Remaining life time of medium-voltage cables

New possibilities for advanced dissipation factor diagnostics

Many outdated, contradictory, or incorrect perceptions about dissipation factor diagnostics and the associated condition analysis of medium-voltage cables prevail. And yet this method has developed into a comprehensive, modern process. Thorsten Schlender discusses the current possibilities and limitations of this technology.

The experience Baur GmbH has in using dissipation factor measurements (TD diagnostics) to determine the condition of medium-voltage cables dates back to the 1990s. For more than thirty years, the company has been providing the measurement technology for this, enabling it to accumulate a wealth of experience. In the following, we will show how this technology has continued to advance – from the measurement of a TD mean value and the introduction of new evaluation parameters and limit values to determining the remaining life time of medium-voltage cables.

The introduction of the statex analysis software is the latest milestone in the history of cable diagnostics. Software is now available to determine in detail the ageing condition, the speed of ageing, and the statistical remaining life time of a cable route.

In addition to the conventional evaluation parameters according to IEEE 400.2 (SDTD, MTD, and ΔTD), the statex software also takes into consideration the new parameter TD-Skirt, which shows the time stability of the dissipation factor. This makes it possible to calculate the ageing index and the speed of ageing of the cable route. It is also possible to receive an exact recommendation for when a subsequent measurement should be performed, or when work is required, e.g. replacement of the cable route (Figure 1).

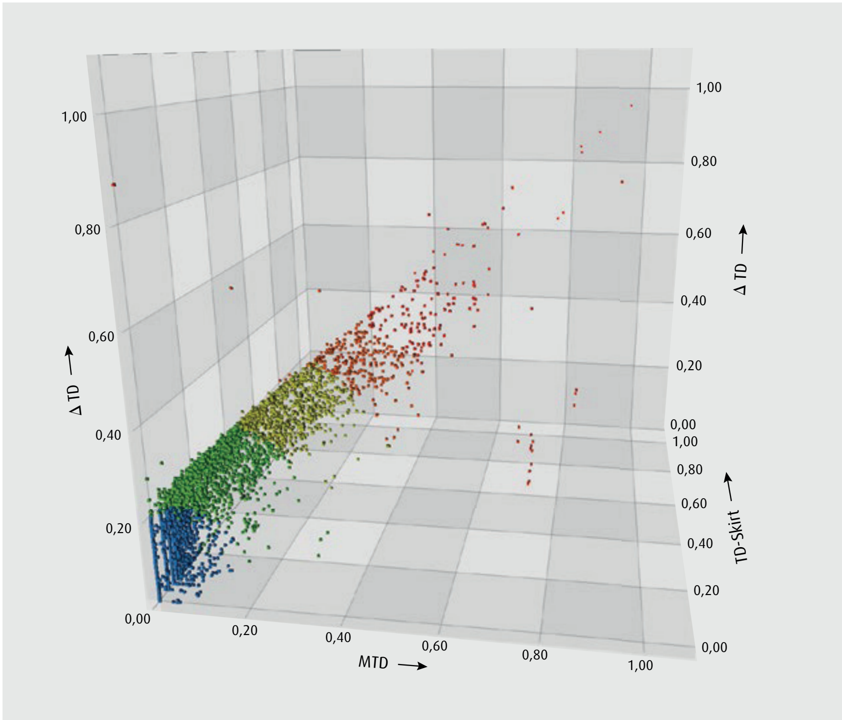

Figure 1: 3D cluster analysis of the ageing index – each point represents one diagnostic measurement

The problems of previous attempts to determine the remaining life time

A cable fault can mask a variety of breakdown mechanisms. It is therefore impossible to determine the remaining life time based on a simple analytical formula. Baur has worked around this problem by basing the solution on statistics and experience. The first step for determining the remaining life time using this approach is to evaluate the ageing condition.

The ageing condition of a medium-voltage cable can be influenced by many factors to a greater or lesser extent. These factors can include:

- Electrical load
- Mechanical load
- Thermal load
- Chemical processes
- Moisture
- Assembly and installation quality
- Material defects
- Differences in quality between different manufacturers of cables and cable accessories

Many of these influencing factors are unknown or can only be uncovered with considerable effort. What load has the cable been subjected to over the past thirty years? How many short-circuits have there been? What type of joints have been installed and by which manufacturer?

How good a job did the installer do on the day? In order to get around this lack of information, use is made of the fact that all of these factors have an effect on the diagnostic values (**Figure 2**).

Advancements in dissipation factor diagnostics

Statistics and experience

Thanks to decades of experience and a database now containing over 100,000 measurements, various advancements have been made possible in cable diagnostics. New knowledge has been gained, e.g. it is now known that a bathtub curve is not correct for the ageing behaviour of medium-voltage cables (**Figure 3**).

New limit values for various insulations, new evaluation criteria, such as TD-Skirt, and new combinations of methods, such as Full MWT (simultaneous testing and TD/PD diagnostics), are just some of the myriad advancements that have also been achieved over recent years.

Additional information thanks to simultaneous diagnostics

Cable testing, dissipation factor measurement, and partial discharge measurement are ideal complements, making it possible to both detect the overall condition and locate individual faults in the cable. With parallel testing and diagnostic measurements, additional information can be obtained without any extra effort.

Identification of water trees is no longer a key application area

Originally, TD diagnostics was increasingly being used on cables damaged by water trees (WT). However, thanks to new laterally and longitudinally waterproof cables, this application area is becoming less and less relevant. As a result, today's applications are even more interesting. Not only is it possible to determine whether water trees exist or not, but also the overall ageing condition of the cable. TD diagnostics and the statex software therefore also function – but not exclusively – on cables that have aged due to water trees.

Saving resources with the intelligent selection of test samples

Another finding gleaned from the analysis of TD measurements is that the dissipation factor values of new or recently laid cables are higher as a result of their insulation outgassing the products of the cross-linking process. In such cases, the dissipation factor reduces over time. It is only worth taking a measurement to determine the condition when this value rises again. This is why the DSP (degradation starting point) was introduced. The chemical analyses carried out every year of operation have been used to demonstrate that with many cable types, ageing begins from the thirteenth year. This finding corresponds with the observations of cable manufacturers.

Doing away with TD measurements on cables that have not yet reached the degradation starting point frees up capacity. This capacity can then be used to diagnose heavily aged and/or critical cable routes.

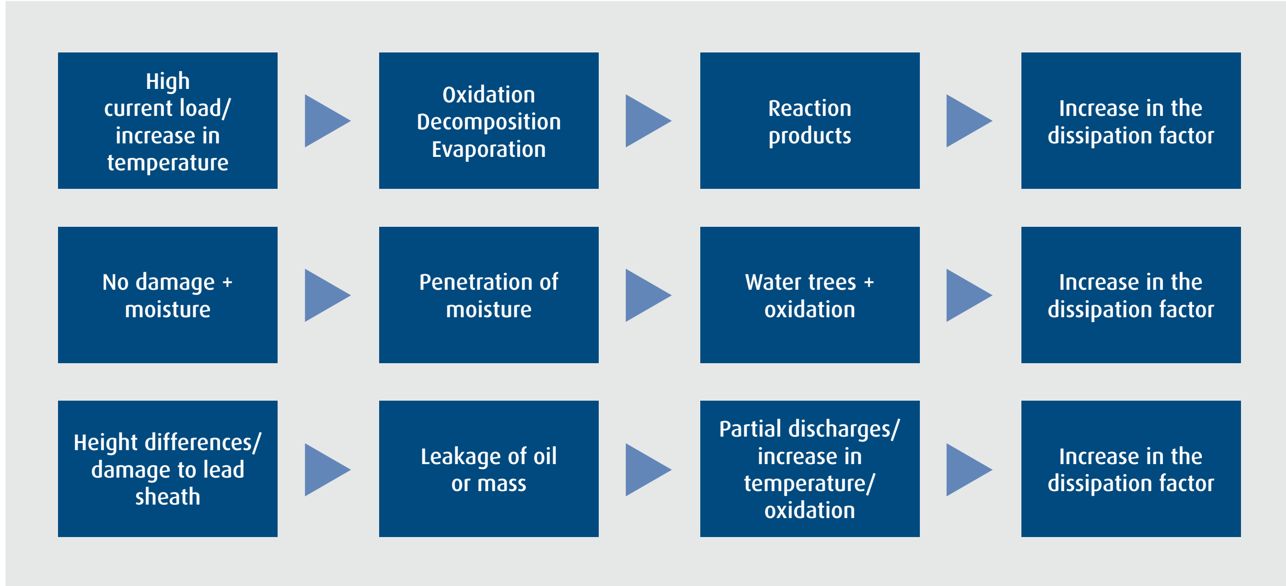

Figure 2: The ageing process in plastic and paper-insulated mass-impregnated cables based on NEETRAC Diagnostic Testing of Underground Cable Systems 12.2010

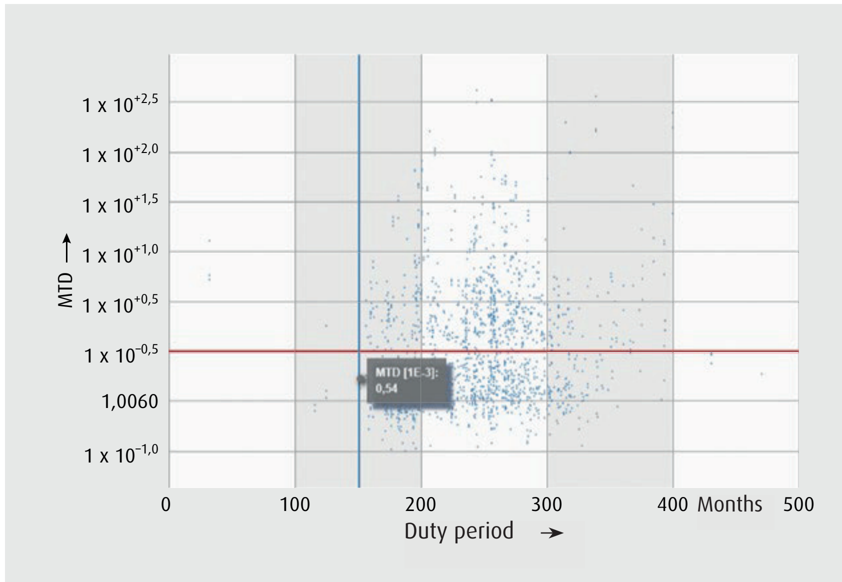

Figure 3: A statistical evaluation of several thousand diagnostic measurements shows that the ageing behaviour exhibits a broad distribution rather than a bathtub curve

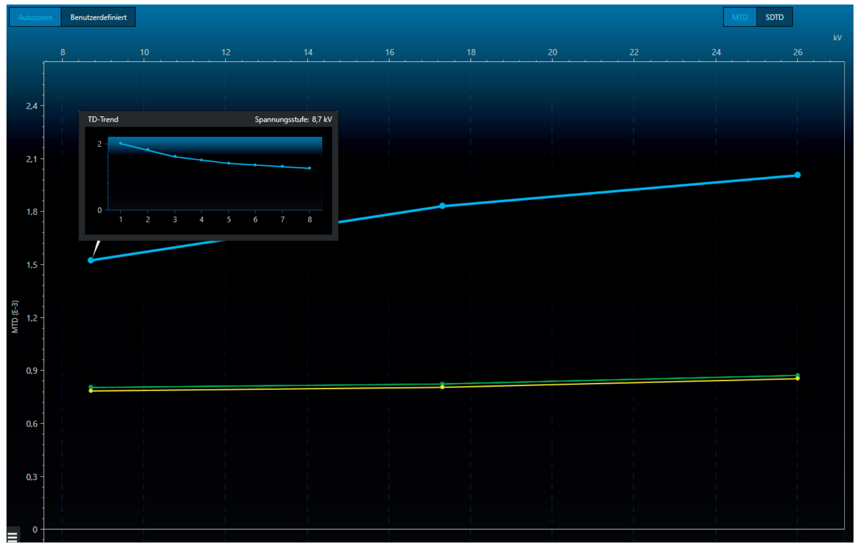

Figure 4: Moisture in the joint on L1 (blue) can be identified by the downward trend

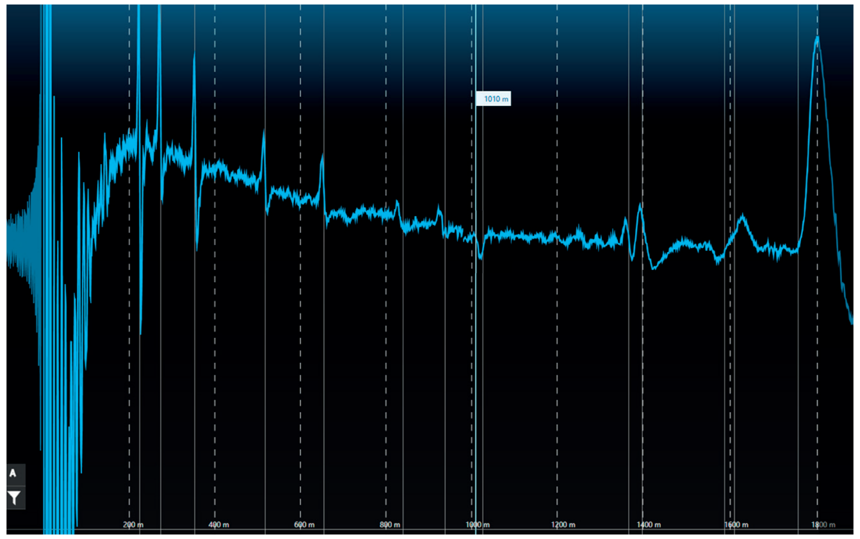

Figure 5: TDR/calibration curve with detection of a joint with water ingress at 1,010 m

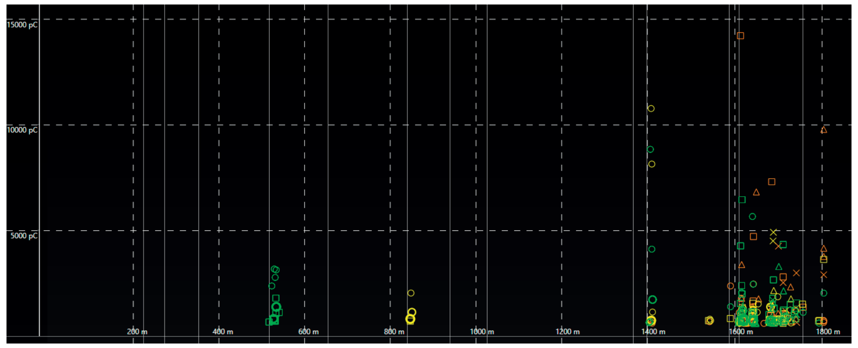

Figure 6: The wet joint detected by the TD measurement is not detected by the PD measurement

Using dissipation factor diagnostics to uncover local weak points

The dependency of the dissipation factor on the voltage and the trend behaviour within a voltage step are suitable for identifying any influence by cable accessories. Wet joints, for example, can be identified by a falling TD trend (**Figure 4**). The position of the joint can then be determined by means of a TDR measurement (**Figure 5**). A partial discharge measurement would not be sufficient for such an application, because it is often not possible to identify partial discharges when there are high levels of moisture (**Figure 6**).

For moisture and for partial discharges in cable accessories, we recommend replacing individual cable accessories in order to achieve better results and determine more accurate remaining life times. It is particularly the case with short cables or cables with low TD values that individual faulty cable accessories exert a greater influence, and they should therefore be replaced. **Figure 7** shows a simplified flow chart for the recommended course of action. On a medium-voltage cable, PD and TD diagnostics are carried out either to schedule or on the basis of a specific event (e.g. fault and repair). If partial discharges or the effect of moisture are identified as a result of this measurement, essential short-term measures must be performed. If the cable is (then) free of partial discharges and not impaired by moisture, the statex software is able to determine the remaining life time and the date for subsequent measurement.

External influencing factors can be compensated for

External influencing factors such as partial discharges or leakage currents can affect the results of the TD diagnostics. However, they can be compensated for without much effort. Corona partial discharges at the connection point and at the end of the cable route can be prevented by means of anti-corona hoods, e.g. aluminium half shells.

Leakage currents drain off via the surface of the cable terminations to earth and therefore affect the measurement result. By placing copper strips around the cable terminations, these currents can be dissipated, measured, and compensated for.

Dissipation factor diagnostics is possible and important for all types of medium-voltage cables

Different cable types differ with respect to their TD values. Paper-insulated mass-impregnated cables, and first and second generation plastic cables, exhibit significant differences in their measured values. Even within this subdivision there are other differentiations, e.g. homo- and copolymer cables differ significantly with respect to their MTD values (mean TD values for each voltage step). As this behaviour is not new knowledge, the limit values of various cable types are already included in the Annex of IEEE 400.2-2013.

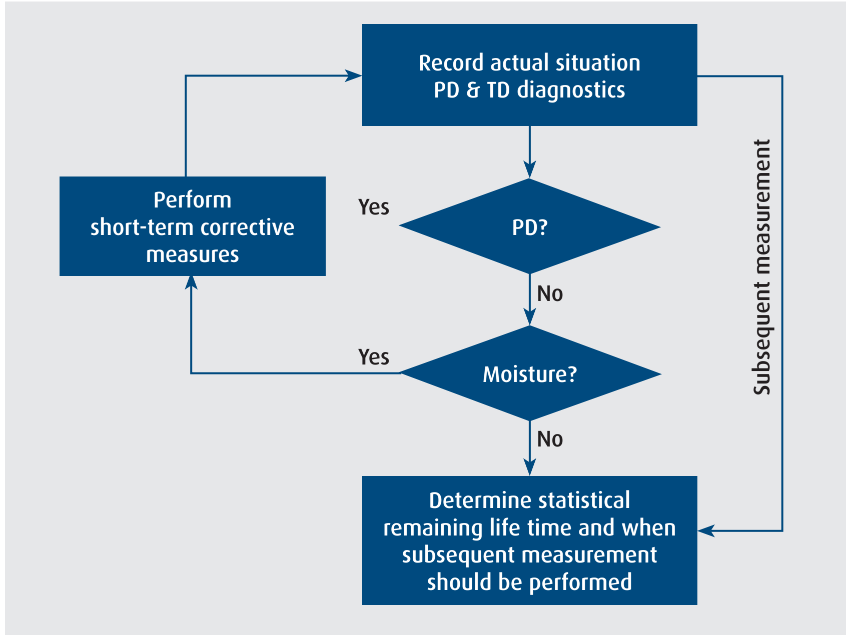

Figure 7: Diagram: short-term corrective measures and determination of the remaining life time

It is also possible to enter various insulations and their subcategories in the statex software. This makes it possible to observe mixed cable routes with different sections of cross-linked polyethylene cable segments separately from one another, for example. It is also possible to determine the remaining life time of mixed cable routes in this way (**Figure 8**).

Of particular interest are the TD analyses of copolymer XLPE cables (from around 2005), as limited research has been conducted so far on the influence of current load, changes in temperature, harmonics, etc. on the ageing behaviour. In this respect it is worth investing in the collection and analysis of the diagnostics data at an early stage in order to monitor the ageing process and prevent future failures.

Conclusion

It has been shown how new hardware and software solutions combined with comprehensive experience have led to the advancement of TD diagnostics. These advancements elevate the application possibilities of TD diagnostics and their evaluation to a new level, including the precise determination of the remaining life time of medium-voltage cables.

Thorsten Schlender M. Sc.,
Sales Engineer
Baur GmbH, Grevenbroich

>> thorsten.schlender@baur-germany.de

>> www.baur.eu/de

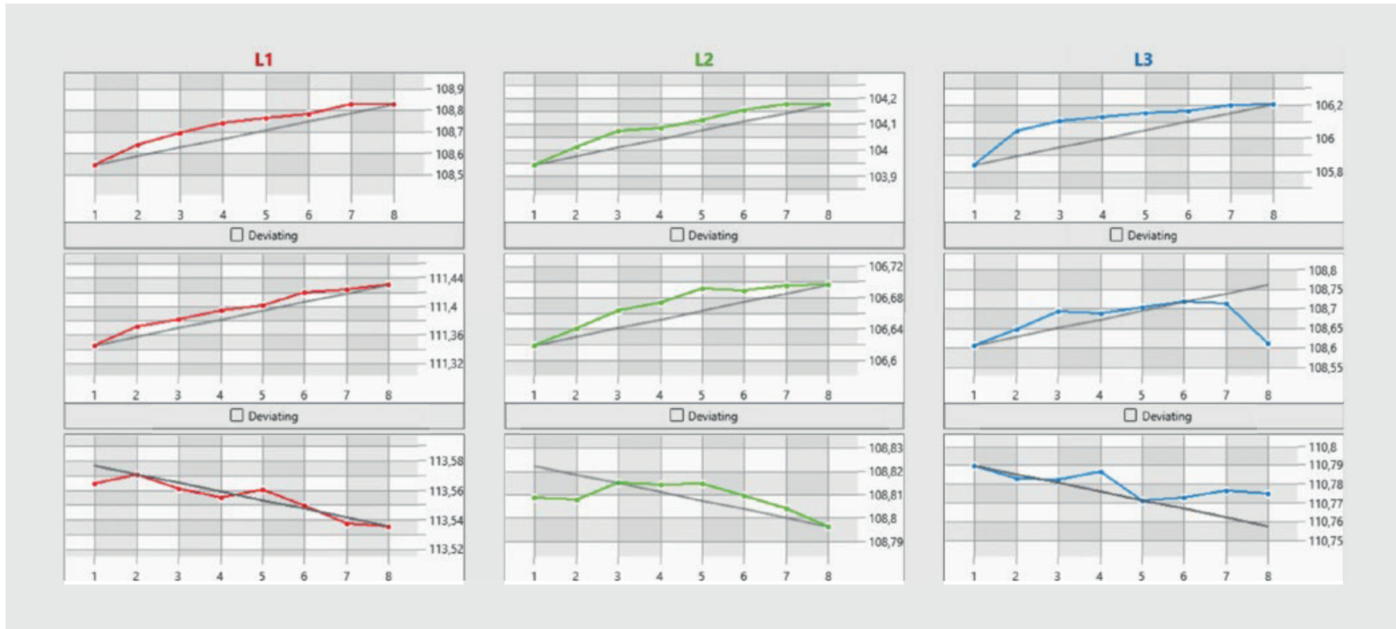

Figure 8: Typical behaviour of an aged mixed cable route; at the first two voltage steps (0.5 U_0 top and 1 U_0 middle) the TD prevails as a result of aged insulation. At voltage step 1.5 U_0, bottom, the effect of moisture can be observed.