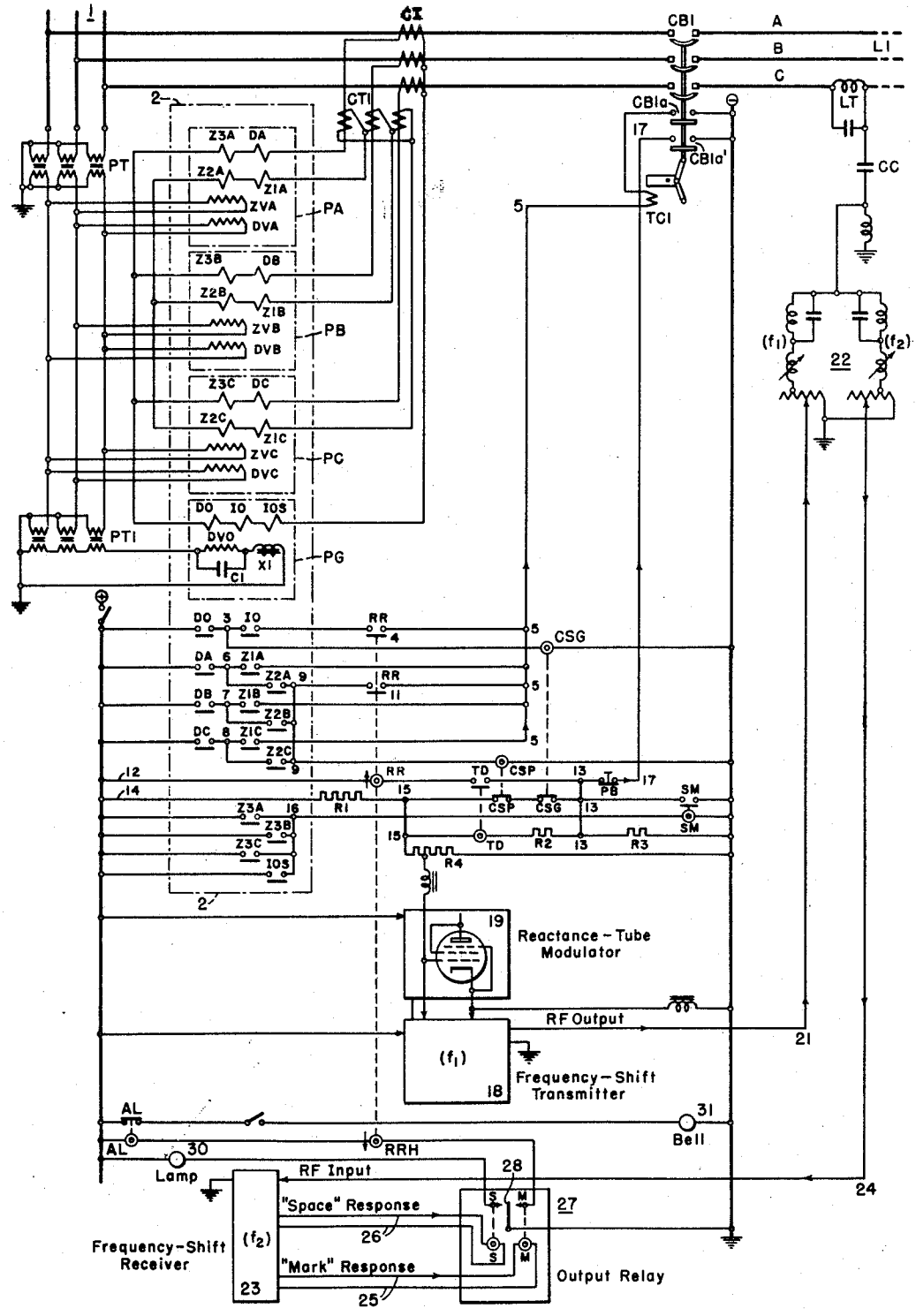
July 28, 1959 H. W. LENSNER ET AL 2,897,406

FREQUENCY-SHIFT CARRIER DISTANCE RELAY

Filed Sept. 15, 1955



United States Patent Office 2,897,406
Patented July 28, 1959

2,897,406

FREQUENCY-SHIFT CARRIER DISTANCE RELAY

Herbert W. Lensner, East Orange, and George D. Rockefeller, Jr., Morris Plains, N.J., assignors to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application September 15, 1955, Serial No. 534,580

10 Claims. (Cl. 317—27)

Our invention relates to improvements in protective relaying-equipment for the fault-protection of a line-section of a commercial-frequency power-line. It aims at the application of frequency-shift carrier to protective systems in which carrier, or other communicating-channel means, is used in conjunction with directional-distance relays such as have been well established for the protection of transmission lines. The directional-distance relay-system offers a high degree of flexibility in the operation of power systems, and is suited to system-expansion without becoming obsolete. In some sections of the country, carrier for relaying purposes and for other services has so saturated the available frequency-spectrum that it has become difficult to find frequencies for new relaying-channels when needed. In many applications, also, the attenuation of carrier-frequencies is sometimes objectionably, and even prohibitively, high, particularly in applications of carrier relaying to power-cables.

The introduction of frequency-shift carrier to a number of communication services such as telemetering and supervisory control has heretofore proved to be an acceptable solution to the problems of limited channel-space and high attenuation. With crystal-control of the frequencies, this type of channel requires only a very narrow bandwidth in the frequency-spectrum. It provides improved sensitivity, a lower response to noise and other disturbances, and a smaller bandwidth which allows expansion of carrier-current equipment.

Our present invention applies this frequency-shift carrier-system to the well-known directional-distance relay-system, with slight variations in the manner of use of the protective relaying equipment, and with provision for not only a continuous supervision of the carrier-current channel, but also an occasional or periodic check on the ability of the equipment to shift the carrier-current frequency, to make sure that the equipment is always in an operative condition.

An exemplary form of embodiment of our invention is illustrated in the accompanying drawing, the single figure of which is a very much simplified diagram of the essential connections, so far as our present invention is concerned.

The drawing illustrates one terminal of a protected three-phase line-section L1, which is a part of a 60-cycle transmission-line or power-system. The protected line-section L1 is connected to a station-bus 1 through a three-phase line-segregating circuit-breaker CB1, which is illustrated as having two auxiliary make-switches CB1*a* and CB1*a'*, and a trip-coil TC1.

The line-section L1 has three phase-conductors marked A, B and C. It is provided with a directional-distance fault-responsive means 2, which is illustrated as comprising three panels PA, PB, and PC of alternating-current connections for phase-fault protection, a fourth panel PG of alternating-current connections for ground-fault protection, and a group of relay-contacts which are distinctively marked to designate their relation to the alternating-current connection-panels.

The illustrated protective relaying system 2 has four directionally responsive elements D, which are distinguished by additional letters A, B, C, and O for distinguishing between the three line-phases A, B, and C, and the residual or zero-sequence current. This relaying system also comprises first-zone phase-fault distance-responsive elements which are illustrated as impedance-elements Z1A, Z1B, and Z1C, for the three phases A, B, and C, and also second- and third-zone phase-fault impedance-elements Z2A, Z2B, Z2C, and Z3A, Z3B, and Z3C. It will be understood that the third-zone distance-elements are more sensitive than the second-zone elements, so as to be able to reach out and respond to faults in a third protective zone which is more remote from the relaying station than the second distance-zone to which the second-zone elements reach. The illustrated relaying system 2 also includes a sensitive residual overcurrent relay IOS, and a less sensitive residual overcurrent relay IO, the latter having sufficient sensitivity, however, to respond to ground-faults which may lie beyond the remote terminal of the protected line-section L1.

The operating coils and the contacts of the various relays are designated by the letters which constitute the relay-designation, so that the relay-designation is sufficient to indicate both the operating-coils and the contacts of the various elements. The relays are illustrated in their unenergized positions.

The protective relays 2 are energized by line-responsive relaying currents and voltages which are provided by means of line-current transformers CT, potential transformers PT, auxiliary delta-connected current-transformers CT1, and auxiliary open-delta potential transformers PT1.

In the illustrated protective relaying equipment 2, the third-zone phase-fault distance-elements Z3A, Z3B, and Z3C, and the three phase-fault directional elements DA, DB, and DC, have their current-coils energized from the several phase-terminals of the star-connected line-current transformers CT, while the first- and second-zone phase-fault current-coils Z1A to Z2C are energized from the proper terminals of the auxiliary current-transformers CT1, so as to be responsive to the corresponding delta-currents of the protected line-section L1. The three impedance-elements of each of the three line-phases have voltage-restraint windings, which are grouped together under the designations ZVA, ZVB and ZVC, respectively, these windings being energized from the proper delta phases of the potential transformers PT as indicated. In like manner, the three phase-fault directional elements DA, DB, and DC have voltage-responsive polarizing coils DVA, DVB, and DVC which are energized from the proper delta phases of the potential transformers PT.

The ground-fault relaying panel PG has its three current-coils DO, IO, and IOS energized from the residual-current circuit or star-point of the line-current transformers CT. In addition, the directional element DO has a voltage-responsive polarizing winding DVO, which is excited responsively to the zero-sequence line-voltage which is obtained from the auxiliary open-delta potential transformers PT1, through voltage-shifting means which are illustrated in the form of a series choke coil X1 and a parallel capacitor C1 which are respectively connected in series and in parallel to the voltage-coil DVO.

In the drawing, a number of direct-current circuits are indicated, after the fashion of an across-the-line diagram, from a positive relaying bus (+) to a negative relaying bus (−).

A simplified form of the protective relaying circuits is shown, in which the ground-fault directional-relay contact DO is connected between the positive bus and a conductor 3, and thence through a ground-fault relay-contact IO and a contact 4 of an auxiliary receiver-relay

RR, to a tripping circuit 5, which is connected to the trip-coil TC1, and thence through the auxiliary breaker-contact CB1*a* to the negative bus (—). The conductor 3 is also used, in a known way, to energize the operating coil CSG of a ground-fault contactor-switch CSG, the energizing circuit of which is continued on to the negative bus (—).

The three phase-fault directional-relay contacts DA, DB, and DC are used, in a similar manner, to energize the circuits 6, 7, and 8 respectively, which are connected to the tripping circuit 5 through the first-zone phase-fault-relay-contacts Z1A, Z1B, and Z1C respectively. The conductors 6, 7 and 8 are also connected to a conductor 9 through three circuits which respectively include the second-zone phase-fault relay-contacts Z2A, Z2B, and Z2C, respectively, in a known manner. The conductor 9 is used for two purposes. First, it is connected to the tripping conductor 5 through another contact 11 of the auxiliary receiver-relay RR. The conductor 9 is also used to energize the operating coil CSP of a phase-fault contactor-switch CSP, the energizing circuit of which is continued on over to the negative bus (—).

The next line 12 of the wiring diagram shows a receiver-relay operating-coil RR as being connected to a conductor 13 through the make-contact TD of a so-called time-delay relay TD, which is in reality a rather fast relay which operates in some such time as one cycle of the power-current frequency, or usually less, so as to serve as a time-hesitation relay for interposing a little bit of time in effecting the closure of the relay-contacts after the energization of its operating coil TD, as will be subsequently described.

In the drawing, the various electrically operated or controlled relays and contactor-switches are indicated diagrammatically as having operating coils, which are designated by the relay-designation, these coils being shown as circles having small concentric circles inside of the same, the small inner circles representing armatures or other movable relay-elements which are lifted in response to an energization of the operating coils of the respective relays and contactors. The particular element-designation of each relay or contactor is also applied to its contact or contacts, as well as to its operating coil, so as to designate the cooperation between coils and contacts.

The next line 14 of the diagram includes a resistance R1 which is connected between the positive bus (+) and an intermediate conductor 15, which is continued on, through the back-contacts CSP and CSG of the two contactors CSP and CSG, and thence to the previously mentioned conductor 13.

Next below the circuit 14, in the diagram, come four parallel-connected circuits which energize a conductor 16 through any one of the third-zone make-contacts Z3A, Z3B, or Z3C, or through the sensitive ground-fault make-contact IOS, respectively. In accordance with our present invention, the circuit 16 is used to energize the operating coil SM of a sensitively responsive test-canceling relay SM, which will be subsequently described, this relay being responsive to the actuation of any one of the four most sensitive fault-responsive elements Z3A, Z3B, Z3C, and IOS. The energizing circuit of the relay-coil SM is continued on over to the negative bus (—).

The intermediate conductor 15, which was energized in the line 14 of the circuit-diagram, is also used, in our invention, to energize the operating coil TD of the time-delay or time-hesitation relay TD, through a resistance R2 which is connected to the circuit 15, so that the TD coil is energized between the circuits 15 and 13, thus paralleling the two serially connected back-contacts CSP and CSG.

The circuit 13 is connected over to the negative bus (—) through a resistance R3 which has a value approximately equal to the combined resistances of the TD coil and the resistance R2. Normally, however, the conductor 13 is also connected to the negative bus (—) through a circuit comprising the normally closed contact of a testing-pushbutton PB, a circuit-conductor 17, and the auxiliary breaker-switch CB1*a'* which is closed when the breaker is closed. Thus, the resistance R3 is normally short-circuited, when the line is in operation, and the conductor 13 is connected directly to the negative bus (—). According to our invention, the conductor 13 is also connected to the negative bus (—) through the make-contact SM of the sensitive test-canceling relay SM, so as to bypass the testing-pushbutton PB whenever the relay SM is energized by the sensitive fault-detecting elements.

The result of the connections thus far described is that the resistance R1 is normally connected directly across the positive and negative terminals (+) and (—). Thus the intermediate conductor 15 is normally at the potential of the negative bus (—), through a circuit consisting of the back-contacts CSP and CSG, the conductor 13, the test-pushbutton PB, the conductor 17, and the circuit-breaker contact CB1*a'*.

If a ground-fault should occur on the transmission system, accompanied by a fault-power current-flow into the protected line-section L1 at the relaying station, the auxiliary ground-fault contactor CSG will pick up, opening its back-contact CSG, and increasing the potential of the intermediate circuit-conductor 15 from the potential of the negative bus (—), which is indicated, for simplicity, as being grounded, to a more positive potential which is controlled by the relative resistances of the resistance R1, the TD coil, and the resistance R2; the circuit 13 being still connected to the negative bus (—). This energizes the coil TD of the time-delay or time-hesitation relay TD, which promptly energizes the operating coil RR of the auxiliary receiver-relay RR, after the lapse of a suitable small coordinating time, such as one cycle of the power-line frequency, for a reason which will be subsequently described.

If a second-zone phase-fault should occur, with an inwardly looking fault-power direction, the phase-fault contactor-switch CSP picks up, and similarly opens the circuit between the conductors 15 and 13, again shifting the potential of the intermediate conductor 15 from that of the grounded negative bus (—) to the aforesaid intermediate potential, and again energizing the time-hesitation relay-coil TD.

According to our invention, the changed potential of the intermediate circuit 15 is used to modulate a frequency-shift transmitter 18 which is located at the relaying station. To this end, this intermediate conductor 15 is connected to the negative bus through a large grid-potential-controlling resistance R4, which is tapped to control the grid-potential of a reactance-tube modulator 19, which is used to modulate the frequency of the transmitter 18.

The frequency-shift transmitter 18 preferably has a crystal-controlled oscillator-tube or tubes, and the necessary buffer and amplifier tubes (not shown), for producing a carrier-current output having a narrow radio-frequency f_1. This radio-frequency output is delivered, through an output-conductor 21, to a tuner 22, and thence through a coupler-capacitor CC to one of the phase-conductors of the protected line-section L1. The transmitted carrier energy is largely blocked from traveling back to the bus 1, by a suitable line-trap LT. Crystal-tuning is very desirable, because it holds the radio frequencies accurate, between extremely close limits, thus increasing the sharpness of tuning, and narrowing the necessary bandwidth of the radio frequencies.

The transmitter 18 normally transmits its radio-frequency energy continuously. When our intermediate control-circuit conductor 15 is at the ground potential of the negative bus (—), the transmitter 18 is oscillating at a so-called "mark" frequency, which may be any frequency,

or any narrow band of radio freqencies, which is characteristic of the state of the transmitter when it is not being modulated by the fault-controlled reactance-tube modulator **19**. When a power-line fault, with inwardly looking fault-power direction, shifts the grid-potential of the reactance-tube modulator **19**, the oscillation-frequency is shifted, by the modulator, to a so-called "space" frequency, which may differ from the "mark" frequency by as little as 120 cycles, more or less, which is an extremely narrow band, in comparison with a radio-frequency which may be anywhere in the range from 40 to 200 kilocycles, or the like.

A fault-controlled frequency-shift transmitter **18** is used at each terminal of the protected line-section **L1**, except that the narrow band of transmitted radio-frequency signals is distinctive of the terminal from which these signals are being transmitted. Thus, the illustrated line-terminal, having the circuit-breaker **CB1**, has a distinctive carrier-current radio-frequency band, which is designated f_1, while the corresponding transmitter (not shown) at the other terminal of the protected line-section **L1** has a narrow frequency-band which is sufficiently different to be distinguishable, as indicated by the frequency f_2, which is applied to a radio-frequency receiver **23** at the terminal which is illustrated in the drawing, as will now be described. In other words, each transmitter transmits its distinctive signals to the remote end or terminal of the protected line-section, and each terminal-equipment has a receiver **23** which is tuned to receive the signals which are transmitted from the other terminal of the protected line-section.

The lower part of the drawing shows a frequency-shift receiver **23**, indicated as being responsive to the narrow radio-frequency band f_2, receiving its radio-frequency input through an input-conductor **24** which is connected to a separate portion of the tuner **22**, and thence to the line, through the coupling-capacitor **CC**. As shown, the tuner **22** is a double-frequency tuner, having one circuit **21** which is tuned to the transmitter-frequency or band f_1 at the relaying station, and another circuit **24** which is tuned to the receiver-frequency or band f_2 at the same station. The frequency-shift receiver **23** preferably has crystal-controlled tuning and discriminator circuits, with any necessary amplifiers, limiters, and relaying-tubes (not shown), discriminatively responding to the "mark" and "space" frequencies of the transmitter at the other end of the protected line-section **L1**.

The frequency-shift receiver **23** thus has two output-circuits, namely a "mark"-response circuit **25** which is energized when the receiver's "mark"-frequency is being received, and a "space"-response circuit **26**, which is energized when the receiver's "space"-frequency is being received. These two output-circuits **25** and **26** of the receiver **23** are used to energize the one or the other of two coils M and S, respectively, of a suitable three-position output-relay **27**, which has a movable contact-member **28**, which is attracted to close a "mark" contact M when the "mark"-response coil M is energized, and which is attracted in the other direction, so as to close a "space"-contact S when the "space"-response coil S is energized. If neither of the output-relay coils M or S should be energized, the movable relay-contact **28** will return to its normal biased off-position, as illustrated.

According to our invention, the "space"-response contact S is used to light a lamp **30** or other indicating means, for indicating the receipt of the "space"-frequency signal from the other terminal of the protected line-section **L1**, while the "mark"-response contact M is used to energize both the operating-coil AL of an alarm-relay AL and a holding or blocking coil RRH of the auxiliary receiver-relay RR, in response to a receipt of the "mark"-frequency signal from the other terminal of the protected line-section.

According to our invention, the alarm-relay AL is provided with a back-contact AL which is used to energize a bell **31** or other indicating means, the ringing of which thus indicates a failure to receive the normally continuously transmitted "mark"-frequency signal from the other terminal of the protected line-section **L1**.

The receiver-relay holding-coil RRH is indicated, by means of a downwardly pointing arrow, as a coil which pulls downwardly on the operating-stem of the auxiliary receiver-relay RR, thus working in opposition to the operating-coil RR which lifts upwardly, as indicated by its associated arrow. The holding-coil RRH is stronger than the operating-coil RR, so that the auxiliary receiver-relay RR cannot respond as long as its holding-coil RRH is energized, even though its operating-coil RR is simultaneously energized. This is in accordance with a previously known normal practice in carrier-supervised directional-distance relaying-systems.

In the operation of our improved equipment, the frequency-shift transmitter **18** at each terminal of the protected line-section will normally be operating continuously at its "mark"-frequency tuning, with a ground-potential on the control-grid of its reactance-tube modulator **19**. Under these circumstances, the bell-circuit at the other terminal will be held open by the energized condition of the alarm-relay AL, and the lamp-circuit at the other terminal will be deenergized by the non-receipt of a "space"-frequency signal.

If a fault should occur on the transmission system, with an inwardly flowing fault-power direction at the relaying station, one of the auxiliary contactor-switches CSG or CSP will respond, opening its back-contact between the conductors **15** and **13**, thereby shifting the potential of the reactance-tube grid to a predetermined positive value, which causes the transmitter **18** to shift its output from its "mark" frequency to its "space" frequency. At the same time, the open contactor-switch contact CSG or CSP removes the short-circuit from the time-hesitation relay TD (if this relay is used), thus causing this relay to close and energize the receiver-relay operating-coil RR, at the end of a very brief time-hesitation period.

If the fault is an external fault, that is, a fault accompanied by a fault-power-flow through the protected line-section and out at the other end, the energization of the operating-coil RR at the relaying end cannot actuate the receiver-relay RR, because the holding-coil RRH continues to be energized by the receipt of the "mark"-frequency signal at the relaying station.

If however, the fault is an internal fault, that is, a fault accompanied by a fault-power-flow into the protected line-section at the remote terminal, the remote transmitter will have shifted to its "space"-frequency, and the receiver **23** at the illustrated relaying-terminal will have opened its "mark"-responsive contact M, thus deenergizing the holding-coil RRH of the receiver relay RR at the relaying station, permitting this relay to pick up in response to the energization of its operating coil RR. However, even though the operating coil RR should become energized before the deenergization of the holding-coil RRH, the receiver-relay RR could not respond until its holding-coil RRH is deenergized, and hence the time-hesitation means TD is not needed if the local receiver **23** is receiving its "mark" frequency at the moment when the CSG or CSP contact opens.

It is a distinctive feature of our invention that we use the contactor-switch contacts CSG and CSP (or their equivalent) to interrupt the normally continuously transmitted "mark"-frequency signal at the relaying station, in response to a power-system fault which is accompanied by an inwardly flowing fault-current at that station.

In the preferred form of embodiment which is illustrated, we do not use our contactor-switch contacts CSG

and CSP to directly remove a short-circuit from across the operating coil RR of the receiver relay, as in previous carrier-current-directional-distance relaying-systems which have been in successful use for a number of years, but we use these contactor-switch contacts CSG and CSP, or, in general, the relaying circuits 3 and/or 9, to introduce a slight time-hesitation, as by means of a time-delay relay TD or its equivalent. Our time-hesitation relay TD is broadly representative, however, of any means, with or without a time-hesitation, for causing the operating-coil RR of the receiver-relay to be energized (or for causing any equivalent line-protecting function to be performed), in response to a predetermined fault-indication which is accompanied by an in-flowing fault-direction at the relaying station.

The provision for a time-hesitation, when used at all (as by means of our time-delay relay TD), is for the sole purpose of preventing a faulty relaying-operation in those frequently encountered transmission-systems in which, in the event of an external fault, that is, a fault on some line-section other than the protected line-section, the opening of the first circuit-breaker in the faulted section may sometimes cause a sudden reversal of the direction of the "through" fault-power flow through the protected line-section. In such an event, the fault-power, at one terminal of the sound protected line-section, will momentarily change from an inward direction to an outward direction of power-flow, and the transmitter at that terminal will quickly change from its "space" frequency to its "mark" frequency. However, the receiver at the opposite terminal will require a certain small finite time to close its previously open "mark"-responsive contact M, to thereby energize its receiver-relay holding-coil RRH. If it were not for the time-hesitation which is provided by the TD relay, the receiver-relay operating-coil RR at this station would have become energized, as soon as the contactor-contact CSG or CSP opened, and before the energization of its holding-coil RRH in response to the reversal of the power-flow from an inwardly flowing to an outwardly flowing direction at the opposite terminal. The time-hesitation thus prevents an erroneous tripping-operation in the sound protected line-section, in the event of a sudden reversal of a "through" fault-current in that line-section when one of the two circuit-breakers of another, faulted, line-section opens a moment before the opening of the other circuit-breaker of said faulted line-section.

An important advantage of our application of frequency-shifted carrier to a directional-distance relaying-system is the ability to thoroughly supervise the carrier-current channel, so as to make sure that the carrier-current transmitters and receivers are always in a perfectly operating condition. The transmitters and receivers are continuously supervised by the bell 31 at each terminal of each line-section, because as long as the transmitters are operating perfectly, they will be transmitting on their "mark" frequencies, so that the receivers at the opposite terminals will be holding their "mark"-contacts M closed, thereby holding their alarm-relays AL energized, and thus holding their bell-circuits open. The ringing of the bell 31 will thus be an instant indication of a failure of the local receiver to receive its proper "mark" frequency from the remote transmitter.

While the continuous transmission of the receiver-relay blocking-frequency provides supervision of the carrier-current channel between the two terminals of the protected line-section, it is also desirable to check the ability of the carrier-current equipment to shift to the "space"-frequency and thus to remove the receiver-relay blocking so that an internal fault may be tripped. The testing circuit to accomplish this consists primarily of the push-button PB in parallel with the resistance R3. An operation of the test-pushbutton PB inserts this resistance R3 in series between the intermediate conductor 15 and the negative bus (−), thus shifting the potential of the intermediate conductor 15 to the same predetermined positive value to which it would have been shifted by an opening of one of the contactor-switch contacts CSG or CSP in response to an inwardly flowing fault-current. This changes the reactance of the reactance-tube modulator 19 and shifts the frequency of the local transmitter 18 from its "mark" frequency to its "space" frequency at the station where the test-pushbutton PB is depressed. At the other station or terminal of the protected line-section, the receiver will thereupon respond to this "space" frequency, causing the closure of its "space"-responsive contact S, and lighting the indicator-lamp at that station, thereby demonstrating that the equipment is in a satisfactory operative condition.

It will be noted that, during the process of a manual test, the test-pushbutton PB is being depressed so as to arbitrarily interrupt the normally continuous transmission of the "mark" frequency. In most cases, it is required, or at least highly desirable, that if a line-fault should develop while this manual test is in process, it should still be possible for the automatic fault-responsive apparatus to properly clear the fault from the transmission-system. To this end, we use our preferably sensitive fault-sensing means, such as the relays Z3A, Z3B, Z3C and IOS, such as was heretofore used to start the transmission of carrier, in the previously used intermittent carrier system; and we make sensitive fault-sensing circuit energize a test-canceling means, which has been illustrated in the form of the SM relay. The effect of this relay is to bypass the testing-pushbutton PB, so that the grid-controlling potential of the intermediate conductor 15 is thereupon brought back to, and held at, the ground potential of the negative bus (−), thus restoring the transmission of the trip-blocking "mark"-frequency signal, unless and until the directional fault-responsive contact CSG or CSP should open in the normal way, in response to a line-fault which is accompanied by an inwardly looking fault-power direction.

It will be noted that the second auxiliary circuit-breaker switch-contact CB1*a'*, which opens when the local circuit-breaker CB1 is open for any cause, causes a "space"-frequency signal to be sent to the other end of the protected line-section, whenever one end is open, thus preventing possible improper blocking of an internal end-zone fault.

While we have illustrated our invention in a single illustrative form of embodiment, we wish it to be understood that we are not limited in every respect to the precise details shown. For example, while we have shown, and prefer, for reasons well known in the art, the use of a known form of protective relaying means 2 which is responsive to a plurality of different severities of fault, we are not in every case limited to the response to a plurality of different severities. Also, while we have shown the use of a known form of an auxiliary receiver-relay RR, having a strong hold-coil means RRH and a relatively weaker operating-coil means RR, and while there are many obvious advantages to this tested and tried form of auxiliary receiver-relay, it would be possible, in the broader aspects of our invention, to provide, in its place, any kind of means which would perform a fault-protecting function in response to a fault-responsive determination of the existence of a predetermined power-line fault which has an in-flowing fault-power direction at that terminal of the protected line-section. Furthermore, the test-canceling means SM may be omitted when its described function may be dispensed with, in any particular protective equipment. The foregoing and other changes of omission or substitution, as well as the addition of many refinements, are all to be considered as being within the scope of our invention, at least in its broadest aspects.

We claim as our invention:

1. Communicating-channel protective-relaying equipment for the fault-protection of a line-section of a com-

mercial-frequency power line, comprising, at each terminal of the protected line-section, a communicating-channel means for transmitting either a normally continuous signal or an occasional different signal from that terminal to the other terminal of the protected line-section, both of said signals being distinctive of the terminal from which they are transmitted, a fault-responsive means for responding to a power-line fault with an in-flowing fault-power direction at that terminal of the protected line-section, a means for causing said communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal and for also performing a fault-protecting function in response to a response of said fault-responsive means, a means for blocking a fault-protecting operation in response to the receipt of the continuous signal from said other terminal of the protected line-section, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal, a test-canceling means for incapacitating said test-circuit means in response to a power-line fault, a first indicating means for indicating a failure to receive the continuous signal from the other terminal of the protected line-section, and a second indicating means for indicating the receipt of the occasional signal from said other terminal.

2. Communicating-channel protective-relaying equipment for the fault-protection of a line-section of a commercial-frequency power-line, comprising, at each terminal of the protected line-section, a communicating-channel means for transmitting either a normally continuous signal or an occasional different signal from that terminal to the other terminal of the protected line-section, both of said signals being distinctive of the terminal from which they are transmitted, a fault-responsive means for responding to a power-line fault with an in-flowing fault-power direction at that terminal of the protected line-section, a time-hesitation means which requires a short time to respond, a means for causing said communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal and for also initiating a response of said time-hesitation means in response to a response of said fault-responsive means, a means for performing a fault-protecting function in response to a completed predetermined response of said time-hesitation means, a means for blocking a fault-protecting operation in response to the receipt of the continuous signal from said other terminal of the protected line-section, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal, a test-canceling means for incapacitating said test-circuit means in response to a power-line fault, a first indicating means for indicating a failure to receive the continuous signal from the other terminal of the protected line-section, and a second indicating means for indicating the receipt of the occasional signal from said other terminal.

3. Frequency-shift carrier-current protective-relaying equipment for the fault-protection of a line-section of a commercial-frequency power-line, comprising, at each terminal of the protected line-section, a frequency-shift carrier-current transmitter for transmitting either a "mark"-frequency signal or a slightly different "space"-frequency signal over the protected line-section to the other terminal of said section, both of said signals having frequencies falling within a narrow band which is distinctive of the terminal from which they are transmitted, a carrier-current receiver which is tuned to the frequency-band transmitted from the other terminal of said protected line-section and which is able to discriminate between the "mark" and "space" frequencies of the transmitter at said other terminal, a fault-responsive means for responding to a power-line fault with an in-flowing fault-power direction at that terminal of the protected line-section, a means for causing said transmitter to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal and for also performing a fault-protecting function in response to a response of said fault-responsive means, a means for blocking a fault-protecting operation in response to the receipt of the "mark"-frequency signal from said other terminal of the protected line-section, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal, a test-canceling means for incapacitating said test-circuit means in response to a power-line fault, a first indicating means for indicating a failure to receive the "mark"-frequency signal from the other terminal of the protected line-section, and a second indicating means for indicating the receipt of the "space"- frequency signal from said other terminal.

4. Frequency-shift carrier-current protective-relaying equipment for the fault-protection of a line-section of a commercial-frequency power-line, comprising, at each terminal of the protected line-section, a frequency-shift carrier-current transmitter for transmitting either a "mark"-frequency signal or a slightly different "space"-frequency signal over the protected line-section to the other terminal of said section, both of said signals having frequencies falling within a narrow band which is distinctive of the terminal from which they are transmitted, a carrier-current receiver which is tuned to the frequency-band transmitted from the other terminal of said protected line-section and which is able to discriminate between the "mark" and "space" frequencies of the transmitter at said other terminal, a fault-responsive means for responding to a power-line fault with an in-flowing fault-power direction at that terminal of the protected line-section, a time hesitation means which requires a short time to respond, a means for causing said transmitter to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal and for also initiating a response of said time-hesitation means in response to a response of said fault-responsive means, a means for performing a fault-protecting function in response to a completed predetermined response of said time-hesitation means, a means for blocking a fault-protecting operation in response to the receipt of the "mark"-frequency signal from said other terminal of the protected line-section, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal, a test-canceling means for incapacitating said test-circuit means in response to a power-line fault, a first indicating means for indicating a failure to receive the "mark"-frequency signal from the other terminal of the protected line-section, and a second indicating means for indicating the receipt of the "space"-frequency signal from said other terminal.

5. Equipment for providing a communicating channel between two separated terminals, comprising a communicating-channel means, at each terminal, for transmitting either a normally continuous signal or an occasional different signal from that terminal to the other terminal, both of said signals being distinctive of the terminal from which they are transmitted, a first intelligence-discerning means, at each terminal, for causing its communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal and for also performing a local function, at its terminal, in response to that same intelligence, a blocking-means, at each terminal, for blocking the performance of said local function in response to the receipt of the continuous signal from said other terminal, a test-circuit means, at each terminal, for arbitrarily causing its communicating-channel means to cease transmitting its continuous signal and to start transmit-

ting its occasional signal, a second intelligence-discerning means, at each terminal, for incapacitating the test-circuit means at that terminal, a first indicating means, at each terminal, for indicating a failure to receive the continuous signal from the other terminal, and a second indicating means, at each terminal, for indicating the receipt of the occasional signal from said other terminal.

6. Equipment for providing a communicating channel between two separated terminals, comprising, at each terminal, a frequency-shift carrier-current transmitter for transmitting either a "mark"-frequency signal or a slightly different "space"-frequency signal to the other terminal, both of said signals having frequencies falling within a narrow band which is distinctive of the terminal from which they are transmitted, a carrier-current receiver which is tuned to the frequency-band transmitted from the other terminal and which is able to discriminate between the "mark" and "space" frequencies of the transmitter at said other terminal, a first intelligence-discerning means for causing said transmitter to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal and for also performing a local function, at its terminal, in response to that same intelligence, a blocking-means for blocking the performance of said local function in response to the receipt of the "mark"-frequency signal from said other terminal, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal, a second intelligence-discerning means for incapacitating said test-circuit means, a first indicating means for indicating a failure to receive the "mark"-frequency signal from the other terminal, and a second indicating means for indicating the receipt of the "space"-frequency signal from said other terminal.

7. Equipment for providing a communicating channel between two separated terminals, comprising, at each terminal, a communicating-channel means for transmitting either a normally continuous signal or an occasional different signal from that terminal to the other terminal, both of said signals being distinctive of the terminal from which they are transmitted, a signaling means for causing said communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal, a receiver-means for responding to the nonreceipt of the continuous signal from the other terminal, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal, a test-canceling means for incapacitating said test-circuit means in response to an operation of a signaling means at that terminal, a first indicating means for indicating a failure to receive the continuous signal from the other terminal, and a second indicating means for indicating the receipt of the occasional signal from said other terminal.

8. Equipment for providing a communicating channel between two separated terminals, comprising ,at each terminal, a frequency-shift carrier-current transmitter for transmitting either a "mark"-frequency signal or a slightly different "space"-frequency signal to the other terminal, both of said signals having frequencies falling within a narrow band which is distinctive of the terminal from which they are transmitted, a carrier-current receiver which is tuned to the frequency-band transmitted from the other terminal and which is able to discriminate between the "mark" and "space" frequencies of the transmitter at said other terminal, a signaling means for causing said transmitter to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal, a receiver-means for responding to the nonreceipt of the "mark"-frequency signal from said other terminal, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal, a test-canceling means for incapacitating said test-circuit means in response to an operation of a signaling means at that terminal, a first indicating means for indicating a failure to receive the "mark"-frequency signal from the other terminal, and a second indicating means for indicating the receipt of the "space"-frequency signal from said other terminal.

9. Equipment for providing a communicating channel between two separated terminals, comprising, at each terminal, a communicating-channel means for transmitting either a normally continuous signal or an occasional different signal from that terminal to the other terminal, both of said signals being distinctive of the terminal from which they are transmitted, a signaling means for causing said communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal, a receiver-means for responding to one of the signals from the other terminal, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its continuous signal and to start transmitting its occasional signal, a first indicating means for indicating a failure to receive the continuous signal from the other terminal, and a second indicating means for indicating the receipt of the occasional signal from said other terminal.

10. Equipment for providing a communicating channel between two separated terminals, comprising, at each terminal, a frequency-shift carrier-current transmitter for transmitting either a "mark"-frequency signal or a slightly different "space"-frequency signal to the other terminal, both of said signals having frequencies falling within a narrow band which is distinctive of the terminal from which they are transmitted, a carrier-current receiver which is tuned to the frequency-band transmitted from the other terminal and which is able to discriminate between the "mark" and 'space" frequencies of the transmitter at said other terminal, a signaling means for causing said transmitter to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal, a receiver-means for responding to one of the signals from the other terminal, a test-circuit means for arbitrarily causing said communicating-channel means to cease transmitting its "mark"-frequency signal and to start transmitting its "space"-frequency signal; a first indicating means for indicating a failure to receive the "mark"-frequency signal from the other terminal, and a second indicating means for indicating the receipt of the "space"-frequency signal from said other terminal.

References Cited in the file of this patent

UNITED STATES PATENTS

2,454,163	Harder	Nov. 16, 1948
2,611,041	Cooper	Sept. 16, 1952
2,615,985	Moynihan	Oct. 28, 1952
2,677,014	Moynihan	Apr. 27, 1954