March 20, 1945. S. L. GOLDSBOROUGH 2,372,078

CARRIER RELAYING

Filed Dec. 8, 1942

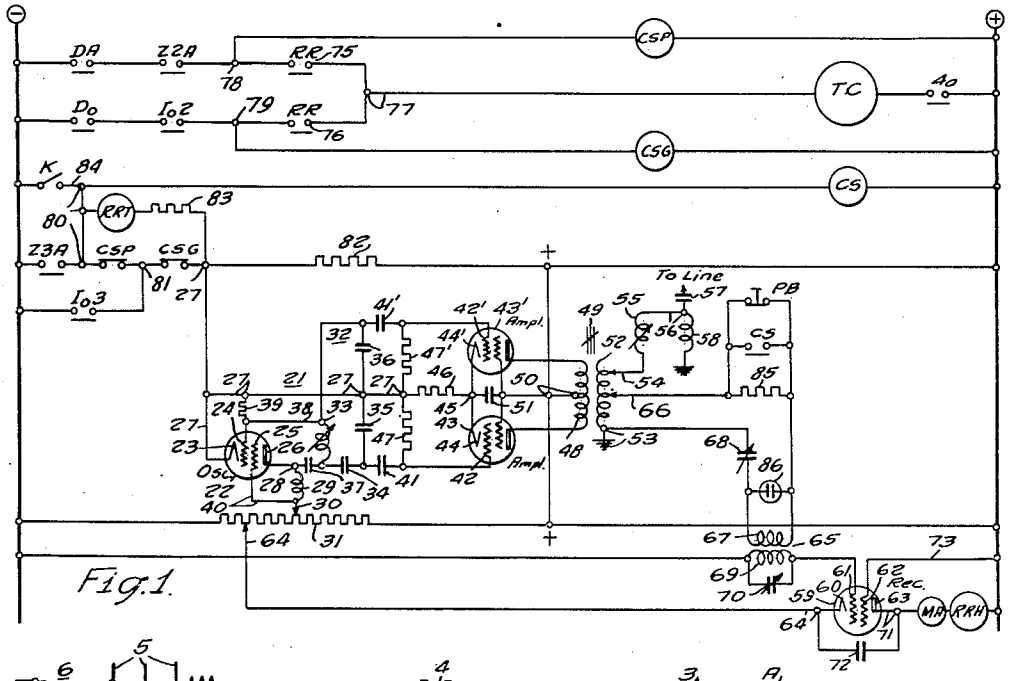


Fig. 1.

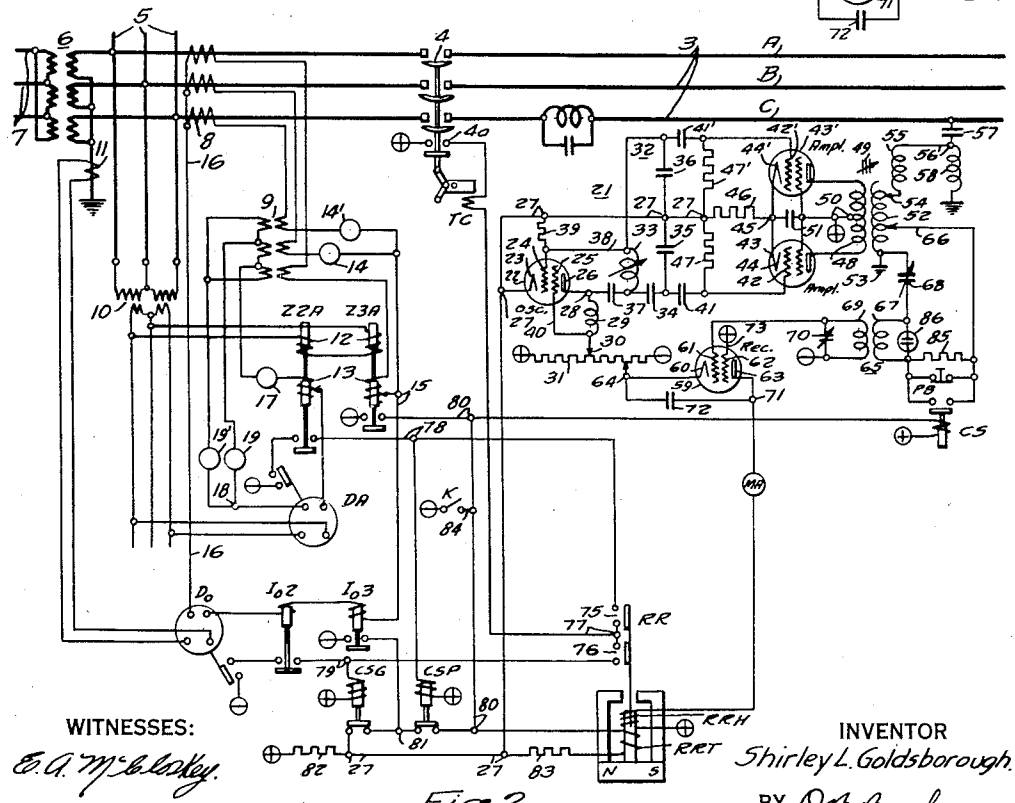


Fig. 2.

WITNESSES:

E. A. McCloskey.

INVENTOR

Shirley L. Goldsborough.

BY O. B. Buchanan

ATTORNEY

Patented Mar. 20, 1945

2,372,078

UNITED STATES PATENT OFFICE

2,372,078

CARRIER RELAYING

Shirley L. Goldsborough, Basking Ridge, N. J., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application December 8, 1942, Serial No. 468,229

2 Claims. (Cl. 175—294)

My invention relates to carrier-supervised protective relaying systems for protecting transmission lines against faults, and it has particular relation to the provision of means for making it possible to utilize the carrier with a desensitized receiver, for purposes other than fault-protection, as in the detection of sleet on the transmission wires, without impairing the full sensitivity and operativeness of the receiver for the proper coordination of the fault-detection, in the event that a fault should occur during the desensitized operation of the carrier-current equipment.

The object of my invention is to provide a system whereby the results just mentioned may be accomplished.

An exemplary form of embodiment of my invention is shown in the drawing, wherein Fig. 1 is a schematic diagram of the direct-current connections, showing a simplified apparatus for illustrating the application of my invention, and Fig. 2 is a wiring diagram showing the alternating-current connections as well as the direct-current connections.

In Fig. 2, I have illustrated my invention as being applied to the protection of one end of a three-phase transmission-line section 3, the three phase-conductors being distinguished by the letters A, B and C. The line-section 3 is connected, through a circuit breaker 4, to a bus 5, which is energized, through delta-star step-up transformers 6, from a generator-bus or supply-line 7.

Various line-responsive relays are provided, which are supplied with energy by means of a bank of line-current transformers 8 which produce the relaying currents I_A, I_B and I_C, corresponding to the three line-phases; a bank of auxiliary current-transformers 9, which produce the relaying currents $(I_A—I_B)$, $(I_B—I_C)$, $(I_C—I_A)$; a bank of potential transformers 10, for supplying the relaying voltages, and an auxiliary current-transformer 11 which is connected in the grounded neutral of the line-connected star-side of the power-transformers 6, for obtaining a convenient source of reference-current for determining the direction of the residual line-currents, as will be subsequently described.

The circuit breaker 4 is provided with a trip-coil TC, which is energized, in accordance with the protective relay means (subsequently described), through an auxiliary breaker-switch 4*a*, and a direct-current source which is symbolized by the battery-terminals (+) and (—).

My invention is illustrated as being applied to a relaying system of a type utilizing a number of phase-fault impedance-relays in each phase, said relays being of increasing sensitivities corresponding to what is known as "first-zone," "second-zone" and "third-zone" operation, the different zones being indicated by the numerals 1, 2 and 3, and the different phases being distinguished by the letters A, B, and C. As this type of relaying-system is well known, it has not been shown in its entirety, but I have selected the second and third-zone impedance relays of phase-A to illustrate my invention, as indicated at Z2A and Z3A. Each impedance-relay element consists of a voltage-responsive restraining-coil 12 and a current-responsive operating-coil 13, suitably energized, in any desired manner, so that the relay is responsive to the line-impedance.

The illustrated relaying-system also utilizes phase-fault-responsive directional elements, which are represented by the phase-A directional element DA, a residual-current directional element D_0, and a number of ground-fault detector-elements of different sensitivities, represented by the elements I_02 and I_03, the latter being the more sensitive. Each of the relaying elements Z2A, Z3A, DA, D_0, I_02 and I_03 has a single make-contact, which is sufficiently identified by designating it with the corresponding relay-designation such as Z2A, etc.

The particular energizing-connections for these relays, as illustrated in Fig. 2, include the energization of the Z3A operating-coil 13 in response to the line-current I_A, said coil being interposed between the phase-A line-current transformer 8 and a neutral conductor 15. Auxiliary relaying apparatus, symbolically indicated at 14 and 14', is energized responsively to the two other line-currents, and also connected to the neutral conductor 15, so that the residual or zero-phase-sequence currents flow through this neutral conductor, and are then supplied to the three ground-fault relays I_03, I_02 and D_0, the circuit being completed with the neutral conductor 16 of the star-connected line-current transformers 8. The polarizing winding of the ground-directional element D_0 is illustrated as being energized from the grounded-neutral transformer 11.

The operating coil 13 of the Z2A relay, and the directional-winding terminals of the phase-directional relay DA, are shown as being energized responsively to the delta-current $(I_A—I_B)$, supplied from the auxiliary transformers 9, in a circuit including other relaying equipment which has been symbolized at 17, and terminating with a star-point connection 18. The other two delta currents are supplied to the star-point 18,

through other relaying equipment symbolized at 19 and 19'. While one particular type of relay-energization, and relay-response, has been illustrated, it is to be understood that my invention is not limited to the precise type of relay.

The relaying system also includes a carrier-current transmitter 21, which comprises an oscillator-tube 22, illustrated as comprising a cathode 23, a grid 24, a screen 25, and an anode or plate 26. The cathode 23 is connected to a cathode-circuit 27 which is adapted to be connected to the negative battery-terminal (—) through the fault-responsive relaying equipment, the circuits of which will be subsequently described. The anode 26 is connected to a plate-circuit 28 which is connected, through a high-frequency choke-coil 29, to a source of positive potential, indicated as being a tap 30 on a potentiometer 31 which is energized across the battery-terminals (+) and (—).

The oscillator-tube 22 is caused to oscillate at a predetermined radio or carrier-current frequency by means of a tuned circuit 32 which is illustrated as comprising a variometer 33 and three capacitors 34, 35 and 36. One terminal of the variometer 33 is connected, through a blocking-capacitor 37, to the plate-circuit 28. The other terminal of the variometer 33 is connected, at 38, to the grid 24, the grid being also connected to the cathode-circuit 27 through a grid-leak resistor 39. The screen 25 is connected to the positive terminal 30 through a conductor 40.

The cathode-circuit 27 of the oscillator is connected to the mid-point between the two capacitors 35 and 36 of the tuned oscillator-circuit 32, these capacitors being matched capacitors, the other terminals of which are connected, through blocking-capacitors 41 and 41', to the grids 42, 42' of two push-pull amplifier-tubes 43, 43'. The cathodes 44 and 44' of the two amplifier-tubes 43, 43' are connected together at 45, and connected to the oscillator-cathode circuit 27 through a biasing resistor 46. The two amplifier-grids 42 and 42' are similarly connected to the oscillator-cathode circuit 27 through two biasing-resistors 47 and 47'. The plates of the amplifier-tubes 43, 43' are connected to the respective terminals of the primary winding 48 of a radio-frequency transformer 49. The transformer-primary 48 has a mid-point-tap 50, which is connected to the positive battery-terminal (+), and which is also connected to the screens of the two amplifier-tubes 43, 43'. This mid-point-tap 50 is also coupled to the two amplifier-cathodes 44, 44', through a blocking-capacitor 51.

The output of the radio-frequency transformer 49 is coupled to one of the conductors of the protected line-section 3 by means of a secondary winding 52 of said radio-frequency transformer. One terminal of this secondary winding 52 is grounded, as indicated at 53, and a tap 54 is provided to energize a variometer 55 which is connected, at 56, to a coupling-capacitor 57 which is shown as being connected to the phase-C line-conductor. The connecting-point 56 is also connected to ground through a choke-coil 58.

In addition to the carrier-current transmitter, which has just been described, I also provide a carrier-current receiver, which is illustrated as comprising a receiver-tube 59, having a cathode 60, a grid 61, a screen 62, and a plate or anode 63. The receiver-cathode 60 is connected, at 64, to a suitable source of negative potential, indicated as being a tap on the potentiometer 31. The receiver-grid 61 is energized, through a coupling-transformer 65, from a tap 66 on the secondary winding 52 of the radio-frequency transformer 49. Thus, one terminal of the primary winding 67 of the coupling-transformer 65 is connected, through a push-button PB, to the tap-point 66 of the secondary winding 52, while the other terminal of the primary winding 67 is connected to the ground-point 53 through a tuning-capacitor 68. One terminal of the secondary winding 69 of the coupling-transformer 65 is connected to the negative battery-terminal (—), while the other terminal is connected to the receiver-grid 61. This secondary winding 69 is also shunted by a tuning-capacitor 70.

The receiver-anode 63 is connected to a plate-circuit 71 which is, in turn, connected, through a milliammeter MA, to one terminal of a holding-coil RRH of a receiver-relay RR, the other terminal of the holding-coil being connected to the positive battery-terminal (+). The high-frequency component of the receiver-tube current is kept out of the holding-coil RRH by means of a by-pass-capacitor 72, which is connected between the receiver-plate circuit 71 and the receiver-cathode circuit 64. The essential circuit-connections for the receiver-tube 59 are completed by a connection 73 from the receiver-screen 62 to the positive battery-terminal (+).

The receiver-relay RR is illustrated in Fig. 2 as a polarized relay having a tripping-coil RRT for energizing it in a direction to close its two contacts 75 and 76, this tripping-coil RRT being not as strong as the holding-coil RRH, so that the receiver-relay will not respond to the tripping-coil RRT unless the holding-coil RRH is substantially deenergized. The two receiver-relay contacts 75 and 76 have a common terminal 77 which constitutes the tripping-circuit of the circuit-breaker 4, for energizing the trip-coil TC through the auxiliary breaker-switch 4a and the positive battery-terminal (+).

The various relaying-controls exercised by the line-responsive relays can now be described. The contacts of the phase-directional relay DA and the second-zone (or less sensitive) phase-fault detector Z2A are utilized to control a relaying-circuit 78, the energization of which can be traced, from the negative battery-terminal (—), through the DA contact and the Z2A contact, and thence to the aforesaid relaying-circuit 78. This relaying-circuit 78 is utilized for two purposes: in one branch, it is connected to the receiver-relay contact 75, and thence to the tripping-circuit 77; while in another branch, this relaying-circuit 78 energizes an auxiliary phase-fault relay CSP, which is thus energized in response to a phase-fault which is accompanied by an inward direction of line-current flow, such as will actuate the directional element DA.

A second relaying-circuit 79 is similarly energized in response to ground-faults, in a circuit which can be traced from the negative battery-terminal (—), through the D_0 contact and the I_{02} contact, and thence to said relaying-circuit 79. One branch of this relaying-circuit energizes the trip-circuit 77 through the second receiver-relay contact 76, while another branch of this relaying-circuit 79 energizes a directional ground-fault-responsive auxiliary switch CSG.

A third relaying-circuit 80 is energized from the negative bus (—) through the Z3A contact, and it is utilized for several different purposes. One branch of the relaying-circuit 80 extends through the back-contact of the CSP relay to a relaying-circuit or conductor 81, and thence

through the back-contact of the CSG relay to the cathode-circuit 27 of the oscillator-tube 22. The effect of this connection is to make the oscillator-cathode 23 negative, and thus to start carrier-current transmission. When the negative cathode-connection from the cathode-circuit 27 to the negative battery-terminal (—), through the three relay-contacts CSG, CSP and Z3A is broken, carrier-current transmission is prevented, by means of a resistance 82 which is connected between the cathode-circuit 27 and the positive battery-terminal (+), so that the oscillator-cathode 23 is held at a positive potential, rather than a negative potential, at all times, except when a direct connection is made from the cathode-circuit 27 to the negative source.

The receiver-relay tripping-coil RRT, in series with a resistance 83, is connected across the two serially-connected back-contacts of the auxiliary directional relays CSP and CSG, so that this receiver-relay tripping-coil is normally short-circuited by these CSP and CSG back-contacts.

Connected between the intermediate point 81 and the negative terminal, is the sensitive ground-detector contact $I_0$3, which is thus placed in shunt-circuit relation to the two contacts Z3A and CSP, in the carrier-starting control, so that, when there is a ground-fault, the ground-fault relays $I_0$3 and CSG take precedence over the phase-fault relays Z3A and CSP in controlling the transmission of carrier.

I have also shown an "other uses" control-contact K, connected, at 84, between the relaying-bus 80 and the negative battery-terminal (—), for the purpose of initiating carrier-current transmission for testing, telemetering, communication, or other purposes. It will thus be noted that the fault-directional contacts CSP and CSG are both in series with the K-contact, in the transmission-controlling circuit, so that, in the event of a line-fault, accompanied by an internal direction, or by a direction accompanied by a line-current flowing into the protected line-section 3, the carrier-current transmission can be interrupted, at all times, by an actuation of one of the auxiliary directional relays CSP or CSG, as is necessary in the proper operation of the protective apparatus.

In accordance with my invention, I provide an auxiliary contactor-switch CS, or other means responsive to a carrier-starting fault-indication, and I have also provided the previously mentioned push-button PB, and also a resistance 85 which is normally shunted by the push-button PB. The operating-coil of the auxiliary contactor-switch CS is energized from the relaying-bus 80, being connected between said bus and the positive battery-terminal (+), so that it is energized, in response to a sensitive phase-fault-determination, by the relay Z3A, or it may also be energized in response to a sensitive ground-fault determination, by the relay $I_0$3, if the latter picks up in response to a fault which does not result in the energization of the CSP relay, the latter circuit being traceable from the negative bus (—), the $I_0$3 contact, the conductor 81, the CSP contact, the relaying-circuit 80, and the CS coil. The CS contactor or relay has a make-contact which is connected in shunt across the push-button PB, and across the resistance 85, so as to make sure that the resistance 85 is short-circuited whenever there is a fault on the transmission system.

In operation, the fault-responsive part of the equipment operates in the manner which is now common in this country. The system is one which requires carrier-current reception, (in the energization of the receiver-relay holding-coil RRH), in order to prevent an erroneous tripping-operation in the event of a "through"-fault, or fault somewhere beyond the other end of the protected line-section 3. It will be understood that the protective equipment will be the same, or similar, at the two ends of the protected line-section, and that the two transmitters 21 will be tuned to the same carrier-current frequency, so that the receivers 59 and RR at both ends of the protected line-section will be energized if either transmitter is operating. When a fault occurs, a sensitive, fault-detector, such as Z3A or $I_0$3, first initiates carrier-current transmission. The initiation of carrier-current transmission instantly energizes the receiver-relay holding-coil RRH, and thus prevents the receiver-relay RR from responding to any closing-impulse of its tripping-coil RRT. At either end of the protected line-section, where the fault-current is accompanied by an internal direction, one of the auxiliary directional relays CSP or CSG will respond, opening its back-contact, thus interrupting carrier-current transmission at that end, and simultaneously energizing the receiver-relay trip-coil RRT at that station. If the fault-current direction is an into-the-line-looking direction at both ends of the protected section, carrier will be removed from both ends, and the receiver-relay holding-coils RRH will be deenergized, permitting both receiver-relays RR to respond and complete a tripping-circuit through their contact 75 or 76, according as the fault is a phase-fault or a ground-fault.

In the protective-relay operation of the receiver-tube 59, in accordance with the mode of operation just described, the tube operates as a saturated tube, so that its plate-current is largely independent of the value of its grid-voltage. The receiver-tube 59 is furthermore usually protected by means of a voltage-limiting neon glow-tube 86, which is connected across the terminals of the primary winding 67 of the coupling-transformer 65 which energizes the receiver-grid 61, the function of this glow-tube 86 being to limit the grid-voltage to a certain maximum amount, which is nevertheless enough to fully saturate the tube, but designed to protect the tube from failure as the result of every excessively large received-signals, such as might be obtained from the transmitter 21 at the same station as the receiver.

In accordance with my present invention, means are provided for, at times, operating the receiver-tube 59 in its non-saturated condition, that is, with a grid-voltage which is small enough so that the plate-current of the tube varies approximately in accordance with variations in the grid-voltage. One such non-saturated use of the receiver-relay 59 is in connection with sleet-detection, whereby it is possible to determine the presence or absence of sleet on the protected transmission-line section, by comparing the intensity of the received carrier-current signal with other readings taken at times when there is no sleet.

For the purpose of detecting small changes in the received carrier-current signal, I utilize any suitable desensitizing means in connection with the receiver-tube 59, this means being illustrated in the form of the resistor 85 in series with the supply-circuit to the coupling-transformer 65 which feeds the receiver-grid 61. The resistance 85 is normally short-circuited by the normally closed contacts of the push-button PB, so that,

under these conditions, the receiver-grid 61 always receives enough carrier-current voltage, when either carrier-current transmitter is operating, so that the receiver-tube 59 will be operating in its saturated range, in which its plate current is a maximum and is not greatly affected by the magnitude of the carrier-current signal. When it is desired to test for sleet, the receiver-desensitizing push-button PB is depressed, and at the same time the carrier-current starting-control switch K is closed, at the other end of the protected line-section, and the magnitude of the receiver plate-current is determined, as by means of a reading of the milliammeter MA in the plate-circuit 71 of the receiver-tube 59.

If a fault should occur on the transmission system, at a time when an operator is testing the line for sleet, by desensitizing the carrier-current receiver, it is necessary to instantly restore the intensity of the received carrier-current signal, in order to enable the receiver-tube 59 to deliver sufficient plate-current to adequately energize the receiver-relay holding-coil RRH, so as to prevent an unwanted tripping-operation in the event of a "through"-fault. To this end, the auxiliary contactor-switch CS is provided, which closes its make-contact, and re-short-circuits the grid-circuit resistance 85, even though the push-button PB might be in its open position at the moment. By making the contactor-switch CS as fast, in its operation, or faster, than the auxiliary directional relays CSP or CSG, it is possible to make sure that the operativeness of the receiver-relay holding-coil RRH is restored, before the receiver-relay trip-coil RRT can be energized in response to an operation of one of the auxiliary directional relays CSP or CSG.

While I have described my invention in a single illustrative form of embodiment, which is at present the preferred form of embodiment, I wish it to be understood that my invention is not limited to this precise form, and I desire that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. A carrier-current protective relaying system, comprising the combination, with a transmission-line section having circuit-interrupting means to be protectively controlled, of protective relaying-apparatus including carrier-current transmitting and receiving-means coupled to the line-section, line-fault-responsive relaying-means for controlling both the carrier-current means and the circuit-interrupting means in a manner requiring a predeterminedly strong receipt of carrier to block erroneous circuit-interrupter operations under some fault-conditions involving faults on the transmission system but not in the protected line-section, the carrier-current receiving-means being normally in a sensitive receiving-condition for receiving a strong carrier-signal but operating saturatedly to produce a receiver-current which is approximately limited to said required predeterminedly strong receipt of carrier, "other-uses" means for at times controlling the carrier-current means in such manner as to desensitize the carrier-current receiving-means so that it will operate substantially unsaturatedly to produce a weakened receiver-current which is approximately proportionate to the strength of the received carrier-signal, "other-uses" means for responding to the magnitude of the weakened receiver-current, and protective-relay-means for giving preferential carrier-current control to the line-fault-responsive relaying-means at all times, including fault-responsive means for restoring the sensitivity of the carrier-current receiving-means so that it will operate saturatedly to provide the required predeterminedly strong receipt of carrier.

2. The invention as defined in claim 1, characterized by said carrier-current receiving-means including a receiver-relay having a trip-coil means and a holding-coil means, the latter being responsive to the receiver-current, and said line-fault-responsive relaying-means including means for initiating carrier-current transmission and means for energizing the trip-coil means of the receiver-relay, as well as the means for restoring the sensitivity of the carrier-current receiving-means, the times of operation being such that the carrier-current transmission is initiated and the receiving-means sensitivity is restored at least as soon as the trip-coil means of the receiver-relay is energized.

SHIRLEY L. GOLDSBOROUGH.