

POWER CABLE LINE

BACKGROUND OF THE INVENTION

5 1. Technical Field of the Invention

The present invention relates to a method to ground metallic sheaths of a cross-bonded power cable line.

2. Description of the Prior Art

10 Figure 3 shows a conventional power cable line where the respective metallic sheaths of single-phase power cables are cross-bonded together by cross-bonding wires at straight-through joints with an insulated flange (hereafter the straight-through joint with an insulated flange is referred to as an "insulation joint"). In Fig. 3, numeral 1 denotes a power cable line consisting of three
15 cross-bonded sections, and numeral 2 denotes each of the metallic sheaths of the power cable. An outer jacket is provided on each of the metallic sheath 2, which is not illustrated in Fig. 3. An insulation joint 3 of a single-phase power cable is cross-bonded with an insulation joint of another single-phase power cable by each of the cross-bonding wires 6. A straight-through joint without an
20 insulated flange 4 (hereafter the straight-through joint without an insulated flange is referred to as a "normal joint") and a termination end 5 of each single-phase cable are grounded by wires 7 and 8, respectively.

The reason for providing a cross-bonded section is to reduce sheath circuit

losses to the extent possible by reducing the generation of an induced voltage in the metal sheath to the lowest possible level. In a single-core power cable, the induced voltage is generated in the metallic sheath by an electrical current flowing through its conductor. It is necessary to reduce the induced voltage
5 below a certain limit for the safety of the single core power cable. Grounding at two or more places of the cable line has been needed in the case of a long power cable line. However, if the power cable of the cable line is grounded without any attention, the electrical current flows through the metallic sheath, and the so-called sheath-circuit-loss which results in the reduction of its power
10 transmission capacity occurs. A metallic sheath transposition by cross-bonding wiring has been proposed as a preventive means against the above-mentioned loss.

In such a conventional cross-bonded power cable line, as shown in Fig. 4, ammeters 9 for detecting abnormal conditions, such as an insulation failure in
15 the outer jacket of the power cable, have been equipped in each of the cross-bonding wires 6 connecting each single-phase insulation joint 3. The basic concept of the detection of abnormal conditions is that an electric current flowing through the cross-bonding wires under normal conditions is different from an electric current under abnormal conditions. For example, if a power
20 cable is damaged externally such that a damaged part in one of the metallic sheaths 2 becomes grounded, then the electric current flowing through the cross-bonding wires 6 becomes different from the electric current under normal conditions.

Electric current data detected by each of the ammeters 9, not illustrated in Fig. 4, are transmitted to a maintenance center through communication lines, such as optical fibers. Abnormal conditions in the outer jacket, for example, are determined by comparing the detected current data with current data patterns under normal conditions by a computer in the maintenance center.

Another numerals shown in Fig. 4 use the same numerals as used in Fig. 3 for denoting the same parts.

The conventional detection method of the abnormal condition was not economical. This was because of the need to equip numerous ammeters at all of the insulation joints for detecting abnormal conditions in the outer jacket of the power cable, as well as many communication lines, such as optical fibers for transmitting these electric current data to the maintenance center.

SUMMARY OF THE INVENTION

One of the features of the present invention is a power cable line in which the metallic sheaths of single-phase power cables are cross-bonded together at respective insulation joints by cross-bonding wires, wherein:

- (a) such cross-bonding of the metallic sheaths are made without grounding;
- (b) the metallic sheaths are collectively grounded at both ends of the cable line by grounding wires for the termination end (hereafter the place where such collective grounding is made is referred to as a "collective grounding place", and such collective grounding means is referred to as the "collective grounding

means"); and

(c) an ammeter is equipped at each of the collective grounding places in both ends of the cable line.

Since the ammeters for detecting abnormal conditions in an outer jacket of a power cable are equipped at each of the collective grounding places in both ends of the cable line, that is, the ammeters are equipped only at two places, it is very economical.

The power cable line of the present invention is highly effectual in the case of a long-distance power cable line or multiple-circuits power cable line that requires the installation of numerous insulation joints.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a diagram illustrating a power cable line of the present invention under normal conditions.

Figure 2 is a diagram illustrating a power cable line of the present invention under abnormal conditions in the outer jacket.

Figure 3 is a diagram illustrating a conventional power cable line under normal conditions.

Figure 4 is a diagram illustrating a conventional power cable line equipped with ammeters for detecting abnormal conditions at an outer jacket.

DETAILED DESCRIPTION OF THE INVENTION

Numerals in Figs. 1 and 2 use the same numerals as used in Figs. 3 and 4 for denoting the same parts.

5 The present invention and the conventional line differ in the following three points.

The first point is the means to ground metallic sheaths at the normal joint 4. In Fig. 4, each phase is grounded individually by a grounding wire. On the contrary, in Fig. 1, a metallic sheath in each phase is connected with sheaths in other phases at normal joint 4 by conductive wires 11 without grounding.

10 The second point is the means to ground the metallic sheaths for the respective phases at termination ends 5. In Fig. 4, each of the termination ends is grounded by each of the grounding wires 8, individually. On the contrary, in Fig. 1, the termination ends are grounded collectively at the collective grounding place 10 at each end of the cable.

15 The third point is the location and the number of ammeters. In Fig. 4, the ammeters 9 are equipped at all of the cross-bonding wires 6 for the insulation joints 3. On the contrary, in Fig. 1, an ammeter 9a is provided on the collective grounding place in each end of the cable line. Namely the ammeters are
20 equipped only at two places.

In Fig. 1, electrical currents that flow through the metallic sheaths in the respective phase are set to;

- i_{a1} , i_{b1} , and i_{c1} in the first cross-bonding section, respectively;
- i_{a2} , i_{b2} , and i_{c2} in the second cross-bonding section, respectively, and
- i_{a3} , i_{b3} , and i_{c3} in the third cross-bonding section, respectively;

then, zero sequence currents, i_1 , i_2 , and i_3 , which flow through the metallic
 5 sheaths 2 of respective cross-bonding sections under normal conditions, become
 as follows, respectively.

$$i_{a1} + i_{b1} + i_{c1} = i_1$$

$$i_{a2} + i_{b2} + i_{c2} = i_2$$

$$i_{a3} + i_{b3} + i_{c3} = i_3$$

10 Since an electrical current flowing through a conductor of the cable is
 originally balanced in three phases (namely, the zero sequence current is zero),
 an induced voltage in the metallic sheaths 2 by the electrical current becomes
 completely zero, if there is no imbalance in the mutual inductance between
 each conductor and each of the metallic sheaths 2, or no imbalance in the cable
 15 length between each joint. Therefore, i_1 , i_2 and i_3 in the above formula become
 zero in this case. However, since the actual power cable line has an unbalance
 in the above-mentioned mutual inductance or in the cable length, some
 electrical currents flow because of the residual voltage caused by their
 imbalance, and i_1 , i_2 and i_3 do not become zero. Electrical currents I_1 and I_3 ,
 20 which are caused by the above-mentioned residual voltages and flow at the
 collective grounding places 10 at cable ends, respectively, and the zero
 sequence currents that flow through the metallic sheaths i_1 , i_2 , and i_3 have the
 relationships of $i_1 = i_2 = i_3 = I_1 = I_3$ from the conditions where the metallic sheaths

for respective phases are connected together with conducting wires at normal joints without grounding.

The occurrence of abnormal conditions in the outer jacket of the cable line of the present invention is explained in Fig. 2.

5 Assumed that abnormal conditions in the outer jacket of the cable occurred at a place 12 of phase C between the two insulation joints in the second cross-bonded section as illustrated in Fig. 2, and a fault electrical current I_x flowed out from the place into the earth. Then, in this case, an imbalance occurs in the electrical current which flow through the metallic sheaths 2. For example, in
10 the first cross-bonded section, ia_1 is changed to ia'_1 , ib_1 is changed to ib'_1 and ic_1 is changed to ic'_1 , respectively. Electrical currents in the second and third cross-bonded sections are changed similarly.

However, since the zero sequence current, which is circulated through the earth, flows at the collective grounding places 10 of each end of the cable, the
15 electrical current $I_1 + I_x$ flows at one of the collective grounding places 10, and the current $I_3 - I_x$ flows at the other of the collective grounding places 10. Since I_x is considerably greater than I_1 and I_3 , a great amount of electrical current compared with the electrical current under normal conditions flows at each collective grounding place 10. Therefore, the abnormality in an outer jacket of
20 the cable can be detected by evaluating these data of the electrical current flows at the collective grounding places 10 under normal conditions.

That is, in the present invention, it becomes unnecessary to measure all electrical currents that flow in all of the cross-bonded wires at the insulation

joints 3 by the ammeters 9 as shown in Fig. 4 and to analyze these data, as needed in the conventional method.

The above example is described for the case of a single circuit of the power cable line. However, according to the present invention, the collective

5 grounding means of termination ends for the respective phases at the collective grounding place at each end of the cable line is applicable also in the case of multiple circuits.

WHAT IS CLAIMED IS:**1. A power cable line having cross-bonded metallic sheaths, wherein:**

- the metallic sheaths for respective phases are connected together with
5 conducting wires at straight-through joints without an insulated flange
 without grounding,
- the metallic sheaths are grounded collectively at termination ends for
 respective phases at a collective grounding place at each end of the cable
 line, and
- 10 - an ammeter is placed at the collective grounding place.

