Nov. 8, 1932. S. SUNAIRI 1,886,985

PROTECTIVE RELAY SYSTEM

Filed Aug. 22, 1928

Fig. 1.

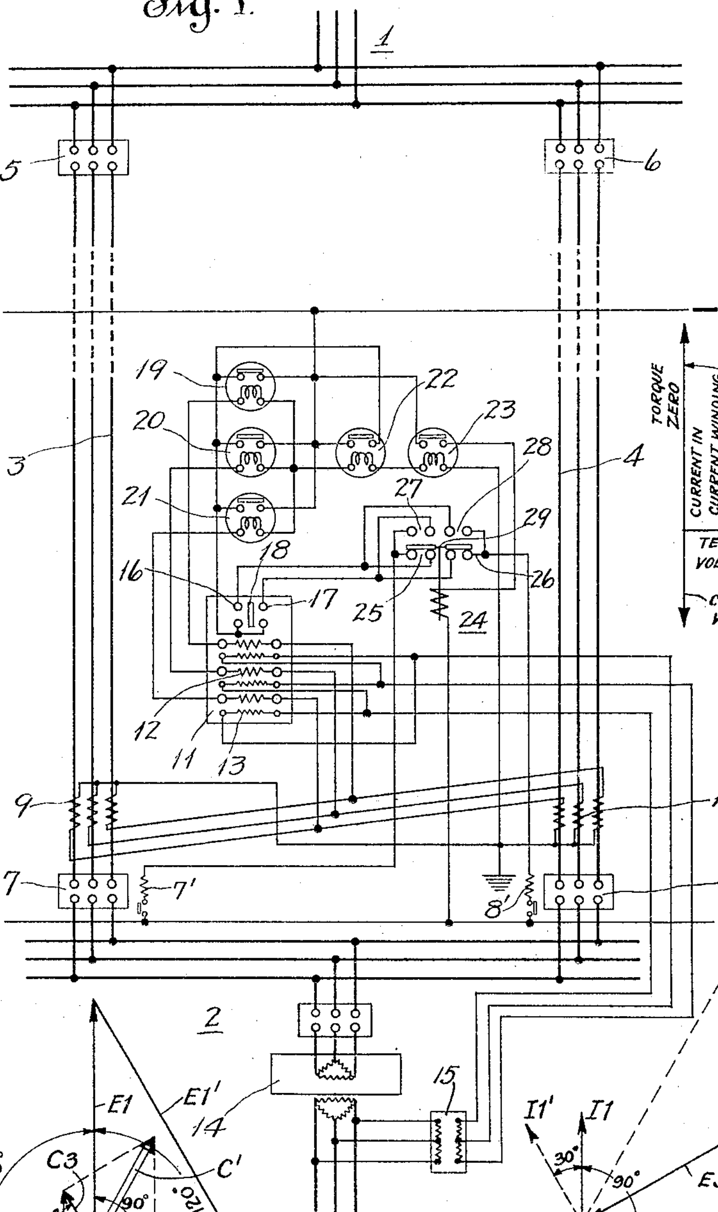
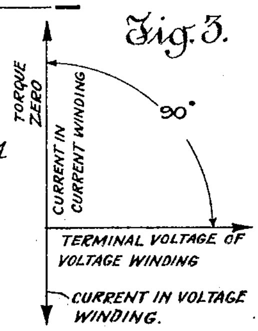


Fig. 3.



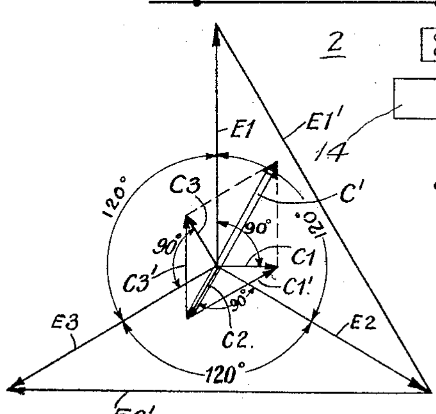
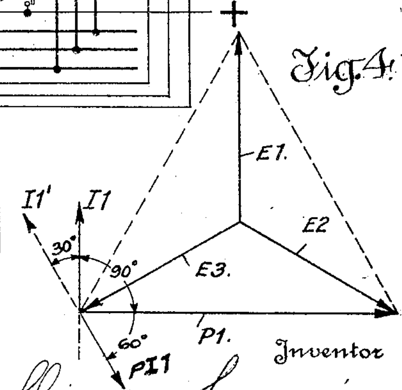


Fig. 2.

Fig. 4.



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PROTECTIVE RELAY SYSTEM

Application filed August 22, 1928, Serial No. 301,404, and in Japan September 13, 1927.

My invention relates to improvements in protective relay systems for double-circuit electrical transmission lines, and more particularly to selective relay systems for double-circuit transmission lines with their neutral points grounded through high resistance, or non-grounded.

One object of my invention is to provide improved means for protecting double-circuit transmission lines of the kind specified against short circuiting and grounding of the lines.

Another object of my invention is to provide improved means for selecting and interrupting a grounded and a short-circuited circuit and protecting the other circuit from damages.

Another object of my invention is to provide improved means for correctly selecting a grounded and a short-circuited circuit and interrupting the same without failure at the sending end.

A further object of my invention is to provide means for obtaining potential elements in a directional power relay for the ground protection, from the low tension side of a power station of the kind specified.

There are other objects of my invention, which together with the foregoing will appear in the following description.

In the accompanying drawing:

Figure 1 is a diagram of circuits and apparatus embodying my invention.

Figures 2, 3 and 4 are vector diagrams.

When double-circuit high tension transmission systems have their neutral dead grounded, there will be no considerable difficulty in selectively protecting the lines from grounding, because short-circuit current will flow in the grounded circuit in a large magnitude, and single means can selectively protect the two circuits from either a grounding or a short-circuiting. If, however, the power system has no neutral grounded or a neutral grounded through a high resistance, as desirable under a certain condition, a ground current of the limited low value will flow through the grounding circuit.

In such latter cases, a particular arrangement must be provided for ground protection. For this purpose, a new protective relay system is proposed and fully explained in the specification of my co-pending patent application Serial No. 301,405, filed on August 22, 1928. In this co-pending application is disclosed a novel system utilizing the leading characteristics of the ground current obtained in the transmission system of this kind. According to a preferred form thereof, a directional power relay is used, in which the potential windings are normally energized in accordance with the phase-to-phase voltages of the low tension side of the system, while the current elements are energized in accordance with the unbalanced current between the corresponding phases of the two circuits, and the relay is so arranged that the movable contact member is actuated to one direction when the current leads the voltages by more than a predetermined degree, such as 30 degrees of phase angle, which is determined by the relative values of the above-mentioned leading ground current and the load current, while it is actuated to the opposite direction when the current does not lead so far. Consequently with the current leading by 30 degrees, for example, the torque becomes zero.

Referring to Figure 2, E1, E2, E3 represent the line voltage of each phase to the ground, and C1, C2, C3 represent the normal charging current in each line. When one phase, say line E2, is grounded, the voltage of the other two lines increase to E1′ and E3′ respectively, and the charging current in lines E3 and E1 increase accordingly, as they are substantially proportional to the voltage of the lines respectively. C1′ and C3′ represent the charging current thus increased. The vectorial sum of them is represented by C′ which has a length three times the vector C1, C2 or C3.

However, a mere arrangement of such nature can only protect the system from grounding, but not from short-circuiting. My present invention provides means for enabling a single directional power relay of the above-mentioned nature to selectively protect the transmission system from short-circuiting, as well as from grounding.

Referring now to the drawing, wherein Figure 1 shows a diagram of circuits and apparatus embodying my invention, a substation 1 receives alternating current electrical power from a power station 2, by way of a double-circuit high tension transmission line, comprising two circuits 3 and 4, including circuit interrupters 5 and 6 at the receiving end, and circuit interrupters 7 and 8 at the sending end, respectively. The neutral point of the system 2 is not grounded, or alternately, it may be grounded through a high limiting resistance as hereinbefore described. But it will not be necessary to illustrate this grounding resistance, because such an arrangement may be readily understood.

With the sending ends of the respective circuits are associated current transformers 9 and 10, whose secondaries are differentially or oppositely connected for respective corresponding phases, with their star points grounded, and energize a directional power relay 11.

The relay 11 comprises current windings 12 connected between respective phases of the current transformers and the ground, and potential windings 13 energized in accordance with the phase voltages at the power station. The potential windings may be conveniently energized from the low tension side of the main transformers 14, through a potential transformer 15, if necessary. With this arrangement, considerable expenses in providing a high tension potential transformer may be avoided.

The directional power relay also comprises two opposed pairs of contacts 16 and 17 controlled by an armature 18 carrying a movable contact, for selectively engaging the contacts 16 and 17 in accordance with the energization of the actuating windings 12 and 13. The contacts 16 and 17 control the tripping circuits of the circuit interrupters 7 and 8.

It must be noted that this relay 11 is so arranged that the armature 18 is actuated to one direction, say to the left when a short-circuit current flows in one circuit, say 3, which current always lags from the normal voltage of the power system, while it is actuated to the opposite direction, i. e., to the right when a ground current flows in the same circuit 3, as hereinbefore described.

In circuit with each current winding 12, there is included the winding of an overload relay 19, 20 or 21, and these windings are star-connected at the outer terminals of the overload relays. Between the star point and the earth is included the windings of two ground current relays 22 and 23, in series. It will be readily understood that these ground current relays will not be energized unless a ground current flows therethrough due to the grounding of one circuit, because the short circuit current or load current balances with each other within the star-connected windings of the relays 11 and 19, 20 and 21.

The contacts of the overload relays 19, 20 and 21, and of the ground current relay 22 are connected in parallel relation with each other, and connected between the multiple contacts 16 and 17 of the directional power relay 11 and the negative side of a direct current control line, while the contact of the other ground relay 23 is included in the energizing circuit for a change-over relay 24 across the control line. The relay 24 is provided with four pairs of contacts 25, 26, 27 and 28, and a movable armature 29, arranged so as to change over the circuits connecting the contacts 16 and 17 and the tripping coils 7′ and 8′ of the circuit interrupters 7 and 8, in a manner as hereinafter described.

In order to provide a better understanding of the invention, I will now describe the operation of selective protection which takes place in case of one faulty circuit.

Now assume that a short-circuit has occurred in the circuit 3, while the other circuit 4 is normal. Unbalanced current will then flow through the current windings 12 and those of the overload relays 19, 20, 21, but these currents balance with each other within these star-connected windings; no current will flow to the ground current relays 22 and 23. The contacts of the overload relays are thus closed and the armature 18 is actuated by the lagging short-circuit current to engage the contacts 16. The tripping circuit of the faulty circuit 3 is thus completed from one side of the control line through the tripping coil 7′, contacts 25, 16, and contacts 19, 20, 21 in multiple to the other side of the control line, and the interrupter 7 is tripped to its open position.

When one line of the circuit 3 is grounded by fault while the other circuit 4 is normal, a ground current will flow through the current windings 12 and the windings of the ground current relays 22 and 23 to the ground, and energize them. The armature 18 is then actuated in the direction to engage the contacts 17, while the relay 23 closes its contacts, and completes the energizing circuit of the change-over relay 24. The armature 29 is then operated to the upper position shown. The tripping circuit of the circuit interrupter 7 is thus completed from one side of the control line through, the tripping coil 7′, the contacts 27, 17 and the contacts of the relay 22, which is now energized, to the other side of the control line. The interrupter 7 is thus tripped to its open position selectively in response to the grounding of the associated circuit 3. It will be obvious from the foregoing, that the relay 22 must be operated after the change-over relay 24 has been completely energized. Otherwise, the energizing circuit of the other tripping coil 8′ would be undesirably completed.

By some reason, such as in the case that the grounding would have occurred at a point adjacent to the receiving end, it would happen that the circuit interrupter 5 is first tripped before the proper interrupter 7 is open. In this case, the whole load is transferred to the other circuit 4, increasing its load current, while in the grounded circuit 3 there flows the leading ground current only. As is obvious from the above-mentioned special arrangement and setting of the relay 11, both the lagging current in the circuit 4 and the leading current in the circuit 3, function to actuate the armature 18 in one and the same direction so as to complete the tripping circuit of the proper interrupter 7.

When a grounding and a short-circuiting should have occured simultaneously, the differential currents in the relay windings 12 and the respective windings 19, 20, 21 are the sum of the large short-circuit current and the relatively small ground current, while through the ground current relays 22 and 23 there flows the ground current only. The relay 11 then operates its armature 18 to the left position, due to the fact that the vectorial sum of heavy short-circuit current and relatively small ground current has such a phase that the relay produces a torque in the same direction with the short-circuit current only. The energizing circuit of the tripping coil 7′ is thus completed across the control line through coil 7′, contacts 25 and 16, and contacts of the relays 19, 20, and 21 in multiple, and the faulty circuit 3 is interrupted at the interrupter 7. It will be readily understood that the overload relay must have a time limit sooner than that of the ground current relay 23, for the large short-circuit current.

In an ordinary watt-hour meter type relay, the torque is maximum when the voltage and current are in phase with each other, that is to say, the current in voltage winding is made to lag the terminal voltage thereof by 90 degrees, that is to say, the power factor of voltage winding circuit is made zero. Consequently, the torque is maximum when the current in current winding is in phase with the terminal voltage of voltage winding, as the torque is maximum when the current flux and voltage flux have 90 degrees phase difference with each other. Therefore, the torque is zero when the current in current winding and the terminal voltage of voltage winding have 90 degrees phase difference.

In the present invention, the power factor of voltage winding circuit is not made zero, but has a suitable substantial value, and by proper selection of the power factor, the relay is made to have its torque zero when line current of the system leads line voltage by a certain angle. With the connection of the relay 11 shown in the drawing, a vector diagram for the relay is given in Figure 4, wherein P1 represents the voltage impressed on the voltage winding of one phase, which is the line-to-line voltage of the system, while I1 represents the current in the current winding of the same phase, which is in phase with the line current. According to the invention, assume that the power factor of voltage winding circuit is made 0.5, that is to say, the current therein lags the terminal voltage by 60 degrees. PI1 then represents the current in voltage winding. The torque will be zero when I1 and PI1 are in phase or in opposite phase with each other. This condition occurs when I1 is shifted forward by 30 degrees and takes the position of I1′, and this signifies that the line current I1 leads the phase voltage E1 by 30 degrees.

The directional relay has normally a zero torque relationship as taught by the position of the vectors I1′ and PI′ in Figure 4 and such zero torque relationship ceases to exist when a short circuit or ground occurs on the system to be protected because of the change of the position of these two vectors.

Although I have shown only one embodiment of my invention, it will be readily understood that various modifications and changes are possible, and I do not intend to limit myself by the specific disclosure but only insofar as set forth in the appended claims.

I claim as my invention:

1. A protective system adapted for use in a grounded neutral system including a high resistance to ground or a non-grounded system, a double-circuit transmission system of such a nature that the faulty ground current is often lower than the load current in the circuit, means for interrupting said two circuits at the power station end, respectively, a directional power relay for controlling said interrupting means and comprising current elements energized in accordance with the unbalance between said two circuits and potential elements energized in accordance with the normal phase voltages of the power station, and a change-over relay operated in accordance with a ground current for reversing the connection of said interrupting means with the contacts of said directional power relay.

2. A protective system adapted for use in a grounded neutral system including a high resistance to ground or a non-grounded system, a double-circuit transmission system of such a nature that the faulty ground current is often lower than the load current in the circuit, means for interrupting said two circuits at the power station end respectively, a directional power relay for selectively controlling said interrupting means in accordance with leading current and lagging

current which flows in one circuit when it is faulty, a ground current relay in series with said directional power relay, a second ground current relay, and a change-over relay controlled by said second ground current relay for reversing the connection of said interrupting means with the contacts of said directional power relay.

3. A protective system adapted for use in a grounded neutral system including a high resistance to ground or a non-grounded system, a double-circuit transmission system of such a nature that the faulty ground current is often lower than the load current in the circuit, means for interrupting said two circuits respectively at the power station end, means for selectively controlling said interrupting means in accordance with lagging current which flows in one circuit when it is short-circuited and means for reversing the function of said first means in accordance with a grounding of said circuit.

4. A protective system adapted for use in a grounded neutral system including a high resistance to ground or a non-grounded system, a double-circuit transmission system of such a nature that the faulty ground current is often lower than the load current in the circuit, a directional power relay comprising an opposed pair of contacts, a plurality of current windings energized in accordance with the unbalance between respective corresponding phases of said two circuits, a plurality of potential windings energized in accordance with the respective phase voltages in the power station end, and a contact-carrying movable armature actuated thereby, said relay being so arranged that the actuating torque is zero when the current leads the phase voltage in phase by a predetermined degree, a change-over relay for reversing the connection of said pairs of contacts, and a ground current relay for energizing said change-over relay.

5. A protective system adapted for use in a grounded neutral system including a high resistance to ground or non-grounded system, a power station, a transmission line of such a nature that the faulty ground current is often lower than the load current in line, a circuit interrupter having a tripping coil for cutting out said line from said power station, a directional power relay for controlling the circuit of said tripping coil of said interrupter, said relay comprising a contact-carrying movable armature which is actuated in one direction in accordance with the ground current when said line is grounded, so as to prepare one tripping circuit, and is actuated in the opposite direction in response to short-circuit current in said line, so as to prepare another tripping circuit, a current relay energized by said ground current for completing a control circuit, and a second current relay included in said control circuit for reversing the tripping circuit completed through said armature.

In witness whereof I affix my signature.

SHIZUO SUNAIRI.