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PROTECTIVE RELAYING SYSTEM

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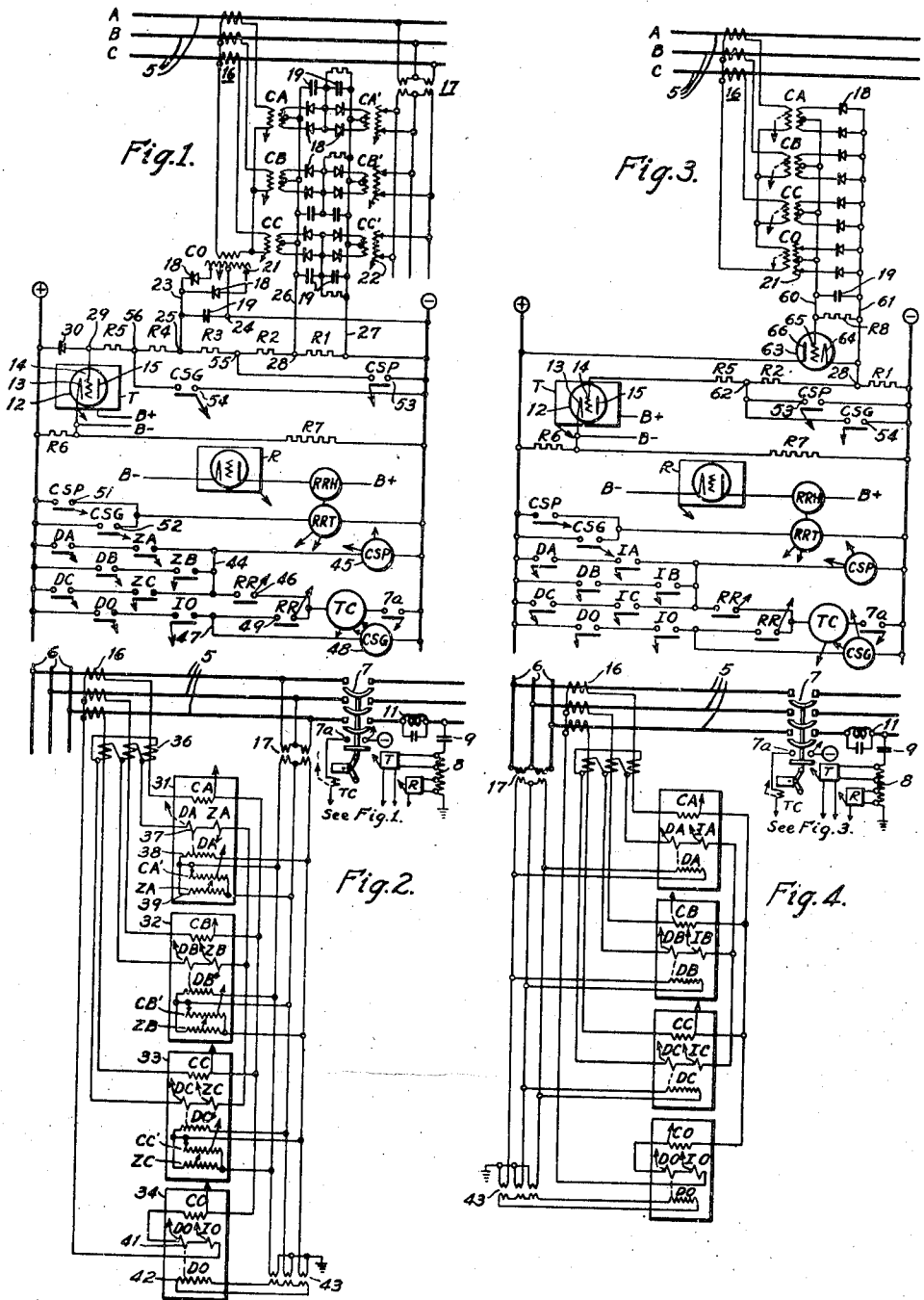

WITNESSES:

James F. Young

Wm C. Groome

INVENTOR

Edwin L. Harder.

BY O. B. Buchanan

ATTORNEY

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PROTECTIVE RELAYING SYSTEM

Edwin L. Harder, Forest Hills, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

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1

My invention relates to an improved protective relaying system, such as is utilized for tripping circuit-breakers, or otherwise controlling the operation of circuit-interrupting means in a transmission line or other extended electrical circuit, and for other purposes.

An object of my invention is to provide an improved high-speed relaying system in which carrier-current is superimposed on the line in order to obtain a quick response to a fault-condition at any point within the protected line-section. More specifically, my invention provides an "all electronic" or tube-type carrier-current relaying system, and particularly a carrier relaying system of the directional-comparison type, as distinguished from the current-comparison type. In the current-comparison carrier system, modulated carrier is utilized to directly compare the 60-cycle line-currents at the two ends of the protected line-section, whereas, in the directional-comparison system, carrier-current is utilized merely to block the erroneous tripping-operation due to oversensitive fault-detectors at the relaying point, utilizing current-direction, or other line-condition, at the other end of the protected section to maintain carrier-current transmission if the conditions at that end are such as to indicate that the fault is at some point beyond that end of the protected line-section.

The indications of the trend of the art point to the ultimate adoption of "all electronic," or at least "no moving part," carrier relaying for the protection of transmission lines. This seems to be indicated, not only because of the increased speed of tube-type relays as compared with mechanical relays having moving contact-parts, but also because of the ever-present possibility of chattering, or bouncing, of mechanically moving contact-points in very high-speed relays. While various bounce-suppressing means have been devised, and are being used with considerable success, at the presently common speeds of high-speed relaying, nevertheless, a carrier-current system which depends, for its accuracy, upon a mechanical relay-contact remaining firmly closed, throughout the entire period when carrier-current blocking is required, is subject to the ever-present danger of a jarring or bouncing or chattering of that contact, which would momentarily remove the restraining or blocking influence of carrier, and cause a faulty relaying operation. On a line where system-stability is involved, a single faulty tripping-operation during a year may do so much harm that it will more than offset the beneficial effects of high-speed fault-clearing during the rest of the year.

2

An important object of my present invention is to provide a "no moving part" carrier-starting mechanism for line-fault-responsive carrier-current systems in general, and particularly for carrier-current systems of the directional-comparison type.

A further object of my invention is to provide means for utilizing a control-circuit relaying voltage or other relaying voltage, and particularly a rectified voltage, produced directly from the fault-currents, or from some other function of electrical conditions of the protected line or circuit, to directly bias the grid of the oscillator-tube to a transmitting condition, or to otherwise initiate carrier-current transmission through electronic or tube-type control.

A further object of my invention has to do with the utilization of means for providing a unidirectional control-circuit or relaying voltage which has a magnitude corresponding to the magnitude of the lowest impedance which is measurable on the several phases of a polyphase line, as by obtaining the difference between a current-responsive relaying voltage and a voltage-responsive relaying voltage, responsive respectively to the line-currents and the line-voltages of the several phases, compared, in pairs, according to phases. In this manner, I obtain a single relaying voltage, which is responsive to the magnitude of the impedance of the faulted phase, and I can use this voltage for directly starting carrier-current transmission, by grid-bias control, or, in general, for energizing any kind of fault-responsive apparatus from said relaying circuit, whether such apparatus be of the tube-type or mechanical relays.

With the foregoing and other objects in view, my invention consists in the parts, element, combinations, sub-combinations, system and methods hereinafter described and claimed, and illustrated in the accompanying drawing which illustrates my invention as applied as a modification of a common type of modern carrier-current relaying system of the grid-voltage-control type, which is shown in a Lenehan Patent 2,144,499, January 17, 1939, assigned to the Westinghouse Electric & Manufacturing Company. I wish it to be understood, however, that my invention is of general application, in many different forms, and in other types of carrier-current systems and control, and I wish it to be understood that the particular system, which I have chosen for illustration, is only an illustrative example of a preferred form of embodiment of my invention.

In the drawing,

Figure 1 is an "across the line" diagrammatic

view of the direct-current connections and the carrier-starting control of a carrier-current relaying system embodying my invention in an illustrative form of embodiment,

Fig. 2 is a diagrammatic view of the alternating-current connections of the apparatus shown in Fig. 1, and

Figs. 3 and 4 are views, similar to Figs. 1 and 2, of a different form of embodiment, illustrating some aspects of my invention.

In the drawing, I have illustrated only one end of a three-phase line-section 5, which is to be protected, the several phases being distinguished by the letters A, B and C. Only one end of the line is illustrated, as the other end is, or may be, a substantial duplicate of the illustrated end. The protected line-section 5 is illustrated as being connected, at each end, to a three-phase bus 6, through an oil circuit-breaker 7, or other circuit-interrupting means which is to be tripped or controlled so as to disconnect both ends of the protected line-section from the rest of the transmission-system, in the event of an internal fault within the protected section. The circuit-breaker 7 is provided with a trip-coil TC, and an auxiliary breaker-switch 7a, which is open when the breaker is open.

My invention is illustrated as being embodied in a carrier-current relaying system, utilizing carrier-current equipment which is diagrammatically represented by a transmitter T and a receiver R which are connected to a coupling transformer 8 which is coupled to the phase-C line-conductor through a coupling capacitor 9, the carrier-current being confined to the protected line-section by means of a wave-trap 11.

While I am illustrating my carrier-current equipment in connection with its use for relaying purposes, it will be understood that the same equipment, when it is not in use for relaying, which means, for most of the time, can be used for telemetering or "other uses," as set forth in my Patent 2,217,480, granted October 8, 1940.

The carrier-current transmitter T is illustrated as an electronic, or tube-type, oscillator-generator, including a master-oscillator tube 12. The master-oscillator 12 is illustrated, in a simple form, as a three-element tube having a cathode 13, a grid 14, and a plate or anode 15. The grid 14, or other control-circuit means, is of such nature that the tube-operation is strongly maintained when the grid-voltage is sufficiently positive with respect to the cathode, (assuming that a suitable plate-voltage is applied to the tube), and such that tube-operation is substantially blocked when the grid-voltage is made sufficiently negative with respect to the cathode. In the particular illustrated embodiment of my invention, the oscillator-tube is of a type which will freely oscillate when the grid-voltage is brought to approximately the same potential as the cathode 13, or when the grid 14 is only slightly negative with respect to the cathode 13, by an amount depending upon the particular characteristics of the tube, and also depending upon the voltage of its plate-current source, which is indicated by the terminals B+ and B−.

Referring more particularly to the control-system shown in Fig. 1, the oscillator-grid 14 is normally given a strong negative bias, with respect to the cathode 13, so that no carrier-current is being transmitted, by connecting said grid to the negative terminal (−) of the station-battery, through a series of serially connected resistors R1 to R5. The cathode 13 of

the oscillator tube is usually held at a potential which is close to the positive terminal (+) of the station-battery, through a potentiometer-connection consisting of the resistors R6 and R7.

In accordance with my invention, as shown in Fig. 1, I directly control the voltage of the oscillator-grid 14, by relaying voltages or control-circuit voltages which are responsive to the line-currents, or responsive to the difference between the magnitudes of a line-current and a line-voltage, or, in general, responsive to any predetermined function of electrical conditions of the protected line 5. By line-current and line-voltage, I do not mean any particular phase of star or delta current or voltage, but any function, or component of phase-sequence quantity, of any single-phase or polyphase current or voltage which is derived from the line.

In Fig. 1, the line-current is derived by means of a bank or star-connected line-current transformers 16, which supply energy to four compensators CA, CB, CC and CO, in different phases of the line-current. In this connection, I am utilizing the term "phase" in a very general sense, so as to include ground or residual-currents, as well as either star or delta phase-currents. In the particular illustration shown in Fig. 1, star phase-currents are utilized to energize the respective compensators CA, CB and CC, to respond to phase-faults, while the residual current is supplied to the fourth compensator CO, so as to respond to groundfaults. These compensators may be any kind of impedance-device which will produce a voltage-drop responsive to the current traversing said impedance; in particular, I utilize, as compensators, iron-core transformers or inductance devices, having an air-gap so that they will have a considerable self-inductance which acts as either a fixed or an adjustable impedance which is traversed by the current.

As shown in Fig. 1, a relaying voltage is also derived from the protected line, through potential-transformers 17, and various delta phases of the derived relaying voltages are utilized to energize the respective voltage-responsive compensators or other auxiliary transformers CA', CB' and CC'.

To control the grid-potential of the oscillator-tube 12 of Fig. 1, the various current-responsive and voltage-responsive derived voltages, as produced in the various compensators CA, CB, CC, CO, CA', CB' and CC', are preferably individually rectified, so as to produce unidirectional derived voltages. I have illustrated a conventional rectifying circuit, for each of these relaying voltages, involving rectifiers or other asymmetrically conducting devices 18. Preferably, also, I utilize capacitors or other voltage-smoothing means 19, for removing some or all of the ripples or pulsations from the various rectified voltages. It will be understood, of course, that any suitable, or more elaborate, means may be utilized for these purposes. Furthermore, any suitable adjusting-means, or pre-setting means, may be utilized, as symbolized by the variable-turn secondary windings 21 of the residual-current compensator CO, and by the variable-turn primary windings 22 of the several voltage-transformer devices CA', CB' and CC'.

In Fig. 1, the residual-current-responsive rectified relaying voltage, which appears across the terminals 23 and 24 of the residual-current compensator CO and its rectifier and capacitor assem-

bly 18–19, is applied between the negative battery-terminal (—) and the junction-point 25 between the resistors R3 and R4 in the grid-control circuit of the oscillator-tube 12, the polarity of this connection being such that the point 25 is given a positive potential, with respect to the negative battery-terminal (—), in response to the magnitude of the residual line-current, or, more exactly, in response to the smoothed-out, double-wave-rectified, product of the residual current times the self-inductance or other impedance of the compensator CO. In this manner, when a residual current of a predetermined magnitude is obtained, a sufficient positive voltage is impressed upon the point 25 of the grid-control circuit to bring the oscillator-grid 14 substantially or approximately to the potential of the positive battery-bus (+), or sufficiently positive to cause the master-oscillator 12 to begin oscillating, thus starting carrier-current transmission.

In the case of the phase-current response, for responding to phase-faults rather than ground-faults, I may utilize only the current-responsive relaying voltages, but I have illustrated, in Fig. 1, a more elaborate control-system in which the phase-fault detection is obtained in response to line-impedance, or its reciprocal, admittance, rather than by overcurrents. This response is obtained by utilizing the rectified voltage-responsive derived voltage of each phase to buck the rectified current-responsive derived voltage of a corresponding or paired-off phase, in the manner shown for a single phase, in the Goldsborough Patent No. 2,027,226, January 7, 1936, assigned to the Westinghouse Electric & Manufacturing Company. As explained in said Goldsborough patent, while it is generally preferable to rectify the current-responsive relaying voltage, so as to avoid the disturbing effect of wave-form distortion, it is not altogether essential to rectify these current-responsive voltages, as the alternating derived voltages can be directly utilized.

In accordance with my present invention, however, I have introduced an additional feature, which was not shown in the Goldsborough patent, in connection with electronic impedance-response, as obtained by the difference between current-responsive and voltage-responsive rectified or unidirectional voltages. Thus, I have provided a single phase-fault relaying-circuit 26–27 which receives energy from three parallel-connected sources of relaying voltages, each of these three sources being the difference between the rectified and smoothed-out voltages produced by the respective current-responsive and voltage-responsive compensators, such as CA and CA', in one pair; CB and CB' in another pair; and CC and CC' in the third pair.

It is essential that the parallel connections, for these three parallel-connected voltage-sources for the relaying-bus 26–27, shall include rectifiers, whereby whichever source has the highest resultant or differential voltage will feed its voltage substantially entirely to the relaying bus 26–27, and will not dissipate or feed back its energy into the circuits of the sources having smaller resultant voltages. In the illustrated example, as will be clearly seen from Fig. 1, the various rectifiers 18 of the phase-current and phase-voltage-responsive output-circuits will perform this function, whereby the largest phase of the resultant differential voltages of the pairs of current-responsive and voltage-responsive voltages will determine the magnitude of the unidirectional voltage which

appears across the terminals of the relaying bus 26–27.

In order to obtain a phase-fault-responsive control of the grid-voltage of the oscillator-tube 12, the largest-phase resultant-voltage which appears across the relaying bus 26–27 is applied across the resistance R1 of the grid-control circuit. In this manner, the relaying bus 26–27 is connected between the negative battery-terminal (—) and an intermediate point 28 in the grid-control circuit, said intermediate point 28 being between the resistors R1 and R2. The polarity of this connection is such that the point 28 is raised to a positive potential, with respect to the negative battery-terminal (—), in response to the largest difference existing between any phase of the line-current and the properly weighted magnitude of a corresponding phase of the line-voltage. When this point 28 is raised to a potential which is substantially the same as that of the station-battery (+) and (—), or which is sufficiently positive to start the operation of the master-oscillator 12, carrier-current transmission will be initiated, and it will be maintained as long as this voltage-condition prevails.

In order to prevent the application of unnecessarily large positive potentials to the oscillator-grid 14, as a result of exceptionally severe faults, the grid-terminal 29 may be connected to the positive battery-terminal (+) through a rectifier 30 which is connected in such polarity as to drain off excessive positive potentials from the grid, while substantially blocking current-flow in the reverse direction.

The rest of the system which is shown in Figs. 1 and 2 is substantially the same as the known control-system which is shown in the above-mentioned Lenehan Patent 2,144,499. The coils and contacts of each relay are given the same letter-designation or legend, except in the case of the receiver-relay RR, which, as subsequently described, has two coils, an operating or tripping coil RRT, and a restraining or holding coil RRH, these two coils being distinguished by the suffixed letters T and H, respectively. Arrows or dotted lines are also used, to symbolically indicate how the various parts of each relay or element are connected together. The relays and switches are invariably shown in their open or deenergized positions. As shown in Fig. 2, four relaying panels 31, 32, 33 and 34, are shown, to provide three panels of phase-fault relaying, and one panel of ground-fault relaying. I have also shown a bank of delta-connected auxiliary current-transformers 36 for supplying delta line-currents to the current-coils 37 of directional and impedance relays, DA and ZA for phase-A, DB and ZB for phase-B, DC and ZC for phase-C. The directional relays DA, DB and DC have voltage-coils 38, which are energized from appropriate voltages derived from the potential-transformers 17, while the impedance-relays ZA, ZB and ZC have voltage-coils 39 which are also appropriately energized from the potential-transformers 17. These directional and impedance relay-elements also have appropriately lettered make-contacts which are utilized in the system of direct-current relay-connections, as shown in Fig. 1, the alternating-current connections being shown in Fig. 2.

In the ground-relay panel 34 of Fig. 2, I have shown ground-directional and ground-current relays DO and IO, having their current-coils 41 energized in the residual circuit of the line-current transformers 16. The ground-directional

relay DO also has a polarizing winding 42, which is energized from any suitable source, such as the auxiliary open-delta potential-transformers 43, or by any other suitable means, as well understood in the art. The ground-directional and over-current relays DO and IO have appropriately lettered relay-contacts which are shown in the direct-current connections of Fig. 1.

In accordance with these direct-current connections, as shown in Fig. 1, each of the line-phases A, B and C is provided with a separate relaying-circuit for energizing an auxiliary bus 44 whenever there is a simultaneous response of the directional element and the impedance element in any one of the three phases, and the energization of this auxiliary bus 44 is utilized to perform two functions: it directly energizes the operating coil 45 of an auxiliary relay or contactor-switch CSP, and it energizes the trip-coil TC through a make-contact 46 of a receiver-relay RR. The ground-current relaying-response on Fig. 1 utilizes the make-contacts of the ground directional and overcurrent relays DO and IO to utilize an auxiliary bus 47 which is also utilized to perform two functions, namely, energizing the operating coil 48 of an auxiliary relay or contactor-switch CSG, and energizing the trip-coil TC through a second contact, 49, of the receiver-relay RR.

The receiver-relay RR is of a known type having two windings. One of these receiver coils or windings is a tripping or operating winding RRT, which is shown in Fig. 1 as being energized by the closure of either a make-contact 51 of the CSP relay, or a make-contact 52 of the CSG relay. The other receiver-relay coil is a holding or restraining winding RRH, which is shown, in Fig. 1, as being directly energized from the tube-type receiver-element R, which is tuned to the carrier-current frequency.

In operation, in accordance with my present invention, carrier-current transmission is started by changing the potential of the grid-terminal 28, from the negative potential of the negative station-battery terminal (—), to a suitable positive potential, which is usually close to the potential of the positive bus (+), as previously explained. This may be accomplished, either by the phase-fault-responsive equipment, which controls the potential of the intermediate point 26, or the ground-fault-responsive equipment, which controls the potential of the intermediate point 25. This carrier-current starting-control is direct and instantaneous. By direct, I mean that it is accomplished without the intermediary of any mechanically moving parts, by the direct application of voltages which are directly derived from, and responsive to, a predetermined function of electrical conditions of the protected circuit of the protected line 5, as previously explained.

The use of wave-smoothing means, such as the various capacitors 19, in combination with full-wave rectifiers 18, makes it possible to derive substantially non-pulsatory rectified voltages from the various functions of the electrical conditions of the protected line, so that the carrier-current transmission does not pulsate, or come on and off, with various portions of the alternating-current wave of the line-current, or other electrical condition of the line. The use of a direct application of a line-function-derived voltage assures that the carrier-current transmitting-condition shall be maintained as long as the fault-condition lasts, in the protected line-section 5, thus providing a safeguard against the inadvertent momentary interruption of carrier-current transmission such as has heretofore been experienced as a result of contact-chattering of mechanical relays.

Carrier-current is removed from the line, or carrier-transmission interrupted, by means of auxiliary contacts 53 and 54 of the auxiliary relays CSP and CSG, respectively, which are utilized to apply the negative voltage of the negative bus-terminal (—), respectively to an intermediate point 55 between the resistors R2 and R3, and to an intermediate point 56 between the resistors R4 and R5 of the grid-control circuit, in the manner which is described and claimed in the Lenehan patent. The connection of the ground-fault control-point 56 closest to the grid-terminal 28 gives the ground-fault relay CSG preference, over the phase-fault relay CSP, in the control of the carrier-current transmission, as set forth in the Lenehan patent. It will be noted these current-stopping relays CSP and CSG are directionally controlled, through their direct-current control-circuits which include the respective directional elements DA, DB, DC and DO, which are responsive to the directions of the various phases of the line-currents.

In the relaying system which is shown in Fig. 1, it is known to be desirable that the carrier-starting fault-response shall be more sensitive than the carrier-stopping fault-response, and this same feature is carried out, in my present design, by proper choice of the magnitudes of the rectified relaying voltages, which are applied to the intermediate points 25 and 26 of the grid-control circuit, in comparison with the negative biasing voltage of the station-battery (+).

In Fig. 3, I have shown a control-system which is somewhat different from that which is shown in Fig. 1. I have simplified the carrier-starting control by utilizing only overcurrent responses, for starting carrier, without utilizing the voltage-responsive restraints which produce the impedance-type of response. In Fig. 3, also, the rectified output-voltage of all four of the current-responsive compensators CA, CB, CC and CO are connected in parallel, across a single relaying-circuit 60—61, so as to obtain a "largest-phase" response, as described and claimed in my Patent No. 2,242,950, granted May 20, 1941. The ground-current response may be properly weighted, with respect to the phase-fault responses, by properly adjusting the ground-fault-compensator CO, as shown at 21.

In Fig. 3, by grouping together the ground-fault and phase-fault carrier-starting responses, I have dropped the feature of ground-fault preference, and hence the CSP and CSG carrier-stopping contacts 53 and 54 are both connected to the same intermediate point 62 in the grid-control circuit, this point 62 being between the resistors R2 and R5, the resistors R3 and R4 being omitted.

In Fig. 3, I have also shown the use of an auxiliary tube 63, for amplifying, or responding to, the rectified voltages appearing across the relaying bus 60—61. The auxiliary amplifier-tube 63 is shown, in a simple form, as a three-element tube having a cathode 64, a grid 65, and an anode 66. This tube is of a type such that tube-operation is strongly maintained when the grid-voltage becomes sufficiently positive with respect to the cathode 64, (assuming an adequate plate-voltage), and preferably the tube-type is such that the tube-operation becomes substantially blocked again, when the grid-voltage becomes

slightly more negative than the positive value required to initiate the tube-operation. The tube 63 is intended to be representative of any controllable tube-means which will provide a good current-flow connection between the point 28 and the positive bus (+) when the grid-voltage becomes slightly larger than a predetermined value, but which will stop the current-conducting operation after the subsidence of the fault-condition which caused the initiation of the tube-operation.

The amplifier-tube 63 of Fig. 3 may also advantageously be a saturating type of tube, that is, a tube in which a very small difference in the grid-voltage, at around the critical point which maks the demarcation between operation and non-operation of the tube, causes the plate-current to suddenly change, from a substantially zero value, to a very large, or "saturated," value. In this manner, I obtain a valve-like response to the voltage of the control-circuit 60—61, and I relieve the oscillator-tube 12 of the requirement that it should have a saturating characteristic in the sense of being able to oscillate freely and strongly when its grid-potential is close to the border-line between operating and non-operating conditions.

The plate-voltage which is applied to the amplifier-tube 63 should be at least as high as the negative grid-bias which is applied by the station-battery (+) and (—), or sufficiently high to give the oscillator-grid 14 a positive-enough potential to start carrier. If the amplifying tube 63 is not of the saturating variety, its plate-voltage should be higher than the negative bias which is imposed by the station-battery (+) and (—), and the output-voltage of the amplifier tube should be applied across the resistor R1 of the grid-control circuit, in the same manner as in Fig. 1.

If, however, as is assumed to be the case, the amplifier-tube 63 is of the saturating variety, it is not necessary that its plate-voltage shall be larger than the voltage of the station-battery (+) and (—), and in fact, the station-battery may be utilized as the plate-voltage source of the amplifier tube, as shown in Fig. 3. In this case, the negative terminal 64 of the tube is connected to the intermediate point 28 in the grid-control circuit of the master-oscillator 12, so as to bring this point substantially to the potential of the positive bus (+) whenever the amplifier tube 63 is changed from its non-operative or non-conducting condition to its operative condition, in response to a sufficiently large positive voltage appearing across the relaying-bus 60—61, which makes the amplifier-grid 65 sufficiently positive with respect to its anode 64.

In Fig. 3, the reverse-current conductivity of the various rectifiers 18 has the same effect as a certain grid-leakage resistance, which may be utilized as a grid-leak, or I may utilize an equivalent or suitable resistance R8, as shown in Fig. 3, in the same manner to which the resistance R1 of Fig. 1 represents the equivalent of the reverse-current resistance of the rectifiers 18 for keeping the oscillator-grid 14 connected to the negative battery-terminal (—) whenever there is no voltage impressed on the control-circuit 26—27 of Fig. 1.

The remaining connections, as shown in Figs. 3 and 4, are substantially the same as those shown in Figs. 1 and 2, except that I have omitted the voltage-responsive compensators CA' and CB' and CC', and I have substituted over-current phase-fault detectors IA, IB and IC for the impedance-type phase-fault-detectors ZA, ZB, and ZC of Fig. 2.

I claim as my invention:

1. Fault-responsive relaying-apparatus for a polyphase circuit which is to be protected, comprising means for developing a plurality of unidirectional derived current-responsive voltages, responsive to different phases of line-currents of the protected circuit, means for developing a plurality of unidirectional derived voltage-responsive voltages, responsive to different phases of line-voltages of the protected circuit, circuit-means for opposing derived current-responsive and voltage-responsive voltages against each other in pairs, to obtain, in each case, a resultant derived voltage for that phase, and means for connecting the resultant derived voltages as a plurality of parallel-connected sources of voltage for a relaying circuit, the parallel connections including rectifiers whereby the largest of said resultant derived voltages is substantially excluded from feed-back into the circuits of the smaller of said resultant derived voltages, and fault-responsive apparatus energized from said relaying circuit.

2. Fault-responsive relaying-apparatus for a polyphase circuit which is to be protected, comprising means for developing a plurality of derived current-responsive voltages, responsive to different phases of line-currents of the protected circuit, means for developing a plurality of unidirectional derived voltage-responsive voltages, responsive to different phases of line-voltages of the protected circuit, circuit-means for opposing derived current-responsive and voltage-responsive voltages against each other in pairs, to obtain, in each case, a resultant derived voltage for that phase, and means for connecting the resultant derived voltages as a plurality of parallel-connected sources of voltage for a relaying circuit, the parallel connections including rectifiers whereby rectified resultant voltages are supplied to said relaying circuit, and whereby the largest of said rectified resultant voltages is substantially excluded from feed-back into the circuits of the smaller of said rectified resultant voltages, and fault-responsive apparatus energized from said relaying circuit.

3. Terminal equipment for one terminal of a direction-comparing type of carrier-current relaying-system for protecting a line-section of an alternating-current transmission line against faults, said terminal equipment comprising a carrier-current transmitter, a carrier-current receiver, relay-circuit means requiring the receipt of carrier current, by said receiver, to block a faulty relaying operation, line-energized fault-detector carrier-starter means for starting and continuously maintaining the operation of said transmitter throughout the continuance of a predetermined line-fault condition, and line-energized directionally responsive carrier-stopping means for insuring that the operation of said transmitter is stopped when said carrier-stopping means responds; said transmitter comprising a voltage-responsive tube which causes the transmitter to transmit an adequate carrier-current when an adequate control-voltage is applied to the tube and to cease transmitting at other times, and said carrier-starter means including means for constantly applying, to said tube, a line-derived unidirectional, smoothed-wave control-voltage which is responsive, in

magnitude, to a predetermined function of electrical conditions of the line.

4. The invention as defined in claim 3, characterized by said voltage-responsive part of the tube being a grid-circuit, and said carrier-starter means comprising a unidirectional-potential source for normally applying a negative biasing voltage to said grid-circuit, said line-derived control-voltage-means being connected between a negative point of said source and said grid-circuit, and a circuit-connection including a rectifier for conducting current from said grid-circuit toward a positive point of said source.

5. The invention as defined in claim 3, characterized by said carrier-starter means comprising means for developing a unidirectional derived voltage, responsive to a line-current function, means for developing a unidirectional derived voltage, responsive to a line-voltage function, and means for applying the difference between these two derived voltages to said tube to control the operation thereof.

6. The invention as defined in claim 3, characterized by said carrier-starter means comprising means for developing a plurality of derived alternating voltages, responsive to different electrical quantities of the protected circuit, means for separately rectifying said derived alternating voltages, and means for connecting the resultant rectified voltages as a plurality of parallel-connected sources of voltage for said tube to control the operation thereof, the parallel connections including rectifiers whereby the largest of said rectified voltages is substantially excluded from feedback into the circuits of the smaller of said rectified voltages.

7. Terminal equipment for a polyphase line, as defined in claim 3, characterized by said carrier-starter means comprising means for developing a plurality of unidirectional derived current-responsive voltages, responsive to different phases of line currents of the protected circuit, means for developing a plurality of unidirectional derived voltage-responsive voltages, responsive to different phases of line-voltages of the protected circuit, circuit-means for opposing derived current-responsive and voltage-responsive voltages against each other in pairs, to obtain, in each case, a resultant derived voltage for that phase, and means for connecting the resultant derived voltages as a plurality of parallel-connected sources of voltage for said tube to control the operation thereof, the parallel connections including rectifiers whereby the largest of said resultant derived voltages is substantially excluded from feed-back into the circuits of the smaller of said resultant derived voltages.

8. Terminal equipment for a polyphase line, as defined in claim 3, characterized by said carrier-starter means comprising means for developing a plurality of derived current-responsive voltages, responsive to different phases of line-currents of the protected circuit, means for developing a plurality of unidirectional derived voltage-responsive voltages, responsive to different phases of line-voltages of the protected circuit, circuit-means for opposing derived current-responsive and voltage-responsive voltages against each other in pairs, to obtain, in each case, a resultant derived voltage for that phase, and means for connecting the resultant derived voltages as a plurality of parallel-connected sources of voltage for said tube to control the operation thereof, the parallel connections including rectifiers whereby rectified resultant voltages are supplied to said tube, and whereby the largest of said rectified resultant voltages is substantially excluded from feed-back into the circuits of the smaller of said rectified resultant voltages.

9. Terminal equipment for a protective carrier-current relaying-system for an alternating-current line, comprising, in combination, a transmitter comprising a voltage-responsive tube which causes the transmitter to transmit an adequate carrier-current when an adequate control-voltage is applied to the tube and to cease transmitting at other times, and a carrier-starter means including means for constantly applying, to said tube, a line-derived unidirectional, smoothed-wave control-voltage which is responsive, in magnitude, to a predetermined function of electrical conditions of the line.

10. The invention as defined in claim 9, in combination with means for limiting the magnitude of the control voltage which is applied to said tube.

11. The invention as defined in claim 9, characterized by said carrier-starter means comprising means for developing a unidirectional derived voltage, responsive to a line-current function, means for developing a unidirectional derived voltage, responsive to a line-voltage function, and means for applying the difference between these two derived voltages to said tube to control the operation thereof.

12. The invention as defined in claim 9, characterized by said carrier-starter means comprising means for developing a plurality of derived alternating voltages, responsive to different electrical quantities of the protected circuit, means for separately rectifying said derived alternating voltages, and means for connecting the resultant rectified voltages as a plurality of parallel-connected sources of voltage for said tube to control the operation thereof, the parallel connections including rectifiers whereby the largest of said rectified voltages is substantially excluded from feedback into the circuits of the smaller of said rectified voltages.

13. Terminal equipment for a polyphase line, as defined in claim 9, characterized by said carrier-starter means comprising means for developing a plurality of unidirectional derived current-responsive voltages, responsive to different phases of line currents of the protected circuit, means for developing a plurality of unidirectional derived voltage-responsive voltages, responsive to different phases of line-voltages of the protected circuit, circuit-means for opposing derived current-responsive and voltage-responsive voltages against each other in pairs, to obtain, in each case, a resultant derived voltage for that phase, and means for connecting the resultant derived voltages as a plurality of parallel-connected sources of voltage for said tube to control the operation thereof, the parallel connections including rectifiers whereby the largest of said resultant derived voltages is substantially excluded from feed-back into the circuits of the smaller of said resultant derived voltages.

14. Terminal equipment for a polyphase line, as defined in claim 9, characterized by said carrier-starter means comprising means for developing a plurality of derived current-responsive voltages, responsive to different phases of line-currents of the protected circuit, means for developing a plurality of unidirectional derived voltage-responsive voltages, responsive to different

phases of line-voltages of the protected circuit, circuit-means for opposing derived current-responsive and voltage-responsive voltages against each other in pairs, to obtain, in each case, a resultant derived voltage for that phase, and means for connecting the resultant derived voltages as a plurality of parallel-connected sources of voltage for said tube to control the operation thereof, the parallel connections including rectifiers whereby rectified resultant voltages are supplied to said tube, and whereby the largest of said rectified resultant voltages is substantially excluded from feed-back into the circuits of the smaller of said rectified resultant voltages.

EDWIN L. HARDER.

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