

A New Separable 170 kV Outdoor Bushing System Creates a Multi-Purpose Transformer or Switchgear

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Abstract: High voltage bushings are commonly used to transmit electric energy from the inner part of a device through a grounded barrier, as known from transformers or GIS. The traditional transformer bushing has an oil filled hollow ceramic insulator or, the later ones, resin impregnated paper combined with a composite insulator. In both cases they are stationary mounted and it's impossible to disassemble them without opening the gas or oil compartment.

The aim of this new development is a simple, rapid and dry installation of the bushing at the destination of use.

It bases on the successfully approved PFISTERER CONNEX Termination System and enables to decide on site whether a cable or a bare line connection is installed. Costly gas or oil processes are not required.

The cast resin socket with its contact system and field controlling parts is the equipment-site component of the system. The separable bushing with its geometric field control is made of epoxy resin and hydrophobic silicone on its surface.

A sophisticated design of the used materials regarding their different permittivities together with the field grading components result in homogeneous field distribution.

INTRODUCTION

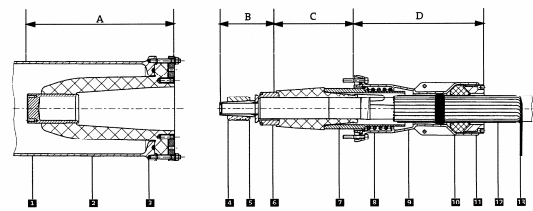
The idea for creating a connectable bushing for high voltage transformers and switchgears is another step in development of the High Voltage Connex System after its introduction in 1996. The CONNEX was created as an alternative for the traditional wet-type cable termination system. It is used for the connection of XLPE insulated cables to electrical equipment such as gas insulated switchgears (GIS), transformers and joint boxes.

It consists of one component on the cable side and another part on the equipment side as shown in Figure 1.

The socket (Fig. 1, Pos. A) is the component of the equipment side. It is an electrical bushing provided with a conical opening, the inside cone and it is installed in the GIS or transformer. It includes the insulator of cast resin and the female contact part. Close to this contact socket field controlling parts are integrated in the cast resin insulator.

The separable connector is the cable side component. This constitutes coaxially designed

system, arranged axially on the stripped cable end. The components of this system are retained by a metallic housing.



A Socket	
1	Contact socket
2	Insulating body
3	Housing
B Contact system	
4	Contact ring
5	Tension cone
6	Thrust piece
C Insulating and field-controlling part	
D Housing	
7	Pressure sleeve
8	Pressure spring
9	Bell flange
10	Sealing ring
11	Union
12	Shrink sleeve
13	Cable screen

Fig 1: Design of the HV-CONNEX termination system

It consists of the contact system, the insulating and field-controlling part and the housing (Fig. 1, Pos. B, C, D). The contact system includes the contact ring, the tension cone and the thrust piece.

The insulating and field-controlling part (Pos. C) is made from highly flexible silicon. Its task is to control the electrical field at the stripped cable end and to ensure that the joint is sufficiently strong. The housing consists of the bell flange, the pressure sleeve and the pressure spring (Pos. D) [1,2].

After fitting to the cable end, the cable connector is plugged into the socket and then fixed by bolts.

The pressure spring is needed to ensure the necessary force in the electrically stressed joints, regardless from tolerances and thermal expansion.

ADVANTAGES OF THE CONNECTABLE SYSTEM

Since the introduction of the High Voltage CONNEX-System for XLPE insulated cables more and more manufacturers of transmission and distribution systems recognize the features of the CONNEX as important advantages compared with the traditional wet-type system:

- The assembly and disassembly of the system with a transformer or switchgear is very simple.
- Gas insulated switchgears and oil transformers can be equipped in the factory with the socket, closed, checked and hence delivered ready for connection.
- On-site the opening of the cable termination compartment – involving expensive gas or oil work – is not necessary during the installation.
- Since the CONNEX systems works on the basis of solid insulating materials, any position may be realised.
- Due to the missing of liquid insulating materials, the assembly times are reduced considerably.
- The use of prefabricated and inspected components guarantees a maximum of safety and reliability.
- The whole gas or oil compartment keeps closed at the place of use. So there is no risk of getting particles or humidity inside the facility.
- The plug-in capability of the system permits in the event of faults rapid and simple disconnection of the cables from the system component.

CONSTRUCTION OF THE CONNECTABLE OUTDOOR BUSHING

The bushing has a total length of 2180 mm according to the required flashover distance of 1450 mm given by the IEC standard for the 170 kV voltage level.

The metal conductor is designed for a nominal current of 2500 A and a short circuit current of 36 kA for 3 s. As shown in Figure 2 the conductor is covered by cast resin with silicone rubber on its surface. With silicone sheds along the core (Fig. 3) a specific creepage distance is 31 mm/kV which meets the highest pollution class of the IEC standard could be obtained. The bushing is fixed on the CONNEX socket size 6 installed in the switchgear or transformer.

Since the bushing works on the basis of solid insulating materials, any position is feasible: i. e. horizontal and vertical arrangements are possible.

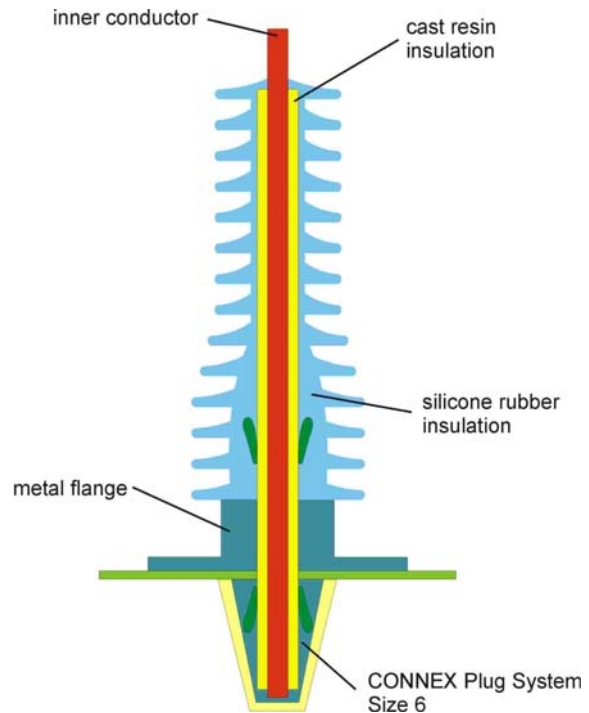


Fig 2: Components of the bushing



Fig. 3: Photo of the outdoor part of the bushing

MECHANICAL CONSTRUCTION OF THE BUSHING

At the outdoor part of the bushing the metal conductor with a diameter of 70 mm guarantees the mechanical ruggedness of the system. Mechanical tests as shown in Figure 4 with bending forces up to 2500 N ensure the necessary mechanical resistance in service.



Fig 4: Arrangement for mechanical tests

In the assembled state, the bushing is fixed by the flange of the socket and the contact ring of the contact system (Fig. 1).

By this means, mechanical stresses that occur during operation are absorbed. The insulating and field-controlling part with its dielectric functions is thus free from these mechanical stresses. The same applies for the contact system. During the plugging-together process, the bushing is automatically centred by the guide rings in the contact ring. These subsequently act as a static fixing within the contact socket. The high-current-proof laminated contacts are decoupled from these mechanical stresses and the current is therefore always transferred in the defined working area (Fig. 5).

DIELECTRIC STRENGTH OF THE SYSTEM

To ensure the electrical strength of the connecting part of the bushing a cone made of highly flexible silicone rubber including field controlling parts is adapted to the lower end of the bushing and inserted in the cast resin socket. The high pressure with

which the silicone insulating part is fixed in the socket is necessary to tighten the electrical joints [2].

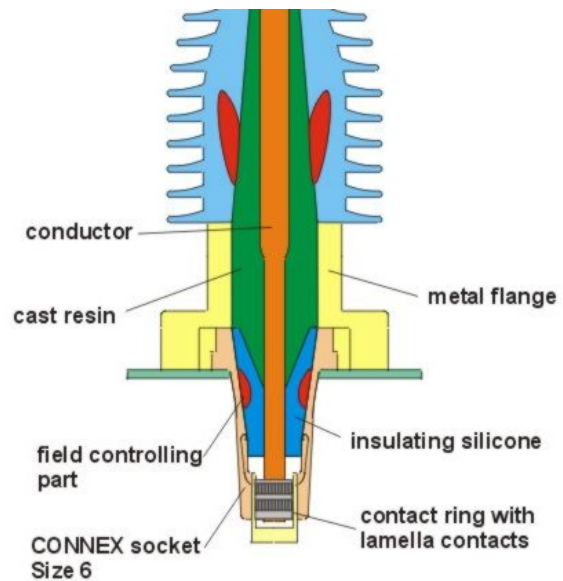


Fig. 5: Construction of that part of the bushing inserted in the CONNEX socket

The field controlling parts inside the insulating silicone are made of conductive silicone rubber. Their optimised shape and position result in an almost homogeneous field distribution in the joint between silicone rubber and cast resin.

Figure 6 shows the course of the tangential component of the electrical field strength in the joint. It can be seen that the field strength of the inserted bushing is not higher than this of a plugged cable connector.

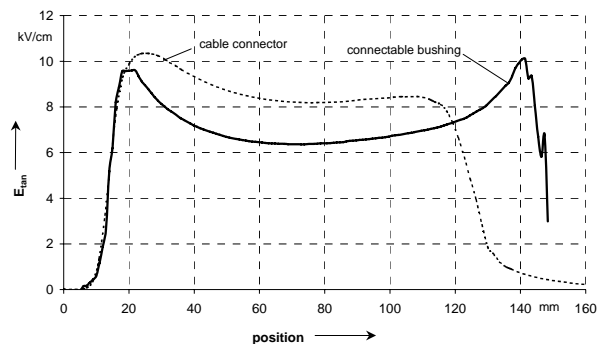


Fig. 6: Electric field strength in the joint standardized for 100 kV

The shape of the cast resin cover and the insulating silicone in combination with their different permittivities result in an electrical field strength on the surface of the conductor not exceeding the limit of the epoxy material.

The graph in Figure 7 shows a maximum of the electrical field strength in the area where the conductor is fixed by the cast resin that is connected with the metal flange.

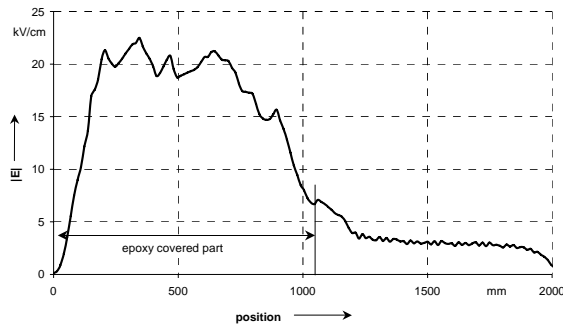


Fig. 7: Electric field strength along the conductor standardized to 100 kV

Even at the highest field strength that occurs during the lightning impulse test of 750 kV, the maximum of 17 kV/mm is far below the limit of cast resin materials for high voltage applications.

But this optimized combination of these materials and the field controlling part are also needed for a homogeneous potential distribution along the silicone surface in the air as shown in Figure 8. This is very important for controlling local field enhancements or displacements caused by pollution.

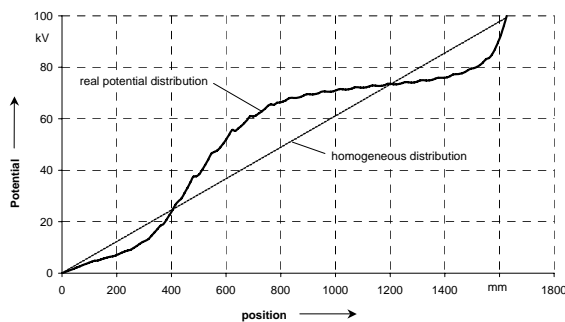


Fig. 8: Potential distribution along the core of the bushing. Calculation standardized to 100 kV

According to this the field distribution on the surface of the silicone also does not show extremely high maxima.

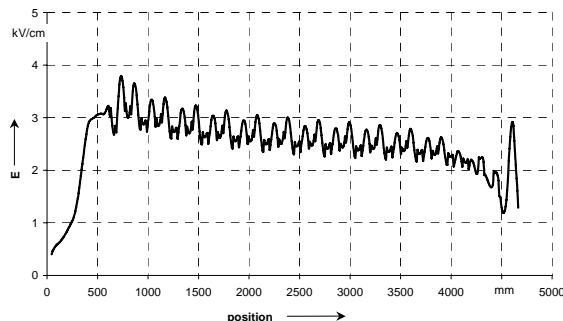


Fig. 9: Electric field distribution in air along the core of the bushing. Calculation standardized to 100 kV

Regarding the highest acceptable electrical field strength in air no partial discharges in service or even at the high voltage AC test will occur. Figure 9 shows maxima of 3,8 kV/cm at 100 kV. During the

high voltage AC withstand test this will result in electrical field strengths up to 12,5 kV/cm which are not critical.

APPLICATIONS OF THE CONNECTABLE BUSHING

In the course of the last ten years, many of the transformers for 110 kV currently in use have been fitted with the CONNEX System on the high voltage side to allow termination with inside cone cable connectors. With the plug-in type system, the advantages of the intrinsically safe, fully encapsulated, plug-in cable termination technology are utilised, covering nearly all conceivable applications [3].

But in the past these advantages only have been available for cable connections. With this connectable bushing also overhead lines can be connected by the CONNEX system. For the application of the bushing with transformers a capacitive layer with a capacitance of 150 pF is inserted in the insulation.

But not only for transformers this system is useful. Gas insulated switchgears as well will increase their flexibility by using the CONNEX for cable and overhead line connections.

CONCLUSION

The development of the connectable bushing for size 6, 170 kV is another step to increase the flexibility and applicability of the CONNEX HV System.

The typical advantages of the system, like simple on-site-assembly without opening gas or oil compartments can be transferred to this application. But they are completed with arguments like the solid insulation without oil or porcelain that ensures an explosion-proof construction of the bushing, which is insensitive to vandalism.

Of course, this is the first step in this new direction. After a successful introduction of the product, it has to be completed by further members of the family, responsible for other voltage levels.

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