

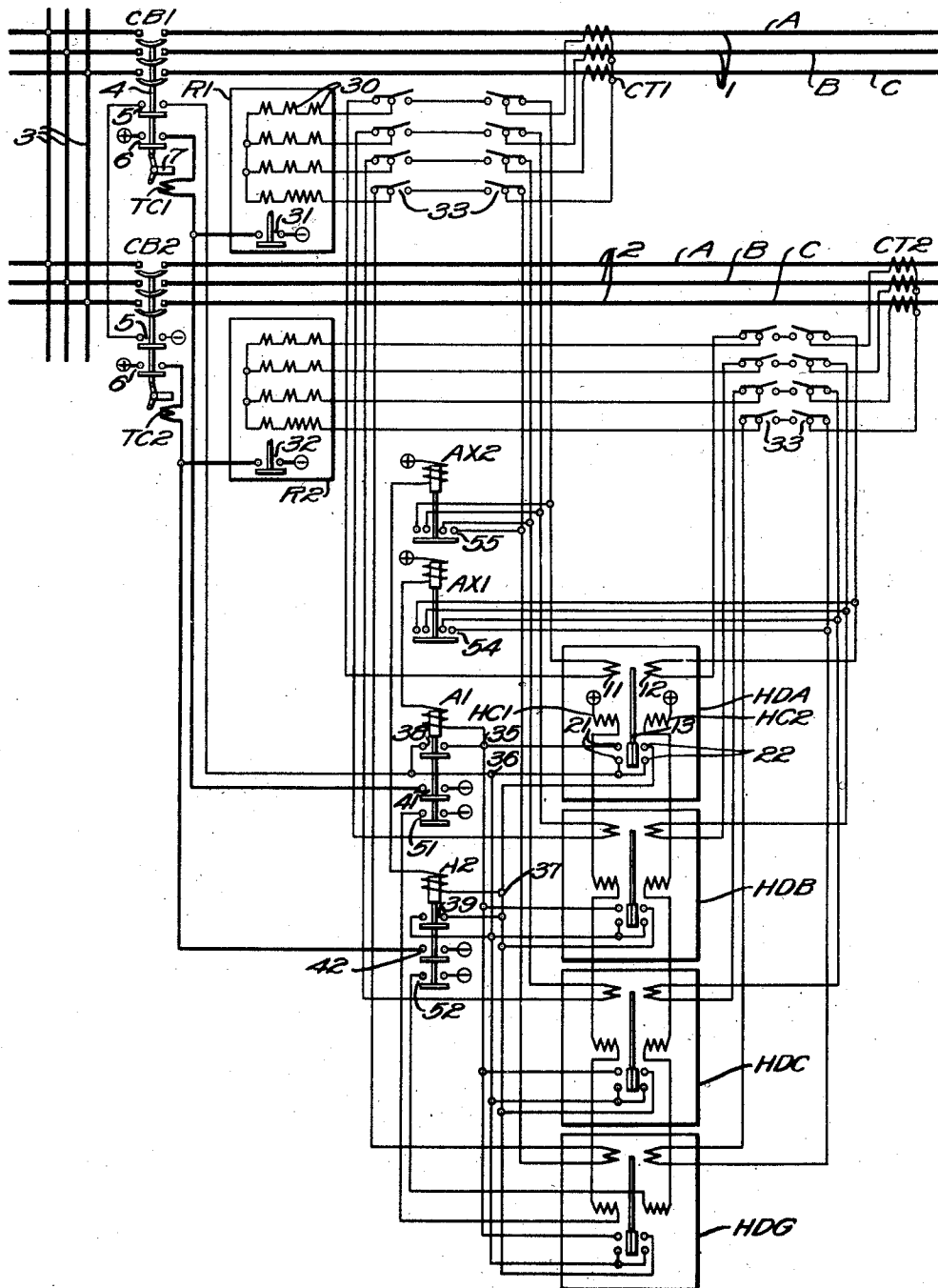
Oct. 24, 1944.

L. F. HUNT

2,361,208

CURRENT BALANCE RELAY SYSTEM

Filed Aug. 26, 1942



WITNESSES:

Robert C. Baird
Wm. L. Groove

INVENTOR

Lloyd F. Hunt.

BY *O. R. Buchanan*

ATTORNEY

UNITED STATES PATENT OFFICE

2,361,208

CURRENT BALANCE RELAY SYSTEM

Lloyd F. Hunt, Glendale, Calif., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application August 26, 1942, Serial No. 456,207

12 Claims. (Cl. 175—294)

My invention relates to differential relay systems, and it has more particular relation to auxiliary apparatus and connections for properly safeguarding and correlating the operations of a high-speed current-balance relay-system for parallel-line protection, particularly in a three-phase system where there are a number of high-speed current-balance relays, usually one for each phase, and one for ground or residual-current response.

As pointed out in the Klemmer Patent No. 2,005,144, granted June 18, 1935, it is possible, under certain circumstances, for various difficulties to be encountered in the operation of differential relaying systems for opening both ends of a faulty line-section on a transmission system having two parallel-connected line-sections between two different stations. These difficulties can arise in several ways.

Thus, the breaker at one end of the faulty line-section may open sooner than the breaker at the other end, resulting in a momentary heavy rush of reverse-power current in the sound line-section, which may result in erroneously tripping out the sound line-section, either in response to the high-speed differential protective relaying apparatus, or in response to the fault-responsive relaying apparatus which is associated with each of the line-sections, regardless of conditions on the other line-section.

It is possible, under certain circumstances, for difficulties to arise from the fact that one pole of any polyphase breaker will, in general, interrupt its arc in advance of the arcing-contacts in the other phases, resulting in a residual current momentarily appearing on the sound line, with the possibility of an erroneous tripping-response of the sound line as a result thereof.

Another difficulty which might possibly arise, under extreme conditions, if suitable safeguarding means were not adopted, could occur in the readjustment-period after a tripping-operation, when certain interlocks might open at a moment when some one of the tripping-relays is in a position indicating the desirability for tripping out the sound line after the faulted one of the parallel line-sections has been switched out, at one or both of its ends.

The above-mentioned difficulties are particularly true of very high-speed relays, particularly when operating under heavy fault-current conditions, resulting in a double-frequency pulsating torque on certain types of relays, tending strongly to vibrate the tripping-contacts between opposite positions, indicating first that one line-

section is faulted, and then that the other line-section is faulted. In pulsating-torque relays of this nature, it has been common, in the past, to provide each relay with two direct-current holding coils, one for each position of the relay, these holding-coils being connected in series with the respective tripping-contacts of the relay, so as to hold the relay in contact-maintaining position, whenever either one of its tripping-contacts is closed, corresponding to a fault on the one or the other of the parallel-connected line-sections.

When there are a number of such current-balance relays having their respective tripping-circuits connected in parallel, one circuit for tripping the breaker on one line, and another circuit for tripping the breaker on the other line, care must be exercised to obtain enough energy in the holding-coils without interfering with the quick and reliable operation of the tripping-coil of the breaker, and this requirement has been particularly hard to meet, in the case of a second balance-relay pulling in, or responding, after the first relay has responded. Thus, on a phase-to-phase fault, involving phases A and B, the differential or balance-current relay comparing the phase-A current of the faulted line with the phase-A current of the sound, parallel-connected line, may respond first, closing its tripping-contact for the faulted line, and simultaneously energizing its holding-coil which is connected in series therewith. The phase-B balance-current relay may then close its tripping-contact, but its holding-coil would then be connected in parallel with the holding-coil circuit of the phase-A relay, which has a low voltage-drop across it, and thus the phase-B relay under extreme conditions, might conceivably fail to receive enough energy to keep its phase-B tripping-contacts from bouncing right open again, under the influence of the pulsating relay-torque, thus producing a condition which might result, subsequently, in a faulty tripping-operation, if the safeguarding or interlocking-means, which are provided, should prove inadequate for their task.

While some or all of the above-mentioned difficulties and possibilities have been known before, and while some or all of them may have been more or less completely safeguarded against, by one means or another, in previous apparatus such as that shown in the Klemmer patent, I have provided means whereby certain different safeguarding-steps or operations may be carried out, which have certain advantages under certain cases.

Thus, it is an object of my invention to prevent the other current-balance relays from having an

opposite direction of contact-closing movement, after any one of a bank of current-balance relays has responded; or to cause the other current-balance relays to respond in the same direction of contact-closing movement as the first relay; or to energize only the holding-coils corresponding to the desired direction of response, of the entire bank of current-balance relays, after any one of them has responded; or to energize some or all of the holding-coils from a circuit which is separate from the tripping circuit; or to make it impossible for the fault-responsive tripping-means which is associated individually with the sound line from becoming actuated toward a tripping position during, or immediately after, the clearing of a fault on a faulted parallel-connected line, thus avoiding the necessity for relying entirely on interlocking trip-circuit contacts in series with the tripping-contacts of relays which would otherwise be permitted to move to erroneous tripping-conditions, with resultant danger of tripping out the sound line.

With the foregoing and other objects in view, my invention consists in the apparatus, parts, combinations, systems, and methods hereinafter described and claimed, and illustrated in the accompanying drawing, the single figure of which is a simplified diagrammatic view of circuits and apparatus embodying my invention in an illustrative form.

I have illustrated my invention as being applied to the protection of a three-phase transmission-line comprising two parallel-connected line-sections 1 and 2, which are connected, at each end, to a bus 3, through circuit-breakers CB1 and CB2, respectively, only one end being illustrated. The line-phases are designated by the letters A, B, and C.

Each circuit breaker, such as the circuit-breaker CB1, is provided with a circuit-interrupting arcing-mechanism 4, two or more auxiliary switches 5 and 6, and a tripping-mechanism 7. The trip-coils for the two breakers CB1 and CB2 are designated TC1 and TC2, respectively.

The two parallel-connected line-sections 1 and 2 are provided with current-balance relay-protection by means of four high-speed differential relays HDA, HDB, HDC, and HCG, for phases A, B, and C, and ground or residual-current, respectively. Each of the high-speed differential or current-balance relays, such as the relay HDA, is provided with two oppositely acting alternating-current operating-coils 11 and 12, which are energized from the corresponding phase or ground-currents from two banks of current-transformers CT1 and CT2, associated with the respective lines 1 and 2. Each current-balance relay is also provided with a centrally biased, movable arm 13, which is moved, in one direction or the other, to close either a tripping-contact 21, in case of a fault on the line 1, or a tripping-contact 22, in case of a fault on the line 2. Each balance-current relay is also provided with two direct-current holding coils HC1 and HC2, for holding the relay in its actuated or contact-making position, for the contacts 21 and 22, respectively, corresponding to the faults on the lines 1 and 2, respectively.

In addition to the differential, or current-balance, relays HDA, HDB, HDC, and HCG, each of the two line-sections has an individual fault-responsive relaying means, R1 and R2, respectively, associated therewith, for responding to predetermined fault-conditions on either line-section alone, regardless of conditions on the other line-

section. I have shown the current-coils 30 of the respective fault-responsive relays R1 and R2 energized from the respective line-current transformers CT1 and CT2, in series with the respective operating-coils 11 and 12 of the current-balance relays. Each of the individual fault-responsive relays R1 and R2 is provided with its own tripping-contact, or a plurality of contacts, as indicated illustratively at 31 and 32, respectively, for tripping the respective line circuit-interrupters CB1 and CB2.

I have also shown banks of double-throw switches 33 whereby the operating coils 11 and 12 of the various current-differential relays HDA, HDB, HDC, and HDG may be switched out of service, leaving each of the line-sections 1 and 2 to be protected only by its individual fault-responsive relaying-means R1 and R2, respectively. The cutout-switches 33 are shown in the position with the differential or current-balance relays connected in service.

In accordance with my present invention, I provide a series of auxiliary relays AX1 and A1 for the line 1, and AX2 and A2 for the line 2. The operating coils of the relays AX1 and A1 are illustrated as being connected in series with each other, between the positive battery-terminal (+) and an intermediate relaying bus or connection 35, and thence, through any one of the four-current-balance line 1 contacts 21, to a second relaying bus or connection 36, from which the circuit-connection is completed through the auxiliary switches 5 of both of the line circuit-breakers CB1 and CB2, the circuit being completed at the negative battery-terminal (-) at the circuit-breaker CB2. These auxiliary interlocking breaker-switches 5 are closed when the breaker is closed, and open when the main breaker-contacts are approximately 50% open. In like manner, the operating coils of the auxiliary relays AX2 and A2 are also illustrated as being connected in series with each other, between the positive battery-terminal through the interlocking breaker-switches 5, as already described.

The auxiliary switches A1 and A2 are thus energized when any one of the differential or current-balance relays indicates a fault on line 1 or line 2, as the case may be. Each of these auxiliary relays A1 and A2 is shown as being provided with three make-contacts. The make-contacts 38 and 39 of relays A1 and A2, respectively, are utilized to bypass the current-balance contacts 21 or 22, as the case may be, which caused the initial operation or response of the auxiliary relays A1 and A2, thus holding in, whichever relay is operated, and maintaining its circuit until the corresponding circuit-breaker CB1 or CB2, respectively, has opened its contacts far enough to break the relaying-circuit at the auxiliary breaker-switch 5.

The respective auxiliary relays A1 and A2 also have trip-contacts 41 and 42 for directly energizing the trip-coils TC1 and TC2, respectively, in parallel with the fault-responsive relay-contacts 31 and 32, respectively. These trip-coil circuits are completed through the auxiliary breaker-switches 6 of their respective breakers, so that each trip-coil circuit is finally interrupted when its own circuit-interrupting arcing-mechanism is about 50% open, or in any other condition of opening according to the adjustment of the breaker-switch 6.

The auxiliary relays A1 and A2 also have contacts 51 and 52 which are utilized to complete a separate energizing-circuit for the holding-coils

HC1 and HC2, as the case may be, for the respective differential relays HDA, HDB, HDC, and HDG, the four line-1 holding coils HC1 being illustrated as being connected in series with each other, and energized from the relay-contact 51, from the positive battery-terminal (+) to the negative battery-terminal (-), while the four line-2 holding-coils HC2 are similarly illustrated as being serially connected in circuit with the relay-contact 52, although it is to be understood that a parallel connection of the respective groups of four holding-coils HC1 or HC2 might have been utilized, instead of the series connection; it being preferable, however, that these holding-coils HC1 and HC2 shall be energized in circuits which are independent of the trip-coil circuits which are controlled by the relay-contacts 41 and 42, respectively.

It will be noted that the other auxiliary relays, AX1 and AX2, respectively, are energized, respectively, when the respective lines 1 and 2 are faulted. When the auxiliary relay AX1 picks up, in response to a differential-current relay-operation indicating a fault on the line 1, it closes a bank of contacts 54 which are utilized to short-circuit the four terminals of the line-current transformer CT2 which is associated with the other line, that is, with the sound line 2. In like manner, when the auxiliary relay AX2 picks up, in response to a differential-relay indication of a fault on the line-section 2, it closes a bank of relay-contacts 55 which short-circuit the four terminals of the line-current transformer CT1 which is associated with the other, or sound, line-section 1. In either case, the short-circuiting of the current-transformer terminals associated with the sound line-section effectively prevents a fault-indicating response, to any currents in the sound line-section, by any one of the four differential relays HDA, HDB, HDC, or HDG, or by the corresponding fault-responsive relay R1 or R2, as the case may be.

In this manner, I prevent any possibility of a faulty relaying-operation during the progress of, or immediately after, the clearing of a fault on either one of the parallel-connected lines 1 and 2, as indicated by the initial response of any one of the four current-balance relays HDA, HDB, HDC, or HDG. In fact, my short-circuiting of the current-transformer terminals of the sound line-section, in the case of the four current-balance relays HDA, HDB, HDC and HDG, not only prevents any one of the relay-contacts 13 from swinging to the sound-line side of its movement, but it actually causes all of the other current-balance relays to follow the lead of the first current-balance relay to respond, and to move over to a contact-making position on the faulted-line side of the relay; this result being produced by the energization of the differential-current relays with current from only the faulted line-section, as compared to practically no current at all from the sound line-section.

At the termination of the tripping operation, or upon the opening of the auxiliary breaker-switch 5 of the tripped circuit breaker CB1 or CB2, as the case may be, the auxiliary relay AX1 or AX2, whichever one was energized, will become deenergized, thus removing the short-circuit from the terminals of the line-current transformer of the sound line, thus making sure that the protective operation is completed before making it possible for any relay to respond to the current flowing in the sound line-section 2.

From the foregoing explanation of my apparatus and of its operation, it will be apparent

that I have provided a novel means for safeguarding the operation of a current-balance differential protective-relay system for parallel lines; and while I have illustrated my invention in a single form of embodiment, which I at present prefer, I wish it to be understood that my invention is by no means limited to this particular form of embodiment, particularly in the broader aspects of my invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language and the prior art.

I claim as my invention:

1. Protective relaying-means for a polyphase transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a plurality of current-balance relaying-means, each having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, line-current-energized means for differentially energizing each of the plurality of current-balance relaying-means from both of the parallel-connected line-sections, the energizing-connections being different for each of the plurality of current-balance relaying-means, and means responsive to a closure of either of the contacts of any one of the plurality of current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for preventing an opposite direction of contact-closing movement of any of the other current-balance relaying-means.

2. Protective relaying-means for a polyphase transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a plurality of current-balance relaying-means, each having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, line-current-energized means for differentially energizing each of the plurality of current-balance relaying-means from both of the parallel-connected line-sections, the energizing-connections being different for each of the plurality of current-balance relaying-means, and means responsive to a closure of either of the contacts of any one of the plurality of current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for causing the same direction of contact-closing movement of the other current-balance relaying-means.

3. Protective relaying-means for a polyphase transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a plurality of current-balance relaying-means, each having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, line-current-energized means for differentially energizing each of the plurality of current-balance relaying-means from both of the parallel-connected line-sections, the energizing-connections being different for each of the plurality of current-balance relaying-means, and means responsive to a closure of either of the contacts of any one of the plurality of current-balance relaying-means for initiating an opening-operation

of the appropriate line circuit-interrupter, and for deenergizing the line-current-energized energizing-means which supplies energy to the plurality of current-balance relaying-means from the other parallel-connected line-section.

4. Protective relaying-means for a polyphase transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a plurality of current-balance relaying-means, each having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, line-current-energized means for differentially energizing each of the plurality of current-balance relaying-means from both of the parallel-connected line-sections, the energizing-connections being different for each of the plurality of current-balance relaying-means, electrically operated holding-means associated with each of the contacts of each of the plurality of current-balance relaying-means for holding its contact closed once it is closed, and means responsive to a closure of either of the contacts of any one of the plurality of current-balance relaying-means for establishing a relaying-circuit for initiating an opening-operation of the appropriate line circuit-interrupter, and for establishing one or more other relaying-circuits for energizing at least one of the holding-means of all of the plurality of current-balance relaying-means.

5. Protective relaying-means for a polyphase transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a plurality of current-balance relaying-means, each having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, line-current-energized means for differentially energizing each of the plurality of current-balance relaying-means from both of the parallel-connected line-sections, the energizing-connections being different for each of the plurality of current-balance relaying-means, electrically operated holding-means associated with each of the contacts of each of the plurality of current-balance relaying-means for holding its contact closed once it is closed, and means responsive to a closure of either of the contacts of any one of the plurality of current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for selectively energizing only those holding-means associated with the corresponding contacts for that line circuit-interrupter in each of the plurality of current-balance relaying-means.

6. Protective relaying-means for a polyphase transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a plurality of current-balance relaying-means, each having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, line-current-energized means for differentially energizing each of the plurality of current-balance relaying-means from both of the parallel-connected line-sections, the energizing-connections being different for each of the plurality of current-balance relaying-means, electrically operated holding-means associated with each of the contacts

of each of the plurality of current-balance relaying-means for holding its contact closed once it is closed, and means responsive to a closure of either of the contacts of any one of the plurality of current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, for selectively energizing only those holding-means associated with the corresponding contacts for that line circuit-interrupter in each of the plurality of current-balance relaying-means, and for deenergizing the line-current-energized energizing-means which supplies energy to the plurality of current-balance relaying-means from the other parallel-connected line-section.

7. Protective relaying-means for a polyphase transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a plurality of current-balance relaying-means, each having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, fault-responsive relaying-means having contacts responsive to predetermined fault-conditions on either line-section alone, regardless of conditions on the other line-section, line-energized means for differentially energizing each of the plurality of current-balance relaying-means from the line-currents of both of the line-sections during parallel-connected line-operation, and for energizing said fault-responsive relaying means responsively to predetermined electrical quantities including the line-currents of their respective line-sections, the energizing-connections being different for each of the plurality of current-balance relaying-means, means responsive to a closure of the contact of either of said fault-responsive relaying-means for initiating an opening-operation of its line circuit-interrupter, and means responsive to a closure of either of the contacts of any one of the plurality of current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for preventing either an opposite direction of contact-closing movement of any of the other current-balance relaying-means, or a contact-closing response of the fault-responsive relaying-means associated with the other line-section.

8. Protective relaying-means for a polyphase transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a plurality of current-balance relaying-means, each having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, fault-responsive relaying-means having contacts responsive to predetermined fault-conditions on either line-section alone, regardless of conditions on the other line-section, line-energized means for differentially energizing each of the plurality of current-balance relaying-means from the line-currents of both of the line-sections during parallel-connected line-operation, and for energizing said fault-responsive relaying means responsively to predetermined electrical quantities including the line-currents of their respective line-sections, the energizing-connections being different for each of the plurality of current-balance relaying-means, means responsive to a closure of the contact of either of said fault-responsive relaying-means for initiating an opening-operation

of its line circuit-interrupter, and means responsive to a closure of either of the contacts of any one of the plurality of current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for de-energizing the line-current-energized energizing-means which supplies energy to the plurality of current-balance relaying-means and to the fault-responsive relaying-means for the other parallel-connected line-section.

9. Protective relaying-means for a transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a current-balance relaying-means having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, fault-responsive relaying-means having contacts responsive to predetermined fault-conditions on either line-section alone, regardless of conditions on the other line-section, line-energized means for differentially energizing the current-balance relaying-means from the line-currents of both of the line-sections during parallel-connected line-operation, and for energizing said fault-responsive relaying means responsively to predetermined electrical quantities including the line-currents of their respective line-sections, means responsive to a closure of the contact of either of said fault-responsive relaying-means for initiating an opening-operation of its line circuit-interrupter, and means responsive to a closure of either of the contacts of the current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for preventing either a reversal of the contact-movement of the current-balance relaying-means, or a contact-closing response of the fault-responsive relaying-means associated with the other line-section.

10. Protective relaying-means for a transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a current-balance relaying-means having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, fault-responsive relaying-means having contacts responsive to predetermined fault-conditions on either line-section alone, regardless of conditions on the other line-section, line-energized means for differentially energizing the current-balance relaying-means from the line-currents of both of the line-sections during parallel-connected line-operation, and for energizing said fault-responsive relaying means responsively to predetermined electrical quantities including the line-currents of their respective line-sections, means responsive to a closure of the contact of either of said fault-responsive relaying-means for initiating an opening-operation of its line circuit-interrupter, and means responsive to a closure of either of the contacts of the current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for preventing a contact-closing response of the fault-responsive relaying-means associated with the other line-section.

11. Protective relaying-means for a transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a current-balance relaying-means having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, fault-responsive relaying-means having contacts responsive to predetermined fault-conditions on either line-section alone, regardless of conditions on the other line-section, line-energized means for differentially energizing the current-balance relaying-means from the line-currents of both of the line-sections during parallel-connected line-operation, and for energizing said fault-responsive relaying means responsively to predetermined electrical quantities including the line-currents of their respective line-sections, means responsive to a closure of the contact of either of said fault-responsive relaying-means for initiating an opening-operation of its line circuit-interrupter, and means responsive to a closure of either of the contacts of the current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for de-energizing the line-current-energized energizing-means which supplies energy to the current-balance relaying-means and to the fault-responsive relaying-means from the other parallel-connected line section.

12. Protective relaying-means for a transmission-line; said line comprising at least two line-sections capable of being operated in parallel, and a line circuit-interrupter for each line-section; said protective relaying-means comprising a current-balance relaying-means having a contact for each of the parallel-connected line-sections for selectively responding to whichever line-section is faulted, fault-responsive relaying-means having contacts responsive to predetermined fault-conditions on either line-section alone, regardless of conditions on the other line-section, line-energized means for differentially energizing the current-balance relaying-means from the line-currents of both of the line-sections during parallel-connected line-operation, and for energizing said fault-responsive relaying means responsively to predetermined electrical quantities including the line-currents of their respective line-sections, means responsive to a closure of the contact of either of said fault-responsive relaying-means for initiating an opening-operation of its line circuit-interrupter, and means responsive to a closure of either of the contacts of the current-balance relaying-means for initiating an opening-operation of the appropriate line circuit-interrupter, and for de-energizing the line-current-energized energizing-means which supplies energy to the fault-responsive relaying-means from the other parallel-connected line-section.

LLOYD F. HUNT.