Fault location on long power cables

Findings and experience concerning the use of submarine cables for long land connections

Container in front of the cable hall Source: Baur/Manfred Bawart

In a few years' time, high-voltage cables hundreds of kilometres long and extending from one end of Germany to another will become part of the country's critical infrastructure. Maximising the availability of these cables is crucial, so any faults need to be located swiftly and reliably and the cables repaired with minimum delay. This goes beyond the capability of conventional fault location technology but, fortunately, special solutions are available for extra-long cables based on technology partly derived from a field in which long cables are commonplace: submarine cables.

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Germany's power grid is set to be upgraded to incorporate extra-high voltage cables with dimensions that dwarf anything that has gone before. To minimise losses, the extra-long north-south routes will take the form of 525 kV direct-current transmission cables. The 700 km Südlink (south link) and around 500 km of the 560 km Südostlink (south-east link) will thus be laid underground. The 300 km A-Nord (A-north) connection, most of which is also to be buried, will be another of the main arteries of Germany's transmission grid of the future. These inland routes will be supplemented by cables bringing electricity to land from offshore wind farms.

Crisis plan: emergency preparations before the first sign of a fault

The construction of these cable routes is not the only major challenge facing network operators. To ensure the availability of this backbone of Germany's power supply, they need to be able to respond rapidly to any faults. This means not only keeping repair times short, but also minimising downtime by locating faults swiftly. It is therefore usually worthwhile investing in a fault location system even before the cable is put into operation, and keeping it ready for use at the cable ends so that the fault can be located immediately.

The time saved means that the investment in fault location technology usually pays for itself the first time a cable fault occurs. For long, system-critical transmission cables, fault location systems housed in containers and based on technology that has already proven itself on submarine cables many hundreds of kilometres long can be kept at the ready in the cable hall.

Land cables are more complex than submarine cables

The investment could be even more beneficial for land cables. Although not exposed to mechanical impacts from anchors and trawl nets, these are subject to many other potential sources of faults. Whereas submarine cables are designed in extremely long continuous lengths, land cables are typically made up of 1 to 2 km long sections for transport reasons. This makes for a large number of joints.

"Statistically speaking, the frequency of faults rises with cable

Measuring cable connection at a dizzying height
Source: BAUR/Manfred Bawart

Today, cables carrying electricity from offshore wind farms to land have to transmit large amounts of energy. Here, too, it's a good idea to have the right equipment at hand for fault location, just in case
Source: Adobe Stock/Shutter81

length and number of joints. So, too, does the amount that network operators need to worry about cable failures," says Manfred Bawart, expert in fault location on extra-long cables at BAUR GmbH (Sulz/Austria).

Keeping people and equipment safe

The technology used for long distances is something special, says Bawart. "The most commonly used fault location methods are not appropriate for the cable lengths in question. Both the equipment and the measurement methods are fundamentally different for long cable systems." For example, special systems are needed to discharge the energy safely, he notes, estimating that thousands of kilojoules are stored in the hundreds of kilome-

Conduits for high-voltage cables for onshore wind turbines Source: Adobe Stock / Kruwt

The "shirla" high voltage measuring bridge allows a Murray bridge measurement to be performed for the location of cable and sheath faults on long power transmission cables. Source: BAUR GmbH

tres long high-voltage cables after DC voltage testing. "Most devices and measurement systems are simply not up to the job of discharging such high energy. Moreover, standard devices are not protected against the extremely high-energy transient waves. This inevitably leads to the devices being damaged and puts operating personnel at risk."

BAUR fault location systems for long cables, which many customers are already using for long submarine cables, have a greatly modified safety concept, particularly in terms of the sheer size of the facilities for safely discharging the high cable capacitance, explains Bawart. The measurement methods are different, too. "Most of the pre-location methods that are appropriate for short land cables and popular because of their ease of use meet their match when they come up against long cable systems. That's why special measurement methods and optimised measurement technology are used."

Locating cable faults from both ends and boosting precision

In addition, measurement systems are often deployed at both ends of long cables to increase the measuring accuracy at large fault distances. Equipment tailored to the application in question and precise pre-location measurement from both ends form the basis for fast and efficient pin-pointing, thereby saving time. "Depending on the measurement method, pre-location accuracies of up to 0.5 % of the overall cable length can be achieved," notes Bawart. "The accuracy of the pre-location can often be increased still further by taking into account the position of known reference points such as joints."

Special measuring technique

A basic measurement after the cable has been laid can also serve as a reference. Many standards therefore recommend a TDR (Time Domain Reflectometry) fingerprint. "Due to the high attenuation of long cables, a particularly high-performance system with high-energy transmitting pulses is used for this," says Bawart.

TDR measurements can be used to locate damage points with low-resistive faults – for example in the case of a short-circuit. This measurement method shows impedance changes over time along the cable system. The measurement sensitivity decreases over the cable length and with the number of screen break joints. High-resistive faults cannot be located using Time Domain Reflectometry unless the high-resistive fault is converted into a low-resistive fault by "burning in" with a high-performance burn down transformer.

Old methods still effective on up-to-the-minute cables

"When performing fault location in particularly long cable systems we need to go back to the basic concepts of cable measurement technology," says Bawart. This is because the bridge method according to Murray is amongst those used for high-resistive faults. It can be used for low- and high-resistive faults as well as sheath faults and is suitable if another healthy phase is available in addition to the faulty one. For measurement, the faulty phase is connected to the healthy one at the far end of the cable. In contrast to pulse-based measuring techniques, the Murray bridge measurement has special properties with regard to length-dependent accuracy. This means that cable faults can be measured with extremely high accuracy regardless of the measurement length – whether in the initial area, in the middle or at the end of the cable. The high-voltage bridge measurement provides accurate results even with high-resistive faults.

Fault location with measuring bridges has already proven itself on cables hundreds of kilometres long, for example on the 450 kV direct current connection between Norway and the Netherlands. Using BAUR technology and the Murray bridge measurement, cable faults were successfully located with an extremely high degree of accuracy on this 580 km long cable system.

Another example is the 300 km long 400 kV submarine cable between south-eastern Australia and Tasmania. Since this cable carries about 40% of the electrical energy required in Tasmania, its failure triggered an energy crisis that lasted for months. After several weeks of expensive troubleshooting, the expert in Austria was called in and the cable fault swiftly and accurately located using TDR measurement and the Murray measuring bridge.

Locating breakdown and intermittent faults

Usually, however, the types of fault that occur in marine and land cables are different, says Bawart. "In my experience, land-based extra-high voltage cable systems are more likely to suffer from breakdown faults or intermittent faults on the main insulation." Cable sheath fault location is also gaining in importance. It can be used to detect and repair damage caused by external factors such as road construction, but also installation faults, before this gives rise to a fault in the main insulation.

Container in front of the cable hall (left)
Container operating area (right)

Source: BAUR GmbH/Manfred Bawart

Only a very restricted range of measurement methods is available for locating breakdown or intermittent faults on very long cable systems, and the large number of screen break joints represents a further technical limitation. All measurement methods based on Time Domain Reflectometry should be viewed in a critical light, says Bawart. “The Differential Decay Method has the best chance of successfully locating cable faults under these difficult conditions.” This measurement method can be used with test voltages of up to 110 kV.

The differential decay method requires a healthy reference cable, which is always present in a bipolar system. Both cable systems are charged simultaneously from an HV source, the fault fires through, and the measurement diagrams are automatically recorded. The fault distance is then determined using another diagram with a transient wave entering from the rear.
The advantage is that both the length-dependent cable attenuation and the large number of screen break joints connected have much less effect on the measurement result. The measurement diagrams are easy to evaluate and enable extremely accurate distance measurement even on particularly long cable systems.

Prevent expensive damage using portable and stationary solutions

BAUR GmbH offers a number of options for cable fault location on long cables. Bawart: “The range extends from portable devices such as our shirla [high-voltage measurement bridge according to Murray and Glaser] device, in combination with the IRG 4000 time domain reflectometer, through specially equipped cable test vans, to the mobile container that stands in the cable hall in many locations so that it can be used without further transport.” Bawart recommends the last-mentioned option for the backbone of the grid, because the failure of a cable such as Südlink, Südostlink or A-Nord could not only weaken the stability of the transmission grid, but also restrict electricity transmission and thus bring about immense financial damage.

The BAUR expert also advises operators of submarine cables for connections to large wind farms to have a fault location solution at the ready, because compensation payments to wind farm operators in the event of a cable failure are immense, making faults potentially very expensive. Bawart recommends precise risk assessment for both land and submarine cables: “Our dependency upon electrical energy is increasing, partly due to the rise of electric vehicles, but also as a result of measures associated with Germany’s ‘Energiewende’, and the effects of this transition. The risks from cable faults in system-critical transmission lines must therefore be reassessed with a more critical eye than in the past.”

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