GROUND-RELAY TRANSMISSION-LINE PROTECTION

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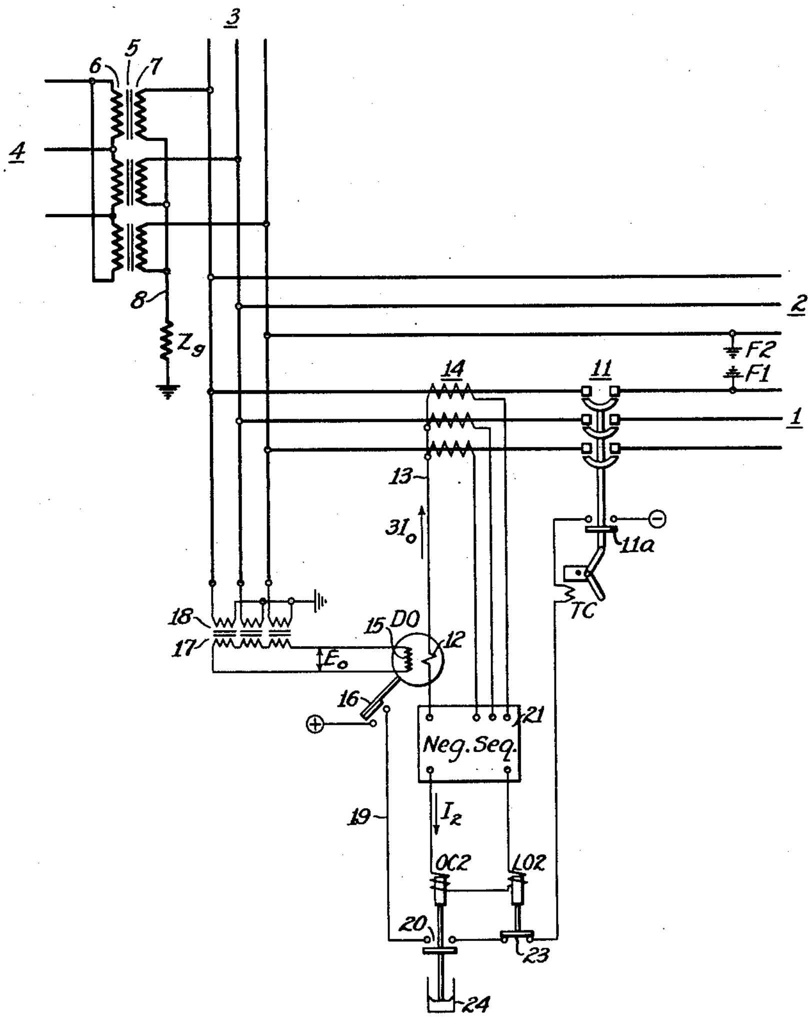

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GROUND-RELAY TRANSMISSION-LINE PROTECTION

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My present invention relates to an improved ground-fault protective-relay apparatus for the directional detection of ground-faults in a polyphase line.

Heretofore, there have been two principal types of directionally responsive ground-fault relays.

One of these previously known ground-fault protective-relay systems has utilized an overcurrent ground-fault detector, which is responsive to the zero-phase-sequence component of the line-current, and a ground-directional element which compares the direction of the zero-sequence line-current with the zero-sequence line-voltage component. This directionally responsive ground-fault relaying-system has the advantage of being extremely sensitive and simple, and has enjoyed a long period of successful use in practice, subject only to two disadvantages: (1) it has sometimes been too sensitive, in systems in which zero-sequence currents are induced, in the protected line, by faults on a nearby line; and (2) it has been subject to inapplicability or failure, on systems which are subject to those relatively rare fault-conditions which are sometimes referred to as simultaneous ground-faults, in which two ground-faults are in existence at the same time, on two different phase-conductors of two different lines which are connected to a common bus, this defect being limited to transmission systems which are only lightly grounded, through a fairly large grounding-impedance, which very greatly limits the magnitude of ground-faults, except in the case of the aforesaid simultaneous grounds.

The other one of the principal previously known ground-fault protective-relay systems has utilized a zero-sequence ground-fault detector, as in the first-mentioned system, but a directional element which is responsive to the negative-sequence line-current component and the negative-sequence line-voltage component, as described and claimed in the Evans Patent 2,066,932, granted January 5, 1937. This second ground-fault relaying-system has operated satisfactorily, from the standpoint of non-operation on induced current, but it has been subject to the previously mentioned difficulty in respect to simultaneous ground-faults.

There have also been other, more complicated, ground-fault relays, using different combinations of a plurality of phase-sequence components in both the fault-detecting element and the directional element of the ground-fault protective-system.

The principal objects of the present invention are to provide an improved, simple ground-fault relaying-system, which operates satisfactorily in systems which are subject to induced zero-sequence currents in a non-faulted protected line-section, and also to provide simple means whereby my new ground-fault protective relaying-system can be prevented from erroneous operation in the event of simultaneous ground-faults on very lightly grounded transmission-systems, that is, systems having a relatively large grounding-impedance at its grounded points, which may be either at the relay-station bus, or at some other bus.

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With the foregoing and other objects in view, my invention consists in the systems, circuits, combinations, apparatus, parts, and methods of design and control, which are hereinafter described and claimed, and illustrated in the accompanying drawing, the single figure of which is a simplified diagrammatic view of one terminal of ground-fault protective-relaying apparatus in accordance with my present invention.

In the accompanying drawing, I show one terminal of a protected three-phase transmission line or line-section 1, and the corresponding terminal of a second three-phase line-section 2, which is connected to the same three-phase bus 3 as the protected line-section 1. The two line-sections 1 and 2 may be either parallel lines, running along the same right-af-way, or they may be lines running in different directions, geographically spaced from each other, except for their termination in the common bus 3. By way of illustration, I have indicated a system in which the three-phase bus 3 is connected to a three-phase supply-circuit 4 through a bank of power-transformers 5, having delta-connected primary-windings 6, and star-connected secondary-windings 7, having a neutral point 8 which is connected to ground through a grounding-impedance Z_g. This grounding-impedance Z_g may be either a large impedance, for a lightly grounded system, or a small impedance, or even a substantially zero impedance, in the case of heavily or solidly grounded systems.

My ground-relay terminal-equipment is illustrated as being utilized in the control of the tripping of a three-pole circuit-breaker 11, which is utilized to connect the protected line-section 1 to the bus 3 at the relaying station or terminal. The breaker 11 is provided with an auxiliary make-contact 11a, which is open when the breaker is open, and a trip-coil TC.

The essential features of my relaying apparatus, in its simplest form, consist of a sensitive zero-sequence directional element DO, and a sensitive negative-sequence ground-fault-detector or overcurrent-element OC2.

The directional element DO is similar to ground-fault zero-sequence directional elements which have been previously known in the art. It has a current-coil 12 which is energized in the residual-circuit 13 of a bank of star-connected line-current transformers 14, so as to be energized in response to the zero-sequence line-current I_0 of the protected line-section 1. The directional element DO also has a voltage-coil 15 which is energized from the zero-sequence line-voltage component E_0, by any suitable means, such as the open-delta secondary-windings 17 of a bank of star-connected potential-transformers 18 which are energized from the bus 3. The ground-directional element DO also has a make-contact 16, which is connected in a tripping-circuit 19, in series with a make-contact 20 of the negative-sequence overcurrent-element OC2, so as to energize the trip-coil TC from a direct-current source (+) or (−), through the auxiliary make-contact 11a of the breaker 11.

The negative-sequence overcurrent-relay OC2 is energized from a negative-sequence network 21, which segregates, or selectively responds to, the negative-sequence component I_2 of the line-currents which are supplied to the network from the line-current transformers 14.

In cases where my new ground-fault relaying-equipment is to be applied to lightly grounded transmission-systems, having a high-value grounding-impedance Z_g, at the station-bus 3 at the relaying-terminal, or at some other bus; and in general in all cases where a general-purpose ground-fault relaying-equipment is to be provided, which is capable of being utilized in all grounded systems, whether the grounding-impedance Z_g is large or small or zero, I also provide an insensitive lockout-relay LO2, which is energized from either the zero-sequence line-current I_0 or the negative-sequence line-current I_2, so as to be responsive to the heavy line-section currents which flow at 14 in the event of simultaneous grounds. A preferred connection is shown wherein the lockout-relay LO2 is energized from the negative-sequence current-component I_2, by having its operating-winding connected in series with the operating-winding of the overcurrent-element OC2.

The lockout-element LO2 is less sensitive than the overcurrent-element OC2, as diagrammatically indicated by a smaller number of turns in the lockout-coil LO2 than in the overcurrent-coil OC2. The lockout-relay LO2 has a back-contact, or normally closed contact, 23, which is connected in series in the tripping-circuit 19. When the lockout-relay LO2 is utilized, it should be capable of opening its back-contact 23 in a smaller time than the time required for the overcurrent-element OC2 to close its make-contact 20, whatever that time may be, whether fast or slow. If necessary, in the event that the overcurrent-element OC2 is an element of the instantaneous or fast-acting type, it may be provided with a light dash-pot 24 or other means for retarding its contact-closing response, so as to allow time for the previous opening of the overcurrent-relay back-contacts 23, if the overcurrent relay is responding at all to the fault-conditions which may be existing at the time.

In operation, the setting of the negative-sequence lockout-relay LO2, (if this relay is used at all), is so high that it will not respond to single ground-faults, but it will respond when there are simultaneous ground-faults on different phases of two different lines which are connected to the station-bus at the relaying point, as indicated, for example, by the faults F1 and F2 in the drawing. It will, of course, respond for phase-to-phase or two phase-to-ground faults on the protected line, or such faults fed through the line, but this does not matter, as phase-relays (not shown) are provided to operate for these faults. In general, the lockout-element LO2 will not be used unless the system is, or may be, grounded through a relatively large grounding-impedance Z_g.

The effect of the large grounding-impedance Z_g is to greatly reduce the value of the fault-current, in the event of a ground-fault, but in reducing this ground-fault current, it consumes most of the fault-voltage, leaving very little negative-sequence line-voltage, in the event of a single ground-fault. This was one of the drawbacks of the Evans relay-system, which used a negative-sequence directional element (which is energized from voltage as well as current), for the directional response of the ground-fault relaying-apparatus.

In the event, however, of simultaneous ground-faults, involving different phases of two different lines, such as the lines 1 and 2, which are connected to the station-bus, the presence of a large grounding-resistance Z_g has heretofore caused an erroneous operation of the directional response of the negative-sequence directional element of the Evans system. In such a simultaneous-fault condition, the ground-fault current, which goes to ground from one of the phase-conductors of one of the lines, does not have to return through the large, current-limiting, grounding-resistor Z_g, but returns from the ground directly to another simultaneously grounded phase-conductor of another line, thus returning to the station-bus without passing through the grounding-resistance Z_g. Under these conditions, the output of the line-current transformers 14, in the protected line-section, no longer gives a true picture of the positive, negative and zero phase-sequence components of the line-current, because the return-current, in another phase, does not come back through the same set of current-transformers. Because of the distorted conditions just described, ground-relays have previously indicated an incorrect direction, under some simultaneous-fault conditions, thus resulting in an erroneous tripping-operation.

Since the indicated negative-sequence current-component is relatively large, under simultaneous-fault conditions, as compared to the indicated negative-sequence current-component which is obtained, from the line-current transformers 14 and the negative-sequence network 21, when there is a single line-to-ground fault on the protected line-section, it is easy to set the lockout-element LO2 so that it will respond to the simultaneous ground-fault condition, and not to the single phase-to-ground fault-condition. If the grounding-impedance Z_g is large, the negative-sequence current-component is limited to a particularly small value, in the event of single-ground faults, and under such conditions, it is particularly easy to make the current-settings or sensitivities of the over-current-element OC2 and the lockout-element LO2 discriminate between single-ground faults and simultaneous-ground-fault conditions, relying upon the phase-fault relays (not shown), which are practically always provided, to protect the line-section against double-ground faults.

In operation, the zero-sequence directional-element DO will get enough voltage and current to operate, on single phase-to-ground faults, when it should, whether the system is grounded through a high impedance Z_g or not. This has been amply proved by many years of successful operation of this kind of zero-sequence directional-element.

In the operation of my apparatus, the use of the negative-sequence current-component I_2, to energize the overcurrent-element or fault-detector element OC2, avoids the possibility of false operation which was possible in previous ground-fault relays utilizing zero-sequence overcurrent-elements, in cases when zero-sequence current is induced in a sound line-section by ground-faults on a nearby line, such as the line **2**.

In the operation of my invention, the negative-sequence lockout-element LO2, if used, avoids the completion of a tripping-operation in response to simultaneous ground-faults when a large grounding-impedance Z_g is used. Such a lockout-relay, responsive to simultaneous grounds, is also useful, in general, in other types of ground-fault relaying-systems, as in the Evans system using a zero-sequence ground-fault detector and a negative-sequence directionally responsive element.

While I have illustrated my invention in its barest essentials, and in a single illustrative form of embodiment, I wish it to be understood that various changes may be made, by way of additions and substitutions of equivalents, without departing from the essential features of the invention. I desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language.

I claim as my invention:

1. A ground-fault protective-relay apparatus for the directional detection of ground-faults in a poly-phase line, comprising a sequence-responsive means for developing a relaying-current having a substantial, selective response to the negative-sequence component of the line-current in the protected line, a fault-detecting relaying-means for detecting faults on the line, said fault-detecting relaying-means having a relay-operating element, means for energizing said relay-operating element solely from said sequence-responsive means, a ground-directional relaying-means for responding to ground-fault currents flowing in a particular direction, means for energizing said ground-directional relaying-means solely with the zero-phase-sequence line-current and line-voltage, and means for performing a relay-circuit operation in response to responded conditions of both the fault-detecting relaying-means and the ground-directional relaying-means.

2. A ground-fault protective-relay apparatus for the directional detection of ground-faults in one of a plurality of polyphase lines which are connected to a common polyphase bus at a relaying-station of a transmission system which is grounded through substantial grounding-impedance, said apparatus comprising a sequence-responsive means for developing a relaying-current having a substantial, selective response to the negative-sequence component of the line-current in the protected line, a sensitive fault-detecting relaying-means for detecting faults on the line, a less sensitive lockout relaying-means for responding to the heavy negative-sequence current which flows when there are simultaneous ground-faults on different phases of two of the lines which are connected to the common bus, means for energizing said fault-detecting relaying means and said lockout relaying-means from said sequence-responsive means, said lockout relaying-means being sufficiently insensitive to fail to respond in the event of a single ground-fault, the response of the fault-detecting relaying-means being slower than the response of the lockout relaying-means under conditions when both of said means respond, a ground-directional relaying-means for responding to ground-fault currents flowing in a particular direction, means for energizing said ground-directional relaying-means with the zero-phase-sequence line-current and line-voltage, and means for performing a relay-circuit operation in response to a responded condition of said fault-detecting relaying-means, a responded condition of said ground-directional relaying-means, and a non-responded condition of said lockout relaying-means.

3. A ground-fault protective-relay apparatus for the directional detection of ground-faults in one of a plurality of polyphase lines which are connected to a common polyphase bus at a relaying-station of a transmission system which is grounded through substantial grounding-impedance, said apparatus comprising negative-sequence-responsive relay-energizing means for selectively responding to a negative-sequence quantity of the protected line, zero-sequence-responsive relay-energizing means for selectively responding to a zero-sequence quantity of the protected line, a sensitive ground-fault-detecting relaying-means, a sensitive ground-fault directionally responding relaying-means, means for energizing one of said sensitive ground-fault relaying-means from the negative-sequence-responsive relay-energizing means, means for energizing the other of said sensitive ground-fault relaying-means from the zero-sequence-responsive relay-energizing means, sensitive lockout relaying-means for responding to the heavy fault-current which flows when there are simultaneous ground-faults on different phases of two of the lines which are connected to the common bus, said lockout relaying-means being sufficiently insensitive to fail to respond in the event of a single ground-fault, the response of the fault-detecting relaying-means being slower than the response of the lockout relaying-means under conditions when both of said means respond, means for energizing said lockout relaying-means from one of said sequence-responsive relay-energizing means, and means for performing a relay-circuit operation in response to a responded condition of said fault-detecting relaying-means, a responded condition of said directionally responsive relaying-means, and a non-responded condition of said lockout relaying-means.

4. The invention as defined in claim 3, characterized by said negative-sequence relay-energizing means having a selective response to the negative-sequence component of the line-current, said zero-sequence relay-energizing means having selective responses to the negative-sequence components of both the line-current and the line-voltage, and said fault-detecting relaying-means being energized from said negative-sequence relay-energizing means.

WILLIAM K. SONNEMANN.

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