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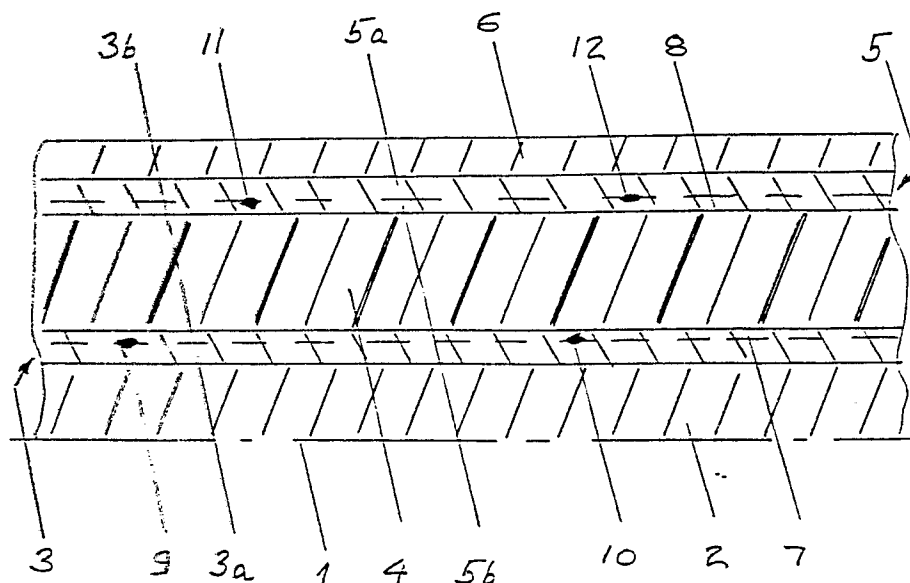
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D-8133 Feldafing(DE)(54) **Power cable.**

(57) This invention relates to electrical power cables having crosslinked extruded insulation (4) and fully bonded extruded semiconductors in contact with the conductor (2) and with the outer screens (6) respectively. In order to provide smooth interfaces between the semiconductors and the insulation and prevent pre-crosslinked semiconductor clots from appearing at the inner (and outer) surface of the insulation layers, the semiconductors are extruded as a composite structure the inner parts (3b, 5b) of which are free from crosslinking agents.



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POWER CABLE

The present invention relates to power cables and in particular to power cables having a conductor, a number of fully bonded dielectric layers including an extruded semiconductor over the conductor, one or more layers of extruded insulation material over the inner semiconductor and an outer extruded semiconductor over the insulation, and finally an outer metal screen and possible outer protective shields, layers and/or sheaths over the outer semiconductor.

Crosslinking agents such as organic peroxides are usually added to the dielectric material before or during the extrusion process to provide a fully crosslinked insulation and semiconductors.

When extruding crosslinkable materials, there will, however, always be a risk that some of the material will crosslink within the extruder. The crosslinking process is a function of temperature and time. It is nearly impossible to design an extruder where all of the material are subject to substantially the same conditions when passing through the extruder. Some of the material may stick to irregularities and corners of the inner surface of the extruder, and some may adhere to even smooth surfaces of the extruder structure if the temperature is too high for a certain length of time. Some of the material may also be delayed within the extruder for other reasons, so that it will start to crosslink and form clots. Some of these clots or lumps will stay within the extruder, but some may flow to the outlet of the extruder together with the main flow of material and be incorporated in the respective cable layer.

The semiconductors are made semiconductive by adding conductive material such as conductive carbon black to the extrudable plastic material. The presence of carbon black particles within the extruder leads to higher friction and higher temperature within the extruded material. This increases the risk of pre-crosslinking and clotting.

The semiconductors are also very much thinner than the insulation, and the extruder passages for the semiconductors are therefore much narrower than the passages for the insulation material. The tendency of clotting is therefore greater in the semiconductors than in the insulation.

When clots of pre-crosslinked semiconductive material are deposited in the semiconductors of the cable this usually interferes with the interface between the semiconductors and the insulation.

Semiconductive clots and other protrusions occurring on the inner and outer surface of the insulation are known to be one of the causes of insulation breakdown and such protrusions should therefore be avoided as much as possible.

When the clots occur in the outer semiconductor they can usually be detected by inspection and repaired. If the clots occur in the inner semiconductor which is usually extruded in tandem with the insulation or in multiple heads, detection is very difficult or impossible.

The most critical place where clots can occur is, therefore, at the interface between the inner semiconductor and the insulation. Clots at this interface is also critical because the voltage gradient is higher than at the interface between the insulation and the outer semiconductor.

The object of the present invention is to improve the dielectric properties of power cables with extruded insulation. This object is obtained by ensuring that the interfaces between the semiconductors and the insulation are smooth and free from clots and lumps which may protrude into the insulation. The main features of the invention are defined in the accompanying claims.

By extruding the semiconductor(s) as composite layers, we obtain the desired smooth interface between the semiconductor(s) and the insulation. We define an inner part of the composite semiconductor(s) as the part which is in direct interface with the insulation, i. e. the inner part of the composite semiconductor as seen from the insulation. From this definition it follows that the outer part of the inner composite semiconductor faces the conductor surface, whereas the outer part of the outer composite semiconductor faces the outer screen.

Multiple head extruders may be used to extrude the inner and outer parts of the composite semiconductor(s). The inner and outer parts of each semiconductor will however, be integrally united, in spite of the fact that crosslinking agents, in accordance with the invention, are not added to the inner parts before or during the extrusion process.

Above mentioned and other features and objects of the present invention will clearly appear from the following detailed description of embodiments of the invention taken in conjunction with the drawing.

In the drawing is schematically illustrated a cut through the longitudinal axis 1 of a power cable. The crosssection of the power cable is symmetrical about the axis 1. The dimensions of the cable are, however, not shown to scale.

A cable conductor 2 is provided with an extruded composite semiconductor 3, one or more layers of extruded insulation material 4 such as crosslinked polyethylene, an outer extruded composite semiconductor 5 and an outer metal screen

and possible outer protective screens, layers and/or sheaths 6. All the dielectric layers are fully bonded. As indicated in the drawing the semiconductor 3 is extruded in two parts, -an outer part 3a, and an inner part 3b - to constitute a composite semiconductor. When extruding the outer part 3a of the composite semiconductor, which part contains crosslinking agents per se, clots or lumps or other protrusions 9, 10 may occur on the surface of the layer. In conventional cables the insulation layers are extruded directly over the crosslinked semiconductor with the risk that said protrusions may cause breakdown of the cable insulation.

The material used for extruding the inner part 3b of the composite semiconductor 3 is, in accordance with the invention, free from crosslinking agents. No clots will therefore occur in the extrusion channels for the inner part 3b of the inner composite semiconductor 3, and the interface 7 between this semiconductor 3 and the inner surface of the insulation layers 4 will be very smooth and free from protrusions into the insulation. The thickness of the inner part 3b should be large enough to cover or at least smoothen the possible protrusions occurring in the outer part 3a.

As schematically illustrated, the outer semiconductor 5 may also be extruded in two parts - an inner part 5b and an outer part 5a - to constitute a composite semiconductor. The material used for extruding the inner part 5b of the composite semiconductor is free from crosslinking agents. No clots or protrusions will therefore occur at the outer surface 8 of the insulation layers 4 and this surface will be smooth. As indicated above in connection with the inner composite semiconductor 3, the thickness of the inner part 5b should be large enough to cover or smoothen possible clots or protrusions 11, 12 occurring in the extruded outer part 5a.

Due to the fact that the composite semiconductor outer parts 3a and 5a, as well as the insulation layers 4 contain crosslinking agents, the inner parts 3b and 5b of the composite semiconductor, will also be crosslinked in the final cable, due to migration of crosslinking agents. In some cases it may, however, be preferred to use relatively thick inner parts 3b and/or 5b when it is allowable to leave some of the semiconductive material in its thermoplastic state.

Typical materials which can be used for the composite semiconductors 3 and 5 are copolymers of ethylene with addition of conductive carbon black. The only difference between the material used to extrude the semiconductive inner parts 3b, 5b and the outer parts 3a, 5a is that crosslinking agents such as organic peroxides are added to the material for the latter parts. As the base materials are substantially identical, said parts will be fully

bonded to each other and to the insulation.

Typical dimensions (thickness of the dielectrics) for a 145 kV cable are:

Inner semiconductor 3: 2 mm Insulation layers 4: 21 mm

Outer semiconductor 5: 1 mm

The thickness of the inner parts of the composite semiconductor should be 0.1 - 0.5 mm, preferably 0.1 - 0.2 mm.

The structure of the composite semiconducting layer should preferably be selected to ensure satisfactory electrostatic screening properties of the layer during all steady state and transient voltage conditions to which the cable is subjected during operation.

The above detailed description of embodiments of this invention must be taken as examples only and should not be considered as limitations on the scope of protection.

Claims

1. Method for manufacturing a power cable comprising a conductor (2), a number of fully bonded dielectric layers including an extruded semiconductor (3) over the conductor, one or more layers of extruded insulation material (4) over the inner semiconductor and an outer extruded semiconductor (5) over the insulation and finally an outer metal screen and possible outer protective screens, layers and/or sheaths (6) over the outer semiconductor, **characterized** by extruding at least one of the semiconductors (3,5) as a composite structure, the inner part (3b,5b) of which is free from crosslinking agents.

2. Method according to claim 1, **characterized** by extruding the composite semiconductor in two parts, - an outer part (3a,5a) containing crosslinking agents and which will be in contact with the power conductor (2) and with the outer sheaths (6) respectively, - and the inner part (3b,5b) which will be in contact with the insulation layer(s) (4).

3. Method according to claim 1 or 2, **characterized** by extruding the inner and outer parts of the composite semiconductor (3a,3b;5b,5a) in a tandem or multiple head extruder, the thickness of the inner parts (3b,5b) being in the order of 0.1 - 0.5 mm, preferably 0.1 - 0.2 mm.

4. Method according to claim 1, 2 or 3, **characterized in this that** the structure of the composite semiconducting layer (3, 5) is selected to ensure satisfactory electrostatic screening properties of the layer during all steady state and transient voltage conditions to which the cable is subjected during operation.

5. Method according to claim 1, 2 or 3, **characterized** by using the substantially identical

material for extruding the inner and outer parts of the composite semiconductor, except that the inner parts are free from crosslinking agents.

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