DRY TERMINATIONS FOR HIGH VOLTAGE CABLE SYSTEM.

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Abstract

Terminations for extruded high voltage cables are traditionally made with a supporting insulator (porcelain or composite), a pre-moulded rubber stress-cone slip on the prepared cable and a fluid (oil or SF6) filling the empty space between the cable and the insulator. This design has a very long and good experience but has also some drawbacks. The sealing of the system has to be perfectly made to avoid any leakage and ensure a good performance along the entire product life time. In the case of internal arc, such fluid filled terminations, especially oil filled, can produce severe damages to the surrounding equipments and human beings.

The use of fluid free or dry termination can eliminate the risk of leak and strongly reduce the risks associated with an explosion in case of internal arc. Dry sealing ends are used since many years for GIS terminations up to the extra high voltage level (550 kV). Such design is now commonly accepted and tends to be more and more the standard for such application. Dry outdoor termination are also being used with success since many years but their voltage application has been limited up to now to the lower end of high voltage class. Actual developments of outdoor terminations are oriented towards dry versions for extra high voltage.

Introduction

Fluid filled sealing ends have been used ever since high voltage cables are in service. This well known technique has been also applied for extruded cable for indoor and outdoor applications with good success. Fluid free sealing ends, also called dry terminations, have been introduced more recently in high voltage systems but are now widely used for the termination of extruded cables. For indoor applications, such as GIS or transformer, the dry systems are now becoming the standard as their figure of merit give them clear advantages over the traditional fluid filled system. Up to now the use of dry outdoor termination has been limited to the lower end of high voltage classes. Fluid free technology advantages will increase the interest for dry outdoor products.

Traditional fluid filled termination

Traditional fluid filled terminations are composed of one supporting insulator filled with oil or SF6 as presented in figure 1. For GIS and transformer terminations the insulator is made of an epoxy based material. Insulators used for outdoor terminations are of porcelain or composite type. The electrical stress control is usually made with a rubber cone slip on the prepared extruded cable. The volume between the cable with its stress-cone and the supporting insulator is filled with some dielectric fluid such as oil or SF6. This termination design is being used for many years and has very long and good experience but has also some drawbacks.

This simple design can be adapted to various cable constructions and dimensions without problems. The volume between the stress-cone and supporting insulator being filled with fluid material the variation in cable dimension is easily adapted without any special care.

One disadvantage of this design is the presence of a fluid. This requires a very careful sealing of the termination to avoid any leak that could lead to an electrical breakdown. Tight sealing between metal parts is usually not a problem. The most critical point where sealing has to be achieved perfectly is the interface between the cable and the termination base plate. As cable dimensions are not always identical, the sealing system has to fit onto various cable sizes. Some examples of sealing systems are schematically presented under figure 2. This potential risk of leak that is present in all fluid filled installations request a periodical inspection to check oil level or gas pressure. To reduce the risk associated to a leak some termination, especially in extra high voltage, are equipped with a monitoring system to detect any fluid seepage before a major problem occurs.

A second drawback of fluid filled terminations, especially the oil filled ones, is that the power released in case of breakdown is very high. The total power involved during the fault corresponds to the electrical power during the internal arc and additional power due to the combustion of the oil initiated by the arc. With oil filled termination the ratio of combustion energy to electrical energy can easily reach a factor 10 depending on the oil volume. This high power released during fault can cause severe damage to the surrounding equipment although that oil filled termination can in some case be equipped with anti explosion device which limit the impact of such failure.

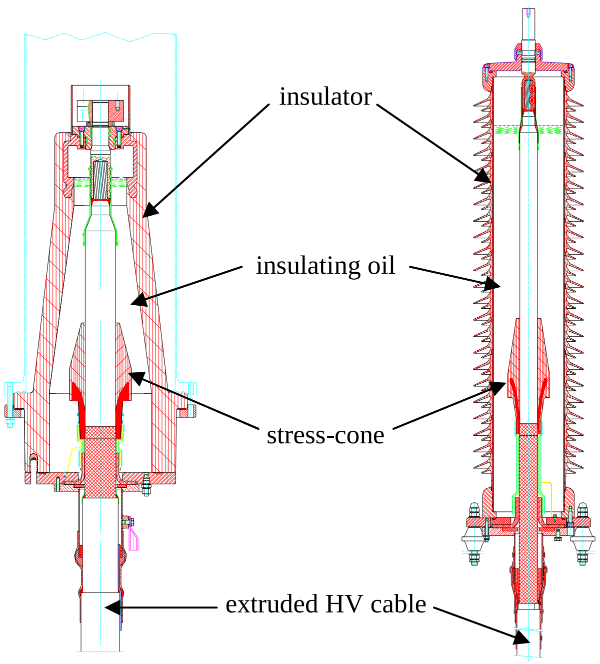


Fig. 1: *typical design of fluid filled GIS and outdoor terminations.*

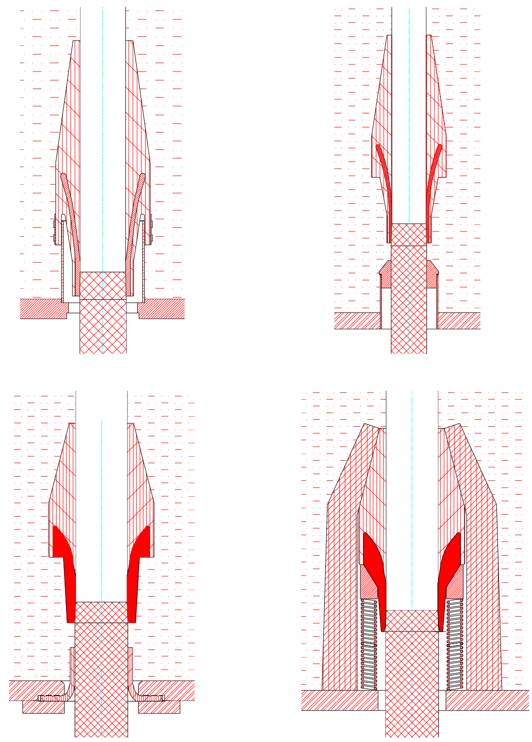


Fig. 2: *example of typical sealing device at the cable / termination base plate interface used in fluid filled terminations.*

Dry termination

Dry terminations have been developed for many years and several designs are now available for the different applications.

Main advantage of dry termination is that they are fluid free which eliminate the risk of any leak and reduce the maintenance work as no oil level or pressure check is necessary.

Additional to the reduced maintenance characteristics, dry termination develop much lower power in case of electrical breakdown. As no burning fluid is present in the product, the power associated with an internal arc will not be amplified by the combustion of oil. This point results in a more safety product and gives less risk of damages to the surrounding materials or people in case of defect.

Finally dry system results in a more environmental friendly product as there is no risk of pollution such as ground contamination by oil or SF6 release in the atmosphere. There is no fluid handling during installation and no dangerous goods to transport. These environment considerations are becoming more and more important.

For GIS terminations, two different general designs are available: the “inner-cone” and “outer-cone” system. In these designs the space between the epoxy insulator and the stress-cone has been eliminated and replaced by a rubber / epoxy interface under mechanical pressure. Both designs are schematically presented in figure 3.

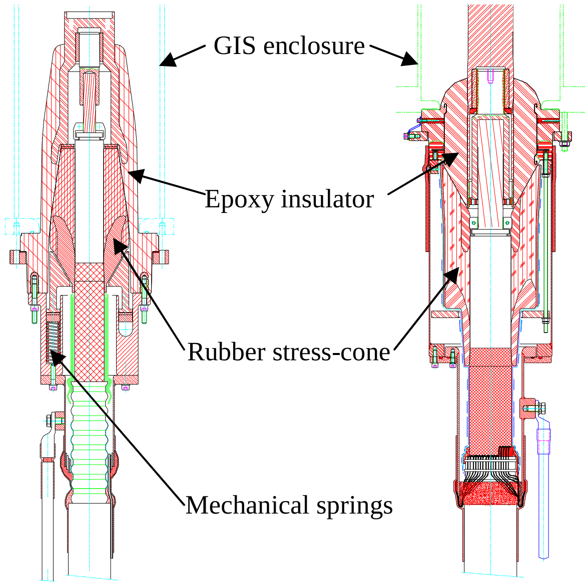
In the “inner-cone” design, the rubber stress-cone is compressed in the epoxy insulator cavity by the mean of mechanical springs. The necessary level of pressure on the various interfaces to insure good dielectric strength is supplied by compressed springs.

In the “outer-cone” design, the rubber stress-cone is expanded over the conical shape of the epoxy insulator. In this case the interfacial pressure is provided by the elastic deformation of the rubber.

For GIS termination a second advantage of dry system is the elimination of oil. This allows reducing the size of the termination which is more compact than traditional fluid filled termination.

Ease of installation is also one advantage of dry termination as no oil has to be filled and most of the time GIS dry termination can be plugged-in. The plug-in technique gives the advantage that the complete switchgear can assembled and factory tested before being delivered to customer for installation. This plug-in technique considerably eases the installation work of switchgear and cable laying as the switchgear can be fully installed independently form the cable and termination.

Such dry design for GIS application is becoming a standard. Less and less fluid filled terminations are used as their figure of merit is lower.



a) inner-cone *b) outer-cone*

Fig. 3: *typical design of dry GIS termination a) inner-cone, b) outer-cone.*

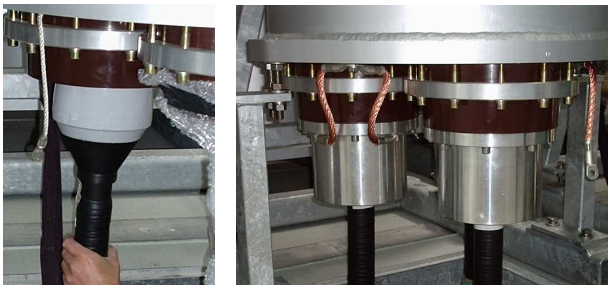


Fig. 4: *example of 145 kV dry inner cone termination during plug-in.*

Fig. 5: *example of 170 kV dry outer cone termination.*

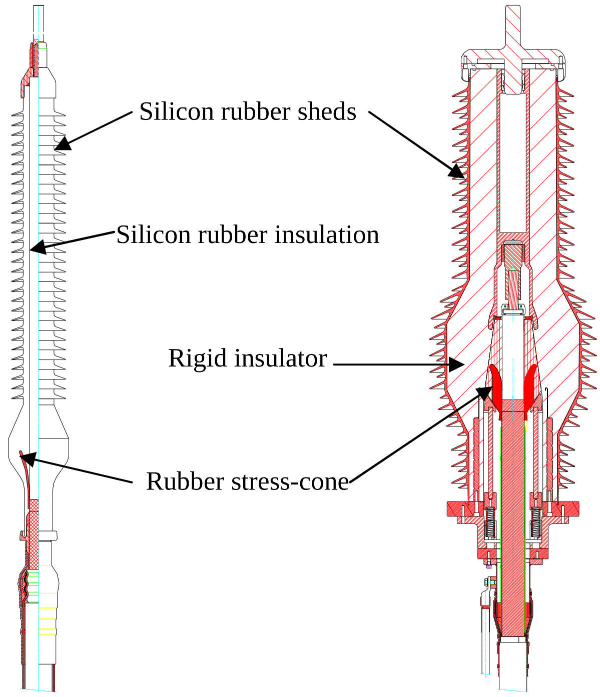
For dry outdoor termination two major designs can be distinguished for high voltage application: the slip-on and the self-supporting model. In these designs the filling with fluid has been replaced by synthetic polymer such as rubber or resin.

Slip-on outdoor terminations are made of one moulded rubber body which is sliped on the prepared extruded cable. Such design is very simple and rapid to install. The termination body is one moulded piece which is routinely factory tested which in association with the absence of any leak risk ensure a high service safety. Such design need to be clamped to a fix point at the termination top end as it has no rigidity. Actual voltage range for flexible termination is going from 52 kV up to 145 kV. The need of a hanging point and the length of the flexible section have limited its application to the lower side of high voltage class. For application in extra high voltage level, the use of self supporting termination is preferred.

Dry self standing outdoor termination can be made via the use of a resin casted insulator covered with silicon rubber sheds. The dielectric stress control is made trough a stress-cone compressed in the insulator cavity in the same way as made with dry GIS termination. The general design is presented under figure 6. Such design has the advantage of fluid free termination like the slip-on one but with rigidity which eliminate the need of a fixed point on top of it. Its installation is also simple and quick as the cable length to be prepared is very short compared to fluid type sealing ends.

Nexans has chosen to use such self supporting design for the development of extra high voltage outdoor termination and is actually performing pre-qualification test with 245 kV voltage level termination (see figure 8). Further development will extend this concept to higher voltage level such as 420 and 550 kV.

The result of these developments will lead to safer and reduced maintenance products. In the future, the use of dry outdoor terminations will increase as their figure of merit will give them clear advantages as it is already the case with GIS sealing ends.



a) slip-on *b) self-supporting*

Fig. 6: *typical design of dry outdoor termination: a) slip-on, b) self-supporting.*

Fig. 7: *123 kV dry slip-on terminations installed on a mast or used for temporary link.*

Fig. 8: *245 kV dry self supporting outdoor termination during PQ test.*

Conclusion

Dry type terminations are more and more widely used in the high voltage class due to their ease of installation, limited maintenance and reduced risk in case of internal defect. The use of such design for outdoor sealing ends will become also possible for the extra high voltage level as it is now the case for GIS terminations.

In future dry termination technology will be more and more used in the high and extra high voltage level for GIS, transformer and outdoor applications.