Aug. 19, 1947. S. L. GOLDSBOROUGH 2,425,735

IMPEDANCE TYPE DISTANCE RELAY

Filed March 29, 1945

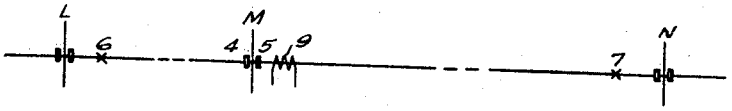


Fig. 1.

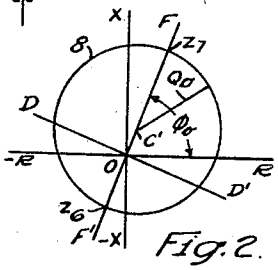


Fig. 2.

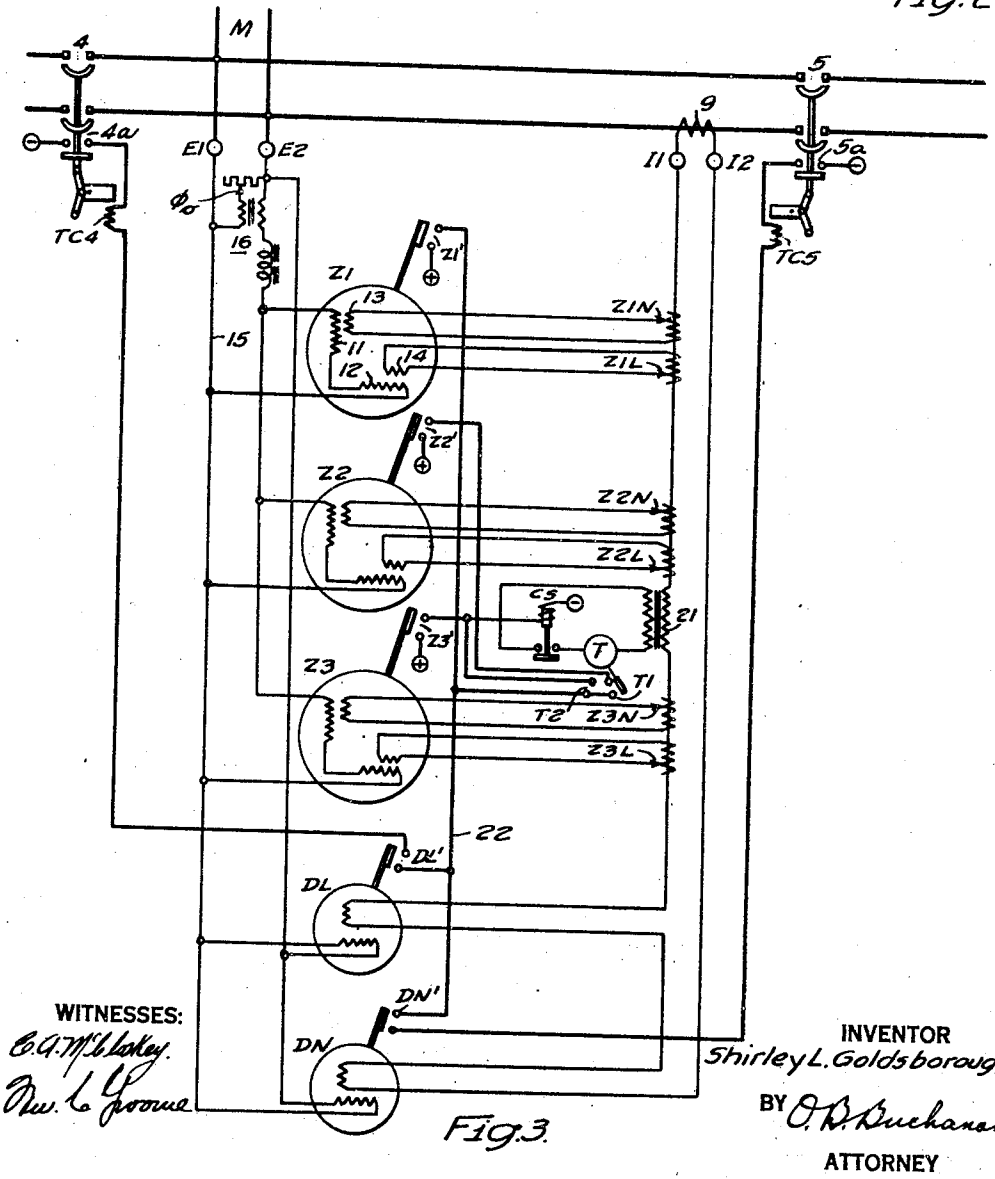


Fig. 3.

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Patented Aug. 19, 1947

2,425,735

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2,425,735

IMPEDANCE TYPE DISTANCE RELAY

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Application March 29, 1945, Serial No. 585,523

2 Claims. (Cl. 175—294)

1

My invention relates to improvements in distance-relays, to reduce the number required.

There is a considerable field of application for distance-relays on low-voltage transmission lines. However, so far, the cost of this type of relay has prevented its widespread use on such lines. Any system or arrangement which reduces the required number of relays would help to encourage their use.

For many years, it has been known that there are types of transmission systems, fairly common in low-voltage lines, and less common in high-voltage lines, in which there is no substantial back-feed from the low-voltage side of the sub-station to the transmission-line, in case of a fault; and it often happens, in such cases, that there is just one incoming transmission-line and one outgoing transmission-line. My present invention relates to such cases, and it has the object of reducing the number of distance relays to one-half, by utilizing one set of relays to protect the two transmission lines. This has been impossible, with the old type of impedance relay, which balanced the line-current against the line-voltage, because said impedance relay would always "see" the same distance in both directions, that is, for both directions of current-flow, so that it would respond for faults at equal distances both east and west of the substation where the relays are located. In general, a distance-relay response, to faults at the same distance on both sides of the relaying station, cannot be utilized, because it almost never happens that the lengths of the protected line-sections on opposite sides of the station are identical with each other.

However, a new type of directionally modified impedance-relay has recently been developed, having an adjustable characteristic, enabling it to be set so that its "balance points" in the two different directions can be made to occur at different distances, and along any desired impedance-angle line, corresponding to the impedance-angle characteristic of the transmission-line. Such adjustable modified impedance-relays are shown in my application Serial No. 547,561, filed August 1, 1944, as a continuation-in-part of my application Serial No. 504,695, filed October 2, 1943, for Long-line fault-detectors and relaying-systems. Another form of embodiment of relays having an adjustable modified impedance-characteristic, utilizing wattmetric or product-responsive elements, is shown in my application Serial No. 578,158 filed February 16, 1945. Still other forms of adjustable modified impedance relays are shown in two Sonnemann applications, Serial

2

Nos. 578,263 and 582,884, filed February 16, 1945, and March 15, 1945, respectively, and in a Lenehan application, Serial No. 578,161, filed February 16, 1945. There are also other possible arrangements for obtaining an adjustable modified impedance-response.

The object of my present invention is to provide a single set of distance-relays, located at an intermediate substation along a transmission-line, that is, a substation having an incoming line-section and an outgoing line-section, said single set of distance-relays utilizing current from only one of the line-sections, and being set so as to respond to faults up to the proper distance out from the sub-station in the direction of that one of the line-sections, but also being set to respond, in the opposite direction, to a different distance, corresponding to the transmission-system conditions on the other side of the relaying station. I then utilize a directional element or elements, having two different contact-members, for selecting the proper circuit-breaker, on either side of the relaying substation, depending upon the direction of the fault-current.

In the accompanying drawing,

Figure 1 is a single-line diagram of an alternating-current transmission-system (usually a three-phase system) of the type to which my invention is particularly applicable.

Fig. 2 is a curve-diagram showing the response-characteristic of one of the distance-relays, and

Fig. 3 is a diagrammatic view of circuits and connections for a complete set of relays for one of the phases of the transmission system at one of the substations thereof.

In Fig. 1, I have shown, in single-line diagram, three substations, L, M and N, of a three-phase transmission-line, for example. By way of illustration, I have indicated a short line-section L—M, followed by a long line-section M—N. A circuit breaker is provided on each side of each of the substation-buses L, M and N, the two breakers at the substation M being indicated at 4 and 5 in Fig. 1. These breakers are frequently gang-operated three-phase breakers, although they may be single-pole breakers.

A protective relaying system, utilizing distance-responsive relays, requires relays which are set to fairly precisely predetermined "balanced points," or distances, in the "internal fault" direction, having some precise reference to the lengths of the line section or sections in the "internal fault" direction from the relaying station, that is, in the direction in which the line-current flows when there is an internal fault within the

confines of the particular line-section being considered. These distance-relays are usually utilized in sets, designated first-zone, second-zone, and third-zone relays, responding to faults located at successively increasing distances, out from the relaying station. The first-zone relays are usually set to respond to, say, 80% of the length of the protected line-section; the second-zone relays will have a balanced-point, say, about the middle of the second line-section beyond the relaying point; and the third-zone elements will respond to still more remote faults. In the ordinary case, the substations are located at convenient locations with respect to load-centers and other considerations, so that, generally speaking, no two line-sections, between successive substations, have the same length; and there are usually rather wide differences between the lengths of different line-sections.

Thus, considering the first-zone relays located at the substation M in Fig. 1, it will be seen that the west-line relays, protecting the west line-section M—L, should have a rather short distance-setting M—6, because the line-section M—L is relatively short, whereas the east-line relays will have a much longer distance-setting M—7, corresponding to the relatively longer east line M—N.

Fig. 2 shows the circular response-characteristic 8 of a modified impedance relay for the line-section M—N at the station M, that is, a distance-relay having a voltage-response to the line-voltage at the bus M, and having a current-response to the line-current in the section M—N adjacent to the bus M, as indicated by the line-current transformer 9 in Fig. 1. In Fig. 2, the line-impedances have been plotted on rectangular coordinates of line-resistance R and line-reactance X, in a familiar manner; and the circle 8 represents the locus of the line-impedance conditions at the balance-points of the relay at all possible phase-angles throughout the 360°. The relay responds to any line-impedance conditions falling inside of the circle 8.

So far as fault-current responses are concerned, the important points of the response-circle 8, in Fig. 2, are the two intercepts Z_7 and Z_6 on the fault-line F—F', which passes through the origin O at an angle ϕ_0 corresponding to the impedance-angle of the line-impedance. As previously indicated, there are several modern adjustable impedance-relays, having modified impedance-characteristics which can be adjusted for the fault-impedance angle ϕ_0, and for the two intercepts Z_7 and Z_6 of the circle 8 on the fault-line F—F' which is disposed at said angle ϕ_0 with respect to the R-axis.

In accordance with my invention, the relay-characteristics of the distance-relay for the line-section M—N at the station M are so chosen that the distance-response Z_7 in the internal-fault direction is the proper response for the protection of the aforesaid line-section M—N, whether for the first-zone, second-zone, or third-zone distance-relay for that section, as the case may be. At the same time, without disturbing the Z_7 distance-setting or intercept, the relay-characteristics are so adjusted that the reverse-current distance-setting or intercept Z_6 reaches out to the proper distance for the protection of the other line-section M—L at the substation M.

Fig. 3 shows, in a simplified form, the complete relaying equipment which is necessary, in accordance with my present invention, to protect both of the line-sections M—N and M—L, for one of the phases of the transmission-system, at the

substation M. By "protecting" the line, I mean, of course, controlling the respective circuit-breakers 5 and 4, so as to segregate a faulty line-section from the rest of the transmission-system.

In Fig. 3, the circuit-breakers 4 and 5 are provided with trip-coils TC4 and TC5, respectively, and also make-contact auxiliary switches 4*a* and 5*a*, respectively.

In Fig. 3, I have also shown three distance-relays Z1, Z2 and Z3, of the modified-impedance type utilizing directional responses as described and claimed in my third copending application, previously mentioned; although, in general, I wish these distance-elements to be regarded as representative of any convenient type of distance-element having modified characteristics which can be set to suit the exigencies of the transmission-system to which they are applied.

In Fig. 3, I have also shown two directional elements DN and DL, for responding to internal and external fault-current directions, respectively, these directional elements being simply wattmetric elements energized so as to be preferentially responsive to the proper phase-angles and directions, as is well understood. While I have shown two separate directional elements DN and DL, for the "internal" and "external" fault-current directions, respectively, I wish it to be understood that such representation is intended to be broadly representative of any kind of directional means for closing the directional contacts DN' or DL', as the case may be, according as the fault-currents may be flowing in the direction from the bus M to the bus N, or from the bus N to the bus M, which is to say, from the bus M to the bus L. The balance-points of the directional elements DL and DN are indicated in Fig. 2 by the line DD'.

Aside from the line-current transformer 9, a contactor-switch CS, a timer T, and various auxiliary current-transformers, this represents the entire relaying-equipment which is necessary, at the substation M, for protecting one phase of both of the line-sections M—N and M—L at the substation M.

Referring to the connections shown in Fig. 3, a description of one of the distance-elements Z1, Z2 or Z3, will suffice for all, because the only difference between them is, or may be, the particular characteristic distance-settings, to which the several elements are adjusted. Referring to the first-zone distance-element Z1, which is characterized by the letter Z to indicate impedance, and the numeral 1 to indicate the zone, this relay is indicated as being of the "wattmetric" or product-type, which responds to the product of two fluxes, represented schematically by the vertical coils and horizontal coils, respectively. Each of these fluxes is the vectorial sum of a voltage-responsive flux and a current-responsive flux, as produced by the two voltage-coils 11 and 12 and the two current-coils 13 and 14.

The voltage-coils 11 and 12 of the impedance-relay Z1 are energized from a derived-voltage relaying-bus 15, having an adjustable phase-angle with respect to the voltage-terminals E1 and E2 of the relays, this phase-shift being brought about by any suitable phase-shifting equipment such as that which is shown at 16, having an adjustment ϕ_0 which can be directly calibrated in terms of the fault-angle ϕ_0 to which it is desired that the distance-relays shall respond. The particular phase-shifting equipment 16, which is illustrated in Fig. 3, is the subject mat-

ter of a Carlin application Serial No. 583,926, filed March 21, 1945.

The current-coils 13 and 14 of the impedance-relays Z1 are energized, respectively, from two adjustable current-transformers Z1N and Z1L, which are supplied with the line-current obtained from the current-terminals I1 and I2 of the relay. The adjustments of the auxiliary current-transformers Z1N and Z1L control the two fault-settings of the relay, or the two impedance-values or distances O—Z_7 and O—Z_6 in Fig. 2, and hence these calibrations Z1N and Z1L can be directly calibrated in line-impedance ohms (or distances) corresponding to the two desired-intercepts Z_7 and Z_6 of the relay response-circle 8 on the fault-line F—F' in Fig. 2.

The relay voltage-terminals E1 and E2 may be energized so as to be responsive to the line-voltage, or to any desired phase or component of the line-voltage, as by being connected to the bus M, either directly or through potential-transformers (not shown), as will be readily understood. The relay current-terminals I1 and I2 are energized so as to be responsive to the line-currents, or to the proper phase or components of the line-currents. In the simple case illustrated, in which only one phase is shown, all of the current-responsive elements are energized from the same current-terminals I1 and I2, which are in turn energized from a single line-current transformer 9. It will be understood, of course, that different line-currents or different phases of the line-current can be chosen for the current-energization of the different relays, as is well known in the art.

The respective relay-contacts of the first, second, and third-zone impedance-relays Z1, Z2 and Z3 are indicated at Z1', Z2', and Z3'. The third-zone contact Z3' is utilized to energize the operating coil of the contactor-switch CS, which is in turn utilized to energize the timer T from an auxiliary saturating current-transformer 21 which is energized from the line-current. The timer T has a first and second set of timing-contacts T1 and T2, which are closed after different time-periods.

The circuit-breaker tripping-circuits are indicated in Fig. 3, and may be traced as follows. The first part of the tripping-circuit, up to a relaying-bus 22, is common to both of the circuit-breakers 4 and 5. This common portion of the tripping-circuits is in three branches: first from the positive bus (+) through the Z1-contact Z1' to the relaying-bus 22; second, from the positive bus (+) to the Z2-contact Z2' and the first timer-contact T1 to the same relaying bus 22; and third, from the positive bus (+) through the Z3-contact Z3' and the second timer-contact T2 to the same relaying bus 22. At the relaying bus 22, the respective directional contacts DL' and DN' will continue the tripping-circuit either to the trip-coil TC4 or the trip-coil TC5, according to the direction of the fault-current. The respective tripping circuits are completed through the auxiliary switches 4a and 5a, respectively, and thence to the negative bus (—).

It will thus be observed that the complete relaying system, for protecting both the incoming and outgoing line-sections at the substation M,

requires only one set of distance-relays Z1, Z2 and Z3, instead of requiring two sets, one for each protected line-section, as has universally been the practice with distance-relays as heretofore utilized.

While I have illustrated my invention in a single illustrative form of embodiment, I wish such illustration to be regarded as illustrative, and not by way of limitation on my invention, as many changes of omission, addition, and substitution of equivalents, may be made by those skilled in the art, without departing from the essential spirit of my invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. Protective relaying equipment particularly adapted for a substation having only one incoming line and one outgoing line, with substantially no feedback from the station-connected apparatus to a line-fault, said incoming and outgoing lines being of different impedances, said protective relaying equipment comprising a line-condition-responsive modified-impedance relay having its response-circle displaced so that said relay has the proper distance-reach for faults in the two opposite directions, in combination with line-condition-responsive directional relaying-means for providing two separate directional responses for the respective directions, means for performing a relaying function for one of said lines in joint response to said modified-impedance relay and one of said directional responses, and means for performing a relaying function for the other line in joint response to the same modified-impedance relay and the other directional response.

2. Protective relaying equipment for controlling the circuit-breakers at an intermediate substation along a transmission-line, said substation having an incoming line-section and an outgoing line-section of different lengths, said protective relaying equipment comprising a distance-relay utilizing voltage from the transmission-line and current from only one of said line-sections, said distance-relay being set so as to respond to faults up to the proper distance out from the substation in the direction of that one of the line-sections, but also being set to respond, in the opposite direction, to a different distance, corresponding to the transmission-line conditions on the other side of the substation, in combination with directional relaying-means, having two different contact-members, for selecting the proper circuit-breaker, on either side of the substation, in response to the direction of the fault-current of the transmission-line, whenever said distance-relay responds.

SHIRLEY L. GOLDSBOROUGH.

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