

SPECIFICATION

Conductor for a moisture-proof electric cable

- 5 This invention relates to a conductor for a moisture-proof plastics-insulated electric cable, particularly for the transmission of higher voltages, of a kind comprising continuous single
10 elements of copper which are assembled together so as to extend in the longitudinal direction, and a closed dense metallic sheath which surrounds these elements and which is constituted by a metal tape which has been
15 bent into a tubular form around these elements and longitudinally seam-welded.

- Recently, numerous investigations have been carried out in this field with the objects of elucidating the mechanism of damage apparently caused by accumulations of water ("water trees") in the insulations of plastics-insulated electric cables, and of taking steps to prevent this damage to cables. The number of published documents describing the growth
20 of the water trees and providing suggestions for preventing such phenomena, which lower the life expectancy of a cable, is correspondingly high.

- All previous investigations were based on
30 the proposition that, initially, moisture enters the insulation. Diffusion of moisture can take place even during manufacture, e.g. during a cross-linking process, due to the action of water vapour during continuous passage
35 through a continuous vulcanization production line; or it can take place during operation, for example in the event of damage to a metal sheath, or by water-vapour diffusion through an undamaged plastics sheath. Under the
40 influence of the electric field strengths prevailing during operation, water trees are then formed, whose continuous growth can finally lead to electric breakdown and ultimately to the destruction of the cable altogether. Cable
45 destruction can also occur, however, if moisture, which may be in the form of free liquid water, is present in the cable conductor, or if it enters the cable conductor during operation, since its presence can lead to corrosion phenomena as a result of a voltaic cell being
50 formed between the conductor material and the inner conducting layer. Aluminium conductors surrounded by conductive layers containing carbon black are particularly susceptible in this respect.

- With a view to preventing moisture from penetrating from the outside into the insulation, numerous proposals have already been put forward. Thus metallic screens in the form
60 of metal bands placed around the cable core are known (US Patent 4,145,567), as too are types of insulation providing a diffusion gradient from the inside to the outside (German Offenlegungsschrift 27 54 336) or moisture-
65 absorbing layers disposed around the insula-

tion (German Offenlegungsschrift 27 37 108). Even if one solution or another really suppresses the diffusion of moisture, or at least greatly confines it, however, this does not
70 make any allowance for the fact that moisture can enter the insulation also from the inside, that is to say via the conductor itself, to cause the above-mentioned damage.

- The possibility has already been raised that,
75 in particular, conductor strands, composed of individual wires, of electric cables could serve as "water conduits", that is to say could be responsible for conveying moisture over the whole length of the cable. In order to provide
80 a remedy for this, so as to limit the conveying of water, filling methods known from telecommunication cable engineering have been used and adapted to the section-by-section filling of power-transmission cables.

- In this connection, reference is made to a known process (German Auslegeschrift 21 54 749) in which an inner conductor, constructed as a bunched conductor, of a high-voltage cable is provided at regular intervals
90 with a closed cross-section of a metallic material. Another known compartment forming technique for a conductor (German Offenlegungsschrift 28 08 438) provides for plugs of a cross-linked elastomeric material to be disposed at intervals along a conductor strand,
95 their axial length being small in comparison with their axial spacing. With these measures a migration of moisture along the cable is made practically impossible, but any moisture
100 present inside the cable, introduced during production, for example, and also condensation water, is able, as before, to enter, between the plug positions, into the inner conducting layer and finally into the insulation;
105 weak points in the insulation and the conducting layer which are particularly favoured by the high field-strengths in the vicinity of the conductor promote the growth of water trees.

- Accordingly it is an object of the invention
110 to provide a means of further reducing the danger of water trees developing, and at the same time preventing the formation of voltaic cells as a result of an unfortunate combination of different materials used in the construction
115 of cables.

- According to the present invention, we provide a conductor for a moisture-proof plastics-insulated electric cable of the kind first mentioned herein, characterised in that: the tape
120 is also of copper; the sheath has been drawn down on to an outer layer of the assembled single elements, and thus securely fixed, as the outermost layer, around these elements, so that it holds these elements together; and
125 the wall thickness (s) of the sheath, in mm, is substantially one-twentieth of the square root of the required total cross-sectional area of the conductor, in mm². The sheath, which also prevents the untwisting of individual wires,
130 e.g. of a conductor strand, during the manu-

facturing process, has the function of preventing penetration of moisture from the direction of the conductor into the insulation or an inner conducting layer. The conductor is sealed over its whole length, and during the installation of the cable no further work, e.g. the removing of filling material at cable joints or connections, need be carried out. The sheath is with particular advantage drawn down on to the conductor elements inasmuch as the latter can then act like a support for a pipe.

Although it is known in itself (German Patent Application P53697D dated 2.9.1949) to produce the conductor of a compressed-gas cable from a stranded core of aluminium wires with a seamless sheath of aluminium, this was done with the aim of making the electric field more uniform, to prevent corona phenomena on the surface and to prevent corrosion at the stranded core. Substantially the same purpose was served by a further known method (British Patent 757,745) in which the conductors of an overhead line were provided with a closed sheath of a welded metal band.

The present conductor, in contrast, is meant for those power-transmission cables which have, around the conductor, extruded layers (conducting layers) for making the electric field uniform with respect to the insulation, and which, according to more recent findings, are sensitive to the action of moisture and must therefore be protected in order to be able to guarantee the expected operational reliability, particularly with increased operational voltages.

Particular advantages, especially with respect to the stability of the conductive cross-section and similar parameters, are obtained by the drawing down of the sheath on to a multi-wire conductor assembly. This eliminates the risk of kinking the closed sheath during cable manufacture and the winding processes associated with this, particularly as the sheath itself is a part of the conductor. In this arrangement the closed sheath simultaneously leads to the production of a more uniform electric field. It is a particularly useful feature that, in effect, the sheath replaces at least an outer layer of the conductor or conductor strand. This results in a compact and mechanically stable conductor strand with good bending and installation properties, which permits the conveying of water in the longitudinal direction but prevents the insulation from being damaged.

It must also be mentioned that the application of the invention is not restricted to conductors of concentric construction; thus shaped elements which are twisted together, e.g. three to six shaped metallic strands twisted together, can also be enclosed in a closed metallic sheath.

In the case of the invention, it is of advantage that the diameter of the conductor should

be smaller than that of a multi-wire stranded conductor with the same resistance. This ensures that the relevant layer structure for the cable concerned (conducting layers, insulation, screen and jacket) can be retained, with a cable diameter which can even be smaller.

A particularly important factor in the design of the conductor of the invention is the ratio of the diameter d of the stranded core to the wall thickness s of the tube welded around it. The greater the d/s ratio, the more the sheath (tube) tends to kink if the conductor is bent around such radii as are liable to be encountered with typical individual production runs and during the running and installing of the cable. Since, on the other hand, the sheath consists of the same material as the stranded conductor core (for reasons including, for example, the desirability of preventing corrosion), the above-mentioned construction is of advantage, the required total cross-sectional area of the conductor being the sum of the cross-sectional area of the core and the cross-sectional area of the sheath. For the present material, copper, a particularly suitable construction is obtained if $d/s = 25$.

For cables with higher voltages and the usual conductor structure, a conductive layer is commonly applied to the conductor surface, e.g. extruded on to or applied in tape form to the conductor surface, e.g. extruded on to or applied in tape form to the conductor surface, for the purpose of rendering the electric field more uniform. The present invention makes it possible to omit this conductive layer altogether, however, in certain cases, so that the relevant operational steps and material can then be saved.

In cases in which either an extruded conductive layer is to be provided around the sheath or an insulation is extruded directly on to the sheath, it may be appropriate to provide the sheath with superficial unevennesses, for example in the form of prominences and depressions, providing a keying effect in respect of the adhesion of a conducting or insulating polymeric material extruded on to the sheath.

The invention will be explained in greater detail with reference to the accompanying diagrammatic drawing, in which Figs. 1 and 2 are respective cross-sectional views of two constructions in accordance with the invention.

In the single-core high-voltage cable shown in Fig. 1, there is a conductor strand 1 which consists of a core 2 of stranded individual wires of copper and a sheath 3 also of copper. The total cross-section for the transmission of the relevant power, therefore, is provided by the core 2 and the sheath 3 together. The sheath 3 is afforded by a copper tape which has been shaped into a tube around the core 2, being run in longitudinally beside the core 2 and longitudinally seam-

welded at the edges after being so shaped into a tube, and being subsequently drawn down closely on to the core 2.

- 5 Around the sheath 3 there is an inner
conducting layer 4 which is covered by an
insulation 5. The moisture-proof conductor
thus securely protects the layers 4 and 5
against the action of moisture which might
have reached them from the inside. An outer
10 conductive layer is shown at 6; 7 is a usual
form of screen, which is here indicated only
diagrammatically, and 8 is a jacket, providing
mechanical protection against the outside,
e.g. of a material based on polyvinyl chloride
15 or rubber, which may be a flame-resistant
material.

- Fig. 2 shows a particularly cost-effective
construction for sector-shaped conductor sec-
tions. In the construction of Fig. 2, four sector
20 conductors 9 are stranded together. A closed
metallic sheath 10 is disposed around the
stranded conductors 9, which can alterna-
tively be in the form of stranded individual
wires. The cable construction appropriate to
25 the field of application is finished around this
conductor structure.

- The shaped conductors themselves can be
twisted around a support tube or a support
spiral if current displacement must be taken
30 into account with large conductor cross-sec-
tions and the core of the conductor does not
contribute to the transmission of power.

- The closed sheath of the present invention
also has the advantage that, if, for example,
35 stranded segment conductors are used, which
can be produced cheaply, the conductive layer
is prevented from pressing into filler material
between the conductive elements if, for
example, cross-linkable polyethylene is ex-
40 truded on as insulating material.

CLAIMS

1. Conductor for a moisture-proof plastics-
insulated electric cable comprising continuous
45 single elements of copper which are assem-
bled together so as to extend in the longitudi-
nal direction, and a closed dense metallic
sheath which surrounds these elements and
which is constituted by a metal tape which
50 has been bent into a tubular form around
these elements and longitudinally seam-
welded, characterised in that: the tape is also
of copper; the sheath has been drawn down
on to an outer layer of the assembled single
55 elements, and thus securely fixed, as the
outermost layer, around these elements, so
that it holds these elements together; and the
wall thickness (s) of the sheath, in mm, is
substantially one-twentieth of the square root
60 of the required total cross-sectional area of the
conductor, in mm².

2. A conductor according to claim 1, char-
acterised in that the sheath additionally func-
tions as an inner conductive layer.

- 65 3. A conductor according to claim 1 or 2,

characterised in that the sheath possesses
superficial unevennesses, providing a keying
effect in respect of the adhesion of a conduct-
ing or insulating polymeric material extruded
70 on to the sheath.

4. A conductor according to claim 1, 2 or
3, characterised in that, within the sheath, it
has a conductor strand which consists of three
to six shaped metallic strands twisted to-
75 gether.

5. A conductor according to any of claims
1 to 4, characterised in that the diameter of
the stranded core constituted by the assem-
bled single elements is substantially twenty-
80 five times the wall thickness of the sheath
constituted by the tube welded around it.

6. A conductor according to claim 1, sub-
stantially as described with reference to either
Figure of the accompanying drawing.

- 85 7. A moisture-proof plastics-insulated elec-
tric cable incorporating a conductor according
to any of claims 1 to 6.

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welded at the edges after being so shaped into a tube, and being subsequently drawn down closely on to the core 2.

- 5 Around the sheath 3 there is an inner conducting layer 4 which is covered by an insulation 5. The moisture-proof conductor thus securely protects the layers 4 and 5 against the action of moisture which might have reached them from the inside. An outer
- 10 conductive layer is shown at 6; 7 is a usual form of screen, which is here indicated only diagrammatically, and 8 is a jacket, providing mechanical protection against the outside, e.g. of a material based on polyvinyl chloride
- 15 or rubber, which may be a flame-resistant material.

- Fig. 2 shows a particularly cost-effective construction for sector-shaped conductor sections. In the construction of Fig. 2, four sector
- 20 conductors 9 are stranded together. A closed metallic sheath 10 is disposed around the stranded conductors 9, which can alternatively be in the form of stranded individual wires. The cable construction appropriate to
- 25 the field of application is finished around this conductor structure.

- The shaped conductors themselves can be twisted around a support tube or a support spiral if current displacement must be taken
- 30 into account with large conductor cross-sections and the core of the conductor does not contribute to the transmission of power.

- The closed sheath of the present invention also has the advantage that, if, for example,
- 35 stranded segment conductors are used, which can be produced cheaply, the conductive layer is prevented from pressing into filler material between the conductive elements if, for example, cross-linkable polyethylene is ex-
- 40 truded on as insulating material.

CLAIMS

1. Conductor for a moisture-proof plastics-insulated electric cable comprising continuous
- 45 single elements of copper which are assembled together so as to extend in the longitudinal direction, and a closed dense metallic sheath which surrounds these elements and which is constituted by a metal tape which
- 50 has been bent into a tubular form around these elements and longitudinally seam-welded, characterised in that: the tape is also of copper; the sheath has been drawn down on to an outer layer of the assembled single
- 55 elements, and thus securely fixed, as the outermost layer, around these elements, so that it holds these elements together; and the wall thickness (s) of the sheath, in mm, is substantially one-twentieth of the square root of the required total cross-sectional area of the
- 60 conductor, in mm².

2. A conductor according to claim 1, characterised in that the sheath additionally functions as an inner conductive layer.

- 65 3. A conductor according to claim 1 or 2,

characterised in that the sheath possesses superficial unevennesses, providing a keying effect in respect of the adhesion of a conducting or insulating polymeric material extruded on to the sheath.

4. A conductor according to claim 1, 2 or 3, characterised in that, within the sheath, it has a conductor strand which consists of three to six shaped metallic strands twisted to-
- 70 gether.

5. A conductor according to any of claims 1 to 4, characterised in that the diameter of the stranded core constituted by the assembled single elements is substantially twenty-
- 75 five times the wall thickness of the sheath constituted by the tube welded around it.

6. A conductor according to claim 1, substantially as described with reference to either Figure of the accompanying drawing.

- 85 7. A moisture-proof plastics-insulated electric cable incorporating a conductor according to any of claims 1 to 6.

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