SlipOver premoulded joints for XLPE-insulated MV cable

SlipOver premoulded joints are designed to be used with XLPE-insulated cable rated at voltages of 12 to 24 kV. No dedicated tools are required for the jointing process, which can be carried out faster and more efficiently than with other makes of joint. An innovative production process was developed for SlipOver, which reliably withstands the effect of water, chemicals and mechanical loads.

From the first cables to be insulated with impregnated paper to modern-day cables with cross-linked polyethylene (XLPE), cable-jointing has always been a complex and time-consuming task.

Today, the most widely used type of taped joint has insulation made of self-amalgamating tape. The tape is stretched and wound tightly around the joint in layers that bond together to form, after a short time, a homogeneous body.

A precondition for a perfectly functioning joint is that there are no air pockets anywhere in the insulation system. To ensure this, the fitter normally winds a strong pressure bandage around the joint to create a high pressure and press out any air bubbles that might be present. For cables rated at 24 kV, an approximately 10 mm thick insulation is applied.

Before the self-amalgamating tape can be wound, the cable insulation must be coned off to obtain a large interface between the cable insulation and the insulating tape. This and other necessary measures have until now made cable-jointing a job that requires a considerable amount of skill and dexterity.

SlipOver – the world's fastest cable joint

The SlipOver joint consists of three layers of rubber around a central space large enough to accept all connectors in use, regardless of their type or how they are crimped. On the outside is a layer of conducting rubber, below it an insulating layer of flexible EPDM rubber, and on the inside of the joint another layer of conducting rubber.

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To enable the same joint body to be used for several cable sizes, it can be enlarged before it is 'parked' on the cable. This is done using a simple tool which inserts a tensioning sleeve into each end of the joint. Since the central part of the joint is already expanded, it does not need to be enlarged.

When the conductors have been joined and the conducting layer of the cable removed, the joint body is placed in position and the tensioning sleeves are simply twisted out of the joint. The joint body then collapses and tightens snugly around the cable **1**. This can be done in just 4 seconds, making SlipOver the fastest cable joint on the market.

The cavity in the center of the joint body has no electrical field, and therefore acts as a Faraday cage. No special demands are therefore made on the shape of the connector. To ensure that the inner conducting layer – the Faraday cage – really is in contact with the conductor potential, a contact spring integrated in the joint automatically establishes electrical contact between the connector and the conducting layer **2**.

SlipOver joints are available for XLPE-insulated cables with rated voltages of 12 to 24 kV and cross-sectional areas of 50 to 630 mm^2. Each size of joint can be used for several different cable cross-sections, allowing inventories to be kept small.

Voltage levels were chosen that fulfil the standard requirements as per IEEE 404 in the USA for service voltages of 15 and 25 kV.

Build-up of the insulation takes just a few minutes

Certain operations involved in the jointing of cables are the same for all types of joint. A comparison of a self-amalgamating tape joint and a SlipOver joint shows, for example, that the amount of work required to prepare the cable and join the conductor is the same. The key advantage of the SlipOver joint, however, is that it

Fitting the SlipOver joint. After the conductors have been crimped together and the conducting cable layer removed, the fitter positions the joint, extracting the tensioning sleeves with a simple twisting movement. The joint collapses and fits snugly over the cable. **1**

enables the insulating system to be built up in a much shorter time. Instead of the 30 to 40 minutes that are needed to build up the insulating system with tape, 4 to 5 minutes are all that is needed with SlipOver.

The SlipOver joint also has two other, even more important advantages:

- The risk of mistakes being made by the fitter is much smaller.
- Voltage tests are carried out already in the factory.

High demands are made on the materials

SlipOver is made to fit all types of cable with crimped conductor connections. This versatility makes major demands on the joint material. It has to be soft and flexible as well as guarantee excellent mechanical and electrical properties for all three rubber layers. These requirements are fulfilled by manufacturing the SlipOver joint from EPDM rubber. EPDM is an elastomer belonging to the polyolefin family.

EPDM rubber can be manufactured with a range of different properties by altering the type of elastomer and the quantity and type of additives used. The elastomer, however, ensures that the EPDM rubber always has certain specific properties:

- Excellent electrical properties, eg high electrical strength, low losses and low dielectric constant
- Good thermal properties: the material withstands 130 °C in continuous operation
- Excellent oxidation and ozone resistance
- Very good chemical resistance, in particular to acids and alkalis, polar oils and solvents
- Very good UV resistance when a suitable UV inhibitor is included in the compound
- Good mechanical properties through the inclusion of a suitable means of reinforcement in the compound
- Limited resistance to non-polar oils and solvents

All three layers of the SlipOver joint are made of EPDM rubber. Since they have different functions, and process requirements are also different, the formulations can differ appreciably. An important common requirement is that they exhibit excellent mutual adhesion.

Inner layer

The Faraday cage formed by the inner layer ensures a favourable distribution of the electrical field. For this, the material has to exhibit an electrical conductivity in the region of 1 S/m. The electrical field distribution in the SlipOver joint is shown in **3**.

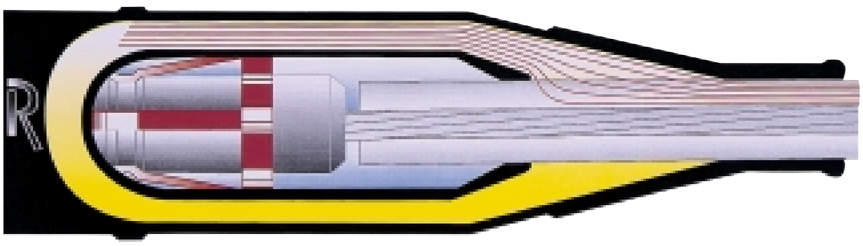
Insulating layer

The insulating layer between the two conducting layers has to be capable of withstanding the electrical stresses for a long period of time (20 to 30 years). Good electrical properties are required for this, for example:

- Dielectric strength ≥ 50 kV/mm
- Loss factor tan $\delta \leq 0.005$
- Resistivity ≥ 10^{15} Ωcm

To keep local electrical stresses as low as possible, the size of the filler particles and any impurities should preferably be smaller than 50 µm.

Electrical field distribution in the SlipOver joint **2**



The insulating layer is softer than the inner layer and also easier to inject. The EPDM polymers and softeners are the same to ensure good adhesion between the two layers. Pretreatment of the filler makes dispersion easier and prevents water from being absorbed.

Table 1:
Routine electrical test carried out on SlipOver joints

System voltage	kV	12	24
Power frequency withstand voltage, 1 min	kV	35	52
Partial discharge measurement, max. 2 pC	kV	13	22

Outer layer

The outer layer, like the inner layer, is made of rubber with conducting properties and therefore also contains conductive carbon-black. This acts as a screen, keeping the electrical stress within the joint.

The working properties of the material play an important role in the injection-moulding of this layer, which is relatively thin. Care must be taken to ensure that the shear forces acting on the layer below it are not too high. This calls for a very low viscosity. The polymer used in the material for the outer layer therefore has a much lower molecular weight and includes a larger proportion of softener.

Additives

Carbon-black, which gives the material its electrical conductivity, is available in more than a hundred different qualities. To be able to manufacture a conductive material without increasing the level of carbon-black to too high a level, a type with particles just a few nanometers in size is used.

The addition of *softeners* changes the modulus of elasticity of the rubber and also improves its working properties. The best softeners for EPDM rubber are paraffin oils based on mineral oil or synthetic oil. If the rubber is to be able to withstand high temperatures, the softeners should have a high boiling point and be chemically stable.

Anorganic fillers are used to improve the mechanical and working properties.

Anti-oxidants protect the polymer from oxidative decay and are especially important for products that are intended for use at higher temperatures than normal or for very long periods of time (more than 10 years).

Water repellents, such as silans, react with anorganic filter particles to make them unable to absorb water. Combining silans with fillers having a low water absorption capacity results in a rubber material which is extremely water repellent.

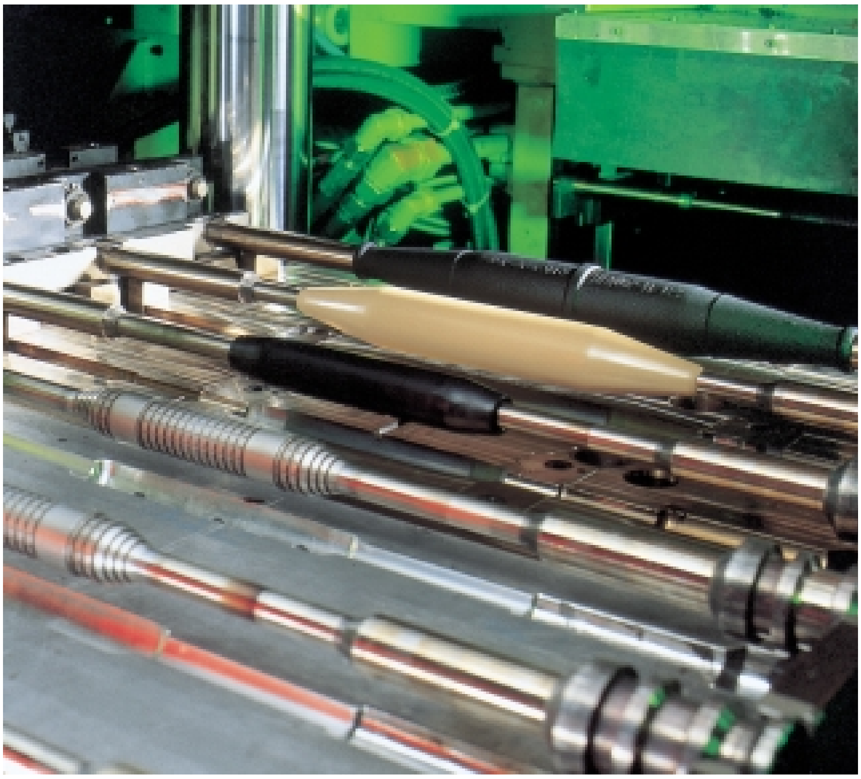
Injection moulding process and post-vulcanization

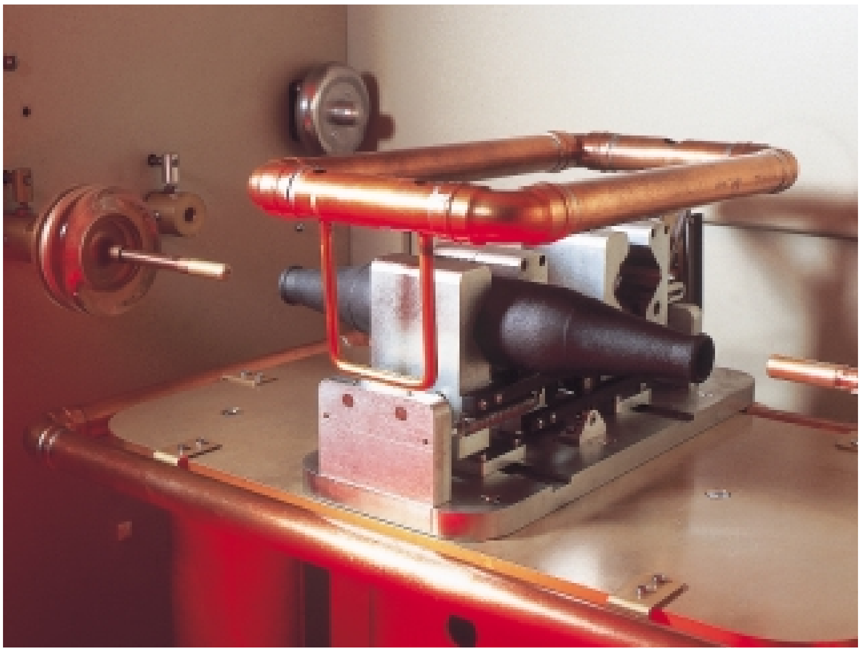
The injection moulding process used to manufacture SlipOver joints is unique in that, for the first time, an injection moulding machine is used which can simultaneously inject three layers of material **4**.

The injection moulding machine runs fully automatically with the help of a computer. An operator checks now and again that there is enough material for the injection units.

To keep cycle times to a minimum, the rubber is cross-linked in the injection moulding machine to only 70–80 %. The remainder of the cross-linking process takes place in a post-vulcanizing furnace, through which the components move on a conveyor belt.

Injection moulding process for the simultaneous manufacture of all three rubber layers of the SlipOver joint **3**





Automatic test equipment for cable joints **4**

Quality assurance

The quality assurance system covers both the material and the process. As a final check that the finished product has the required quality, each joint body is subjected to a routine electrical test (*Table 1*).

The test equipment is also unique, since it performs the test under dry conditions. There is therefore no need to immerse the joint body in insulating oil, as was the usual practice earlier. Oil loss and contamination due to electric breakdown are thus avoided.

After the joint body has been placed in the test equipment **5**, the test is carried out automatically and the results are recorded by a computer. The operator receives a straightforward message: ‘approved’ or ‘not approved’.

Type-tests

Proposals for type-testing have been submitted by both the International Electrotechnical Commission and by Cenelec, which is preparing the European standard. The latter is somewhat more comprehensive, and is therefore the standard on which testing of the new SlipOver joint is based.

The most complicated part of the standard is a cyclic loading test during which voltage is simultaneously applied. The test continues for a total of 1000 h, the joint having to lie submerged in water for half of this time.

Tests were carried out earlier at KEMA in Holland in accordance with their own standard, which in some respects is even more rigorous than the Cenelec standard. For example, tests are performed under water at a pressure of 2 bar (200 kPa). KEMA uses this method to ascertain the proper operation of products buried under ground where the groundwater level is extremely high. The SlipOver joint passed KEMA’s test in every respect and is thereby approved for use in the Dutch cable network.

Comprehensive tests have also been performed, and are still in progress, at ABB Kabeldon’s own test site outside of Gothenburg. The tests involve subjecting the joints to high voltage under the conditions prevailing at the site, which is on an archipelago of marshy land that provides a hostile environment for the joints.

‘Sheaths on rolls’

The outer sheaths of the cables can be regenerated using any one of several different methods.

Standard PVC adhesive tape and thermo-shrinkable sleeving have been used for many years with good results, but both methods involve a good deal of work. Cold-shrinkable sleeving – a new technology – provides good mechanical protection but the fitting work is still time-consuming.

The ‘sheath on a roll’ is designed to be used with SlipOver joints. The sheath is in the form of a 60-mm wide strip of EPDM rubber with an adhesive sealing layer of butyl, allowing easier and much faster application than with conventional adhesive tape. ‘Sheaths on rolls’ provide the same good mechanical protection and sealing as the cable sheath.

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