New Design of Dry Type Cable Terminations up to 170 kV

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The traditional design of most outdoor cable terminations at the higher voltages has been based on a hollow core insulator made from either porcelain or a composite tube covered by silicone sheds. The insulators in both cases are equipped with a field control element made from silicone rubber and are filled with an insulating liquid or gas.

Completely dry terminations were first developed during the 1990s, driven by easier field installation, more stability in service and improved safety in the event of failure. This article, contributed by Matthias Freilinger of Pfisterer Ixosil in Switzerland, discusses new developments in dry cable terminations when it comes to materials, production technologies and customized designs.

Traditional cable terminations are based on self-supporting porcelain or composite insulator housing.

Among the main goals behind the development of an entirely new generation of dry type terminations has been better meeting customer requirements for easy installation and greater cost efficiencies while also maintaining all the advantages of the outdoor terminations currently in use. For this to become a reality, however, it became necessary to look at separating the mechanical requirements of the termination from its basic electrical design.

Electrical Design Requirements

The electrical design of the new generation of dry terminations was based on existing field control devices and therefore relies on the same type of semi-conducting deflector found in traditional outdoor terminations. This ensures that all internal standards governing distribution of electric field inside the silicone and at its interface with the XLPE or EPR cable would be satisfied – including maximum and minimum defined contact pressure of the silicone onto the cable.

Similarly, the outer sheds had to be designed according to the principles of IEC 60815-3 (2011) while taking into account possible changes in shed geometry due to expansion of the termination during the process of slipping it onto the cable. Moreover, all additional required standards, including IEC 60840 (High voltage cables and accessories up to 170 kV) and IEC 60071-1 (Insulation coordination), also had to be met.

The end result of this electrical design process was a flexible, dry type outdoor termination but without the self-supporting function.

Material Requirements

Finding the right silicone material was essential to allowing such a product concept to be realized. For example, it was important that both the semi-conducting silicone used in the deflectors and the silicone used for insulation could be bonded together without adding any special agent to prevent de-lamination. The mechanical properties and flexibility of the cross-linked silicone were also important parameters given the different diameters of cable insulation. In addition, the liquid silicone material had to have the proper viscosity to achieve perfect filling of the mold during production.

Finally, to ensure the electrical performance required, inclined plane tests had to be performed on material samples according to IEC 60587 (3rd Edition, Electrical insulating materials used under severe ambient conditions – Test methods for evaluating resistance to tracking and erosion). For example, applying a constant voltage of 4.5 kV, the performance criteria of the material slabs included not exceeding 60 mA of leakage current as well as no tracking within 25 mm of the bottom electrode.

Finally, to help justify commercialization of this new concept, a decision was made that deflectors for the new generation of terminations had to be capable of being manufactured using existing molding and dosing equipment as well as the current production technology for terminations made from liquid silicone rubber (LSR).

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Examples of flexible as well as supported dry terminations up to 170 kV.

Fig. 1: Schematic of flexible dry-type outdoor termination.

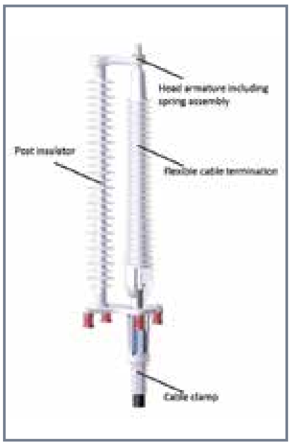


Fig. 2: Mechanical design of self-supported, dry-type outdoor termination.

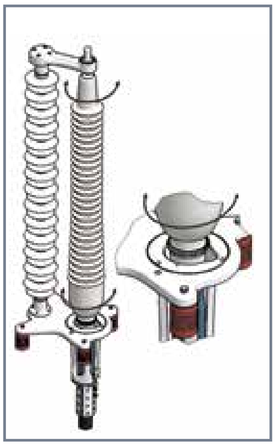
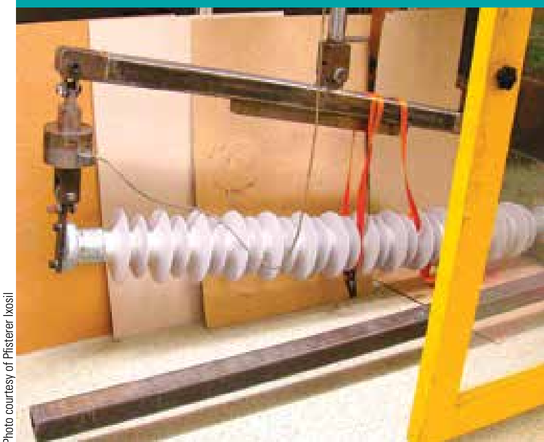


Photo courtesy of Pfisterer Ixosil

Fig. 3: Design of 360° rotating support on dry type termination.



Cantilever load test on post insulator selected for new dry type terminations.

New dry type terminations lifted onto tower for final installation.

Lifting 170 kV dry type outdoor termination with no need for scaffold on tower.

Photos courtesy of Pfisterer Ixosil

Dry type flexible outdoor terminations for railway applications.

Mechanical Requirements

Replacing standard outdoor cable terminations by the new dry types made it necessary to look at different mechanical aspects of their design. In particular, the mechanical support function offered by either porcelain or a composite tube in standard terminations would have to be taken on by an adjoining post insulator. Such a solution, based on an FRP core with silicone sheds molded on, is a well-accepted insulator technology used widely on overhead networks. In this case, the post insulator must be capable of withstanding cantilever forces up to 4 or 5 kN to deal with maximum short circuit forces at minimum phase-to-phase clearances.

To guarantee a perfectly straight termination under all installation and service conditions as well as to compensate for all thermal movements of the conductor, it was determined that the cable had to be clamped at the bottom. Moreover, the top fitting is equipped with a special spring design. This combination of clamping and spring assembly offers the benefit of being able to move the complete cable system after installation.

The cable screen is connected to the unit's base plate to achieve a typical cable termination design. This base plate has 360° rotating parts to ensure that, if necessary, the post support insulator and the top fitting can all be turned around the termination. This makes it possible to easily lift the terminations onto towers.

Manufacturing Facilities

Production of the new design of dry type cable termination requires some modifications to the usual equipment set-up. For example, the semi-conducting deflector used for field control must be embedded into a fully functional silicone termination and mounted on the core before filling the mold with pre-heated silicone. This meant making certain adjustments to the typical layout of clamping machine and dosing unit.

Another manufacturing consideration was curing time. The new design of dry type termination has increased thickness and therefore a greater volume of silicone material is used. If all process parameters remained the same, this would mean longer vulcanization time and reduction in manufacturing capacity of each clamping unit.

To shorten the vulcanization process and maximize output with existing equipment, a new process was tested and set-up using proprietary curing technology. The result is that vulcanization time has been significantly decreased, with a corresponding increase in machine capacity and there has been higher stability in quality as well.

Advantages of Dry Type Outdoor Terminations

Dry type cable terminations offer a range of potential benefits in terms of installation, safety and reduced overall project costs. For example, they are designed for convenient installation on the ground. Related line de-energization time is also minimized. Moreover, their stable construction allows them to be easily and safely lifted onto towers.
At the same time, the 360° rotating support construction compensates for cable torsion and ensures rapid fixing of the lifted terminations. Since scaffolding is no longer necessary with these dry type designs, there are also appreciable savings in construction and installation costs.

In regard to performance, all the usual risks in service are minimized with a dry type termination design since normal monitoring requirements linked to the presence of internal insulating oil (e.g. leakage, moisture behavior and impact of ambient temperatures) are no longer needed. With no internal volume of oil or gas, there is no risk of over-pressure caused by thermal expansion of the fluid during an internal failure such as short circuit. Dry type cable terminations therefore fulfill the requirement of being 'explosion proof'.

Apart from all these advantages for common XLPE power cables, dry type termination designs also offer a solution for EPR type cables.

Applications

Dry type outdoor terminations can be grouped into two broad categories – flexible and self-supported – and cover a range of applications.

Movable preassembled energy back-up solutions for easy and quick installation to bypass transmission lines.

170 kV dry type outdoor cable termination installed on tower.

Photos courtesy of Pfisterer Ixosil

• Flexible Dry Type Outdoor Terminations
In the 52 kV to 72 kV range and up to conductor cross-sections of 1200 mm2, flexible dry type outdoor terminations without added support function can be used in both power industry and railway systems. Here, fixing of the termination is generally done by cable clamps and lugs instead of using head fittings.

From 72 kV to 170 kV and for conductor cross-sections up to 2500 mm2, flexible terminations can be used for movable testing cables or as movable energy supply systems for building work stations on complete cable drums. In particular, installed movable systems with EPR cables consisting of flexible Class 5 conductor and dry type outdoor terminations are known for their flexible yet robust design.

• Self-Supported Dry Type Outdoor Terminations
Self-supported dry type outdoor terminations are available from 72 kV up to 170 kV and for conductor cross-sections up to 2500 mm2 for power systems or for movable energy back-up solutions.

Robust construction under high cantilever forces, explosion-proof design and capability for convenient on-ground installation at towers have together resulted in rapid acceptance of this design concept to replace conventional outdoor terminations that use hollow core composite insulators in the lower high voltage range up to 170 kV. ☒