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(54) **High voltage DC power cable**

(57) The present invention relates to high voltage direct current (HVDC) cables and to subsea installation of such cables. It further relates to a HVDC power cable including a central conductor (1) and insulation layers (2) covered with a metal sheath (3) such as a lead sheath as well as outer armouring (8) and corrosion protection (9). The cable includes a concentrical return current conductor (6) arranged between the metal sheath (3) and the outer corrosion protection layers (9).

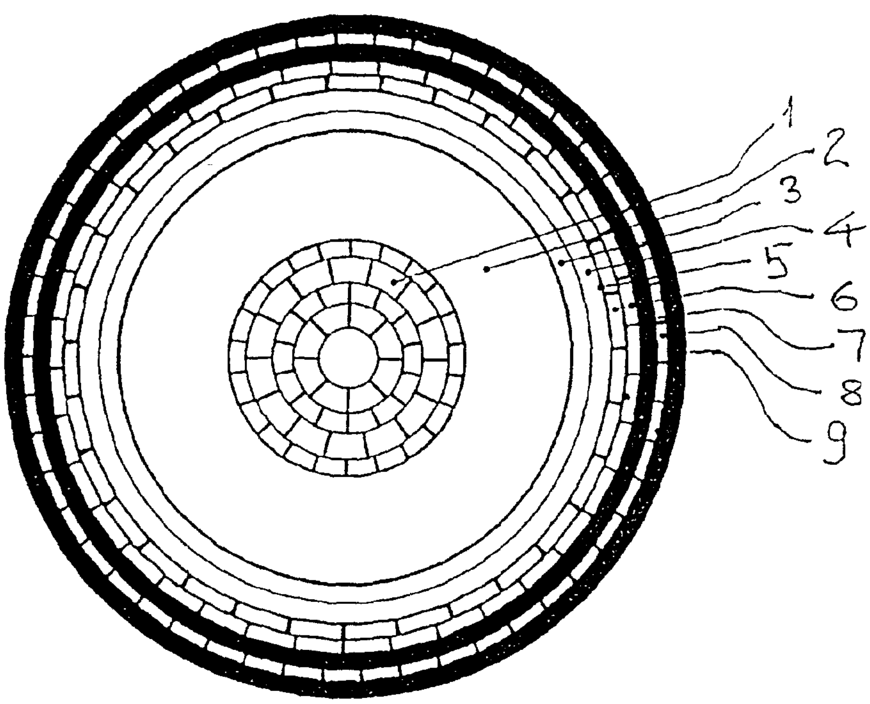

Fig. 1

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Description

[0001] The present invention relates to high voltage direct current (HVDC) cables and to subsea installation of such cables. Such cables and installations are described in WO 97/04466 (G Balog 13).

[0002] UK 2 295 506 describes a HVDC system in which rectifier and convertors are connected by a DC link, the inverter extinction angle is used to control the rectifier firing angle in a closed loop to maintain the inverter extinction angle at or above predetermined values. Each converter has a closed loop controller to control the firing angle in dependence upon DC current, DC voltage, own extinction angle and own firing angle.

[0003] DE 1 262 425 relates to a device for 'voltagewise relief' of cables in HVDC installations where both ends are connected to an AC network via 'smoothing' coils and rectifiers, - and where the feeding and the receiving AC network as well as the associated rectifier are such that the number of phases on the two AC sides do not contain the same prime numbers.

[0004] A normal way to transfer energy from one place to another across a body of water such as between Norway and Denmark, - is to use a HVDC cable having a central insulated conductor and use the seawater for the return current. This cable is installed between AC circuits having the same number of phases. An alternative is to install a separate HVDC cable for the return current in parallel with the first cable. This is an expensive solution.

[0005] The object of the invention is to provide a new cable and a new installation technique in order to satisfy customers requirements for reliable long distance transfer of high energy between to locations which are separated by a body of water, - at a reasonable cost.

[0006] The main features of the invention are defined in the accompanying patent claims. With these solutions we have succeeded in satisfying the requirements of the customers. Our cable operates in a monopolar mode without having an external magnetic field. The installation eliminates sea electrodes which may cause high cost and large environmental problems.

[0007] 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 drawings, where

Figure 1 schematically illustrates the crossection of a HVDC cable, - and
Figures 2 and 3 illustrate two alternative cable installations.

[0008] In Figure 1 the cable crossection shows a central cable conductor having one or more layers of insulation material 2 enclosed within a metal sheath. Inner and outer semiconductive layers arranged respectively over the cable conductor 1 and underneath the lead sheath 3 are not shown. Over the lead sheath there are successively arranged an insulation sheath 4, reinforcements 5, armour 6, insulation 7, armour 8 and outer protective layers 9.

[0009] The conductor 1 may be a multiwire copper conductor. The insulation 2 may be wrapped tapes or extruded insulation. The metal sheath 2 may be a conventional lead alloy sheath. The first layer 4 over the metal sheath may be a polymer such as polyethylene (PE). This layer may be semiconductive in order to avoid or reduce potential differences. Transversal reinforcements 5 such as stainless steel tapes are arranged over the layer 5. Next is a two layer armour 6 which may be hard-drawn profiled copper wires. Then follows an insulation sheath 7 which may be a PE sheath, an armour 8 which may consist of galvanized steel wires and outer protection 9 which may consist of polypropylene yarn and asphalt.

[0010] With a cable capable of transferring 800 MW at 500 KV over a subsea cable route of more than 500 Km, the central conductor should have a crossection of 1.600 mm2 and the return conductor some 1.900 mm2 . The cable should preferably be buried in the sea bed, preferably down to 2.5m depth.

[0011] In Figure 2 is schematically indicated the main parts (conductor 1, return conductor 6 and armour 8) installed between two end stations A and B. The stations A and B include convertors (not shown) for interconnection with AC networks (not shown). The conductor 1 transfers the cable current from A to B and the armour 8 is earthed continuously. The concentrical return conductor 6 is connected to ground potential through surge arrestors (valves)10 and 11 installed in both ends of the cable, - and the return conductor is earthed midway between A and B. This earthing may be achieved with semiconductive material.

[0012] The earthing of metallic return conductor must be done in such a way that no circulating currents will exist. At the same time the converters must experience the true earth. The circulating currents are divided according to the resistances in the different loops. As the sea can be regarded as a very large conductor, only the resistance in the leads to the electrodes, the electrode resistance and eventual resistance in earth defines the loop resistances.

[0013] In Figure 3 the installation is similar to the installation of Figure 2, but in this alternative the return conductor 6 is earthed at one end (the A end) and it is connected to ground through a surge arrestor (valve) 12 in the other end (the B end).

[0014] A cable with a metallic return conductor will at 800 MW load experience approximately 10 kV DC voltage buildup at a 540 km length. It is possible to use resistors to limit the earth current, but it is undesireable with any earth current. Another approach is to hinder the circulating current by singlepoint bonding. If direct earthing of one of the valves are necessary this may be possible; but the other valve group at the other end would experience 10 kV to earth.

[0015] If the cable system is earthed in the middle (Figure 2) both valve groups would experience approximately 5 kV DC-voltage to earth. In this case diodes may be used as Zener diodes at both ends to protect the outer insulation against overvoltages.

[0016] The above detailed description of embodiments of the invention must be taken as examples only and should not be considered as limitations on the scope of protection.

Claims

1. HVDC power cable including a central conductor (1) and insulation layers (2) covered with a metal sheath (3) such as a lead sheath as well as outer armouring (8) and corrosion protection (9),
characterized in that
the cable includes a concentrical return current conductor (6) arranged between the metal sheath (3) and the outer corrosion protection layers (9).

2. Cable according to claim 1,
characterized in that
it over the metal sheath (3) successively includes a polymer insulation (or semiconductive) layer (4), steel tape reinforcements (5), a copper armour (6) functioning as return current conductor, at least one polymer insulation layer (7), armouring (8) as well as outer sheaths (9).

3. Cable according to claim 2,
characterized in that
the polymer layer (4,7) are PE layers.

4. Subsea cable installation for a HVDC cable as defined in claims 1-3,
characterized in that
whereas the armour (8) is continuously grounded along the cable route between A and B - the return conductor (6) is grounded midway between the end connections (A,B).

5. Cable installation according to claim 4,
characterized in that
the return conductor is grounded through surge arrestors (10,11) arranged in both ends (A,B).

6. Subsea cable installation for a HVDC cable as defined in claims 1-3,
characterized in that
whereas the armour (8) is continuously grounded along the cable route between A and B - the return conductor (6) is directly grounded in one end (at A) and grounded through a surge arrestor (12) in the other end (at B).

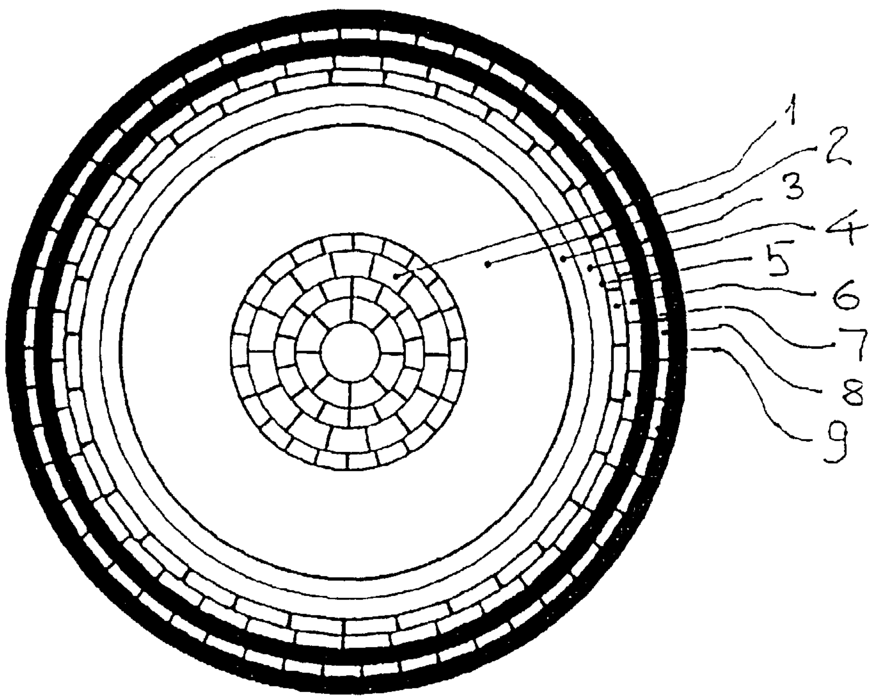

Fig. 1

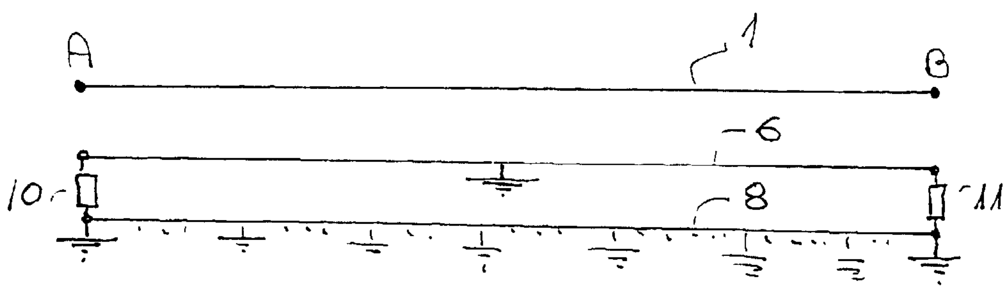

Fig. 2

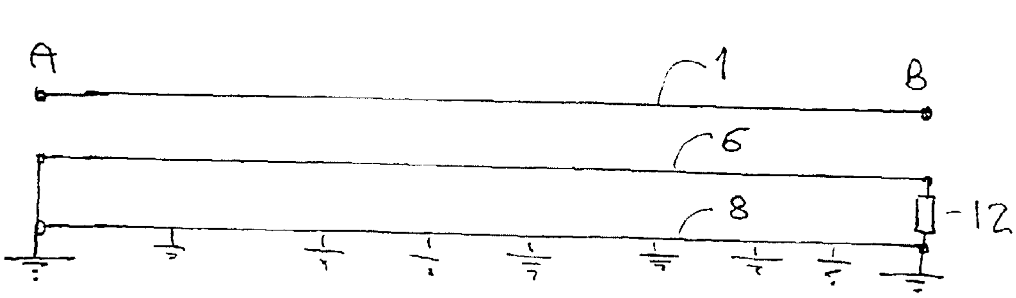

Fig. 3