyond its capacity. An initial assessment of the cable condition is formed. The test protocol is shown below.

\[ \text{tan } \delta \text{ stability standard deviation of 6-10 measurements at } U_0 \text{ (rated voltage)} \]

\[ \Delta \text{ tan } \delta \text{ difference of the average values at } 1.5 \text{ } U_0 \text{ and } 0.5 \text{ } U_0 \]

\[ \text{Mean tan } \delta \text{ (MTD) average value of 6-10 measurements at } U_0 \]

In figure 2, the results of testing an MV cable are shown. Diagnostic measurements of tan δ were made following repair. The graph of tan δ versus voltage shows that the cable is aged. Phase 1 and 2 show appreciable Δ tan δ with increasing voltage. The standard deviation in tan δ is also a good indicator. A high value or increasing value can respectively be markers for water ingress in cable joints and partial discharges.

It is important for the application of the VLF MWT, that the measurement is simple and automated. This requires a VLF sine voltage, because this voltage shape allows a precise and combined tan-delta measurement. Additionally it is possible to perform the tan-delta measurement at a constant frequency, where limits are available and where a comparison of different measurement results is possible. This fact allows the electric utility system operator to gain the experience with cable diagnostics.

In fig 3 the test set up for combined partial discharge and VLF testing is shown. The Baur FRIDA VLF generator is connected to the Baur PD-TaD-60 combined partial discharge and tan measurement device. In fig 4, the results of a VLF test are shown.

In sum, the use of an integrated testing package combining VLF testing and partial discharge measurement is recommended for comprehensive cable testing. The Baur PD-TaD-60 with maximum testing voltage of 60 kV peak is provided with a partial discharge decoupling circuit to permit sensitive observation and measurement. By connecting the FRIDA VLF generator and integrating this with partial discharge detector, a complete testing protocol is available.

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Figure 1

Figure 2

Figure 3

Figure 4