

Dec. 21, 1965

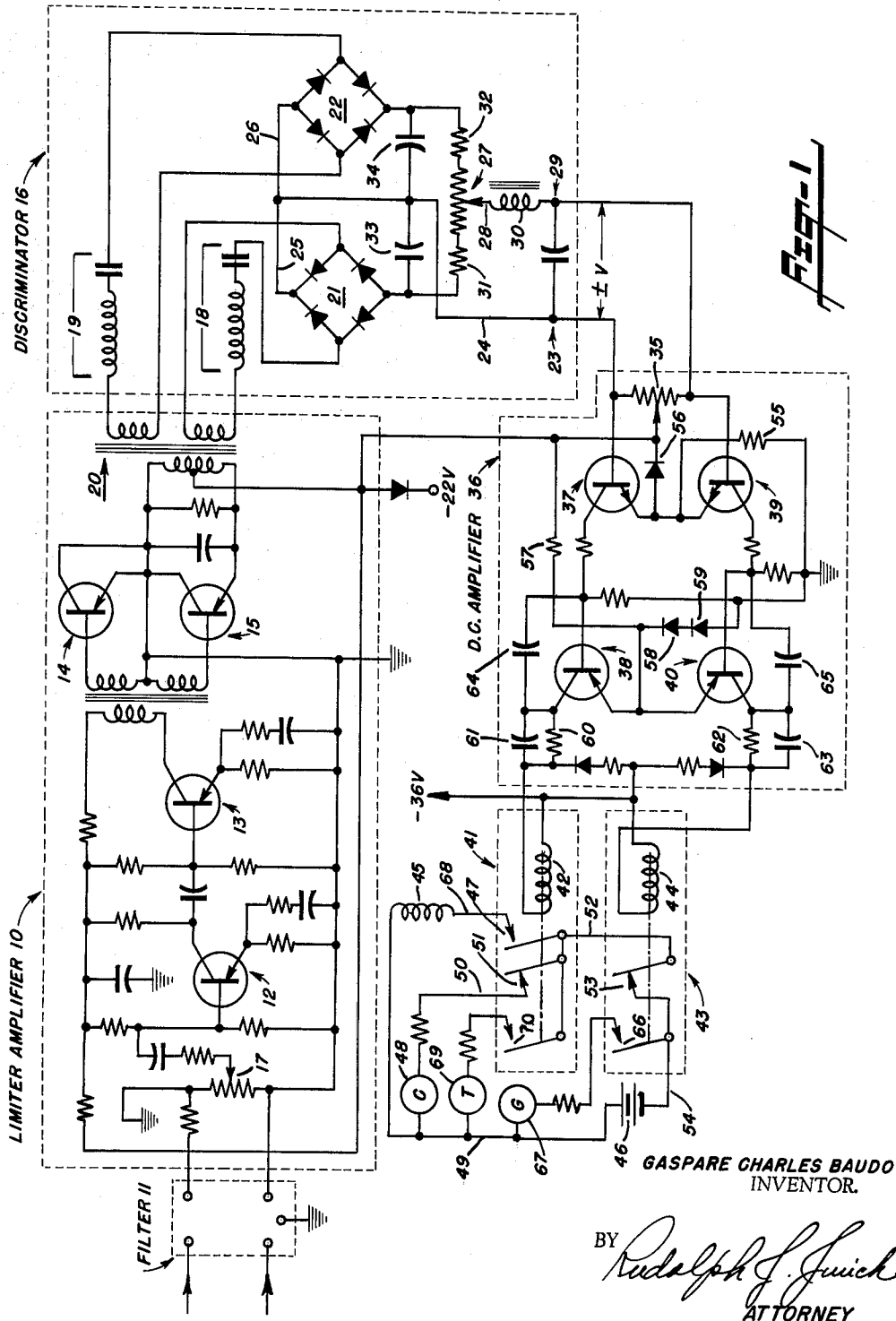
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3,225,266

PROTECTIVE RELAYING CIRCUIT

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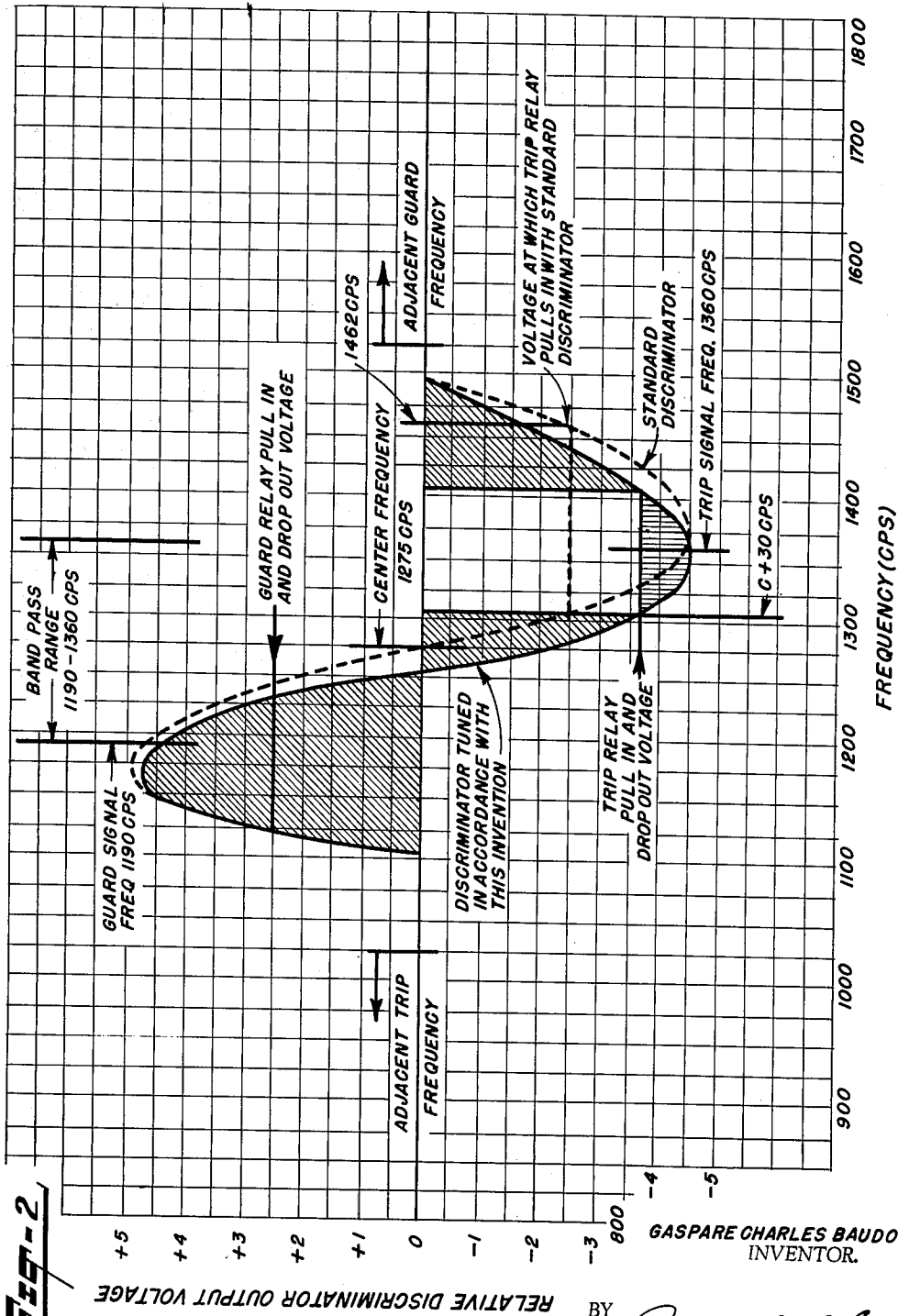
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PROTECTIVE RELAYING CIRCUIT

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This invention relates to a protective relaying circuit and more particularly to apparatus responsive to transmitted signals and providing an alarm and/or control function in response to the receipt of signals of predetermined character.

Frequency-shift tone signals are used in protection relaying apparatus for preventing damage to electrical apparatus located at a remote point. In apparatus of this class, speed of response to an alarm signal is a critical requirement as a fault which develops in large electrical apparatus results not only in costly damage to the apparatus but also may result in the shut down of an entire plant. For example, in the case of large power transformers connected to a high tension line, it is desirable to open the supply line within one cycle of the line frequency voltage. Additionally, all protective relaying arrangements require a maximum security against false operation caused by noise and spurious signals and a maximum degree of reliability when operation is required.

Associated with the particular apparatus to be protected are suitable devices which continuously sense predetermined operating parameters of the apparatus. Such devices control the operation of a frequency-shift tone transmitter having a predetermined center frequency. For example, in the case of a transmitter having a center frequency of 1275 cycles per second, the device which senses the insulation resistance of a power transformer will cause the transmitter to transmit a continuous 1190 cycle tone signal when the insulation resistance falls within a predetermined safe range. Such signal generally is referred to as a guard signal. However, upon insulation deterioration beyond the safe range, the transmitter is caused to transmit a continuous 1360 cycle tone signal, generally referred to as a trip signal. These guard and trip tone signals are transmitted over suitable lines to a receiver located at the central power station. Such receiver effects operation of control apparatus to provide a "safe" signal as long as the guard tone signal is being received, and a "check" signal in the event no signal is being received, the latter signaling the requirement for a checking of the protective apparatus. However, upon the receipt of a trip signal, the control apparatus effects the actuation of the circuit breaker to open the transmission line to which the power transformer is connected.

Various protective relaying circuits, operating on the guard and trip tone signal principle, are available. These, of course, utilize various means for discriminating between the received guard and trip signals as well as various arrangements for effecting actuation of the circuit breaker or other protective devices. One difficulty with existing protective relaying systems is the problem of noise sensitivity. In a conventional discriminator, noise frequencies just above the trip signal frequency often results in the false operation of the protective circuit. This is due to the fact that a conventional electrical discriminator peaks at a frequency above that of the trip signal frequency. Prior attempts to overcome this problem have led to the use of separate discriminators for the guard and trip signal frequencies or the use of separate band pass filters for each of the signal frequencies. While these approaches to the problem have reduced false opera-

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tions due to noise, they are not completely satisfactory, operationally, and involve added, complex circuitry.

Apparatus made in accordance with this invention utilizes a single discriminator, solid state components and series-arranged relay contacts in the output circuit, thereby resulting in a relatively simple circuit having a long, reliable operating life and a minimum possibility of false operation. Unlike normal, frequency-shift telegraph and control systems, the trip signal, in protective relaying systems of the class under discussion, will be transmitted only infrequently, perhaps only once in two years.

Consequently, normal voltage bias distortion is not a critical factor so that the guard and trip signals need not necessarily fall on the linear portions of the discriminator output curve. Therefore, in the apparatus to be described hereinbelow, the discriminator is specially tuned and biased to peak at the frequency of the trip signal and at a frequency below the guard signal.

An object of this invention is the provision of an improved protective relaying circuit of the frequency-shift class.

An object of this invention is the provision of protective relaying apparatus responsive to two, distinct, signals having predetermined fixed frequencies, which apparatus incorporates a frequency discriminator tuned to peak at the frequency of one signal and below the frequency of the other signal.

An object of this invention is the provision of protective relaying apparatus comprising receiver apparatus responsive to two signals having predetermined, different frequencies, frequency discriminator means energized by the receiver apparatus and providing a voltage output which varies in sign in correspondence with the signal received by the receiver apparatus, and a pair of control members one or the other of which is actuated in correspondence with the sign of the discriminator output voltage.

These and other objects and advantages of the invention will become apparent from the following description when taken with the accompanying drawings. It will be understood, however, that the drawings are for purposes of illustration and are not to be construed as defining the scope or limits of the invention, reference being had for the latter purpose to the claims appended hereto.

In the drawings,

FIGURE 1 is a schematic, circuit diagram of protective relaying apparatus made in accordance with this invention; and

FIGURE 2 is a set of curves showing the relative output voltage to frequency relation of two discriminators, one of conventional design and the other tuned in accordance with this invention.

Reference, now, is made to the schematic circuit diagram of FIGURE 1. The incoming tone signals are applied to a three-stage limiter amplifier 10 through a bandpass filter 11 which is tuned to pass those frequencies falling within the range of the particular, predetermined tone signals transmitted by the associated transmitter located at the remote station where the apparatus to be protected is in operation. For example, in the case of a frequency-shift transmitter having a center frequency of 1275 cycles per second, the guard signal will have a frequency of 1190 cycles, the trip signal will have a frequency of 1360 cycles, and the filter is tuned for positive rejection of adjacent channel frequencies lying outside of the range 1190-1360 cycles. The filter is of conventional design, tuned to reject adjacent channel frequencies by at least 40 db. The limiter amplifier, comprising the transistors 12-15 and associated circuitry, also is of conventional design and provides full limiting of the voltage applied to the discriminator 16 to approximately -45

dbm. An input potentiometer 17 serves as a means for adjusting the amplifier sensitivity.

The discriminator 16 comprises two, tuned circuits 18 and 19 and the associated full wave rectifiers 21 and 22, each circuit being connected to the separate secondary windings on the output transformer 20 of the limiter amplifier. The circuit 18 is tuned to peak at the trip signal frequency (1360 cycles) whereas the circuit 19 is tuned to peak below the guard signal frequency (1190 cycles) for purposes which will be explained hereinbelow. When a trip or guard signal is received by the limiter amplifier, voltages of equal, predetermined magnitude appear across the secondary windings of the output transformer 20. However, the voltages applied across the input diagonals of the bridge rectifiers 21 and 22 will depend upon the frequency of the voltage appearing across the output transformer 20. Thus, when a guard signal is received, the voltage applied to the input diagonals of the rectifier bridge 22 exceeds that applied to the input diagonals of the bridge 21. Conversely, when a trip signal is received, the voltage applied to the bridge 21 exceeds that applied to the bridge 22. One output junction of each rectifier bridge is connected to the output terminal 23, of the discriminator, by the leads 24-26. A potentiometer 27, having a slider 28 connected to the other discriminator output terminal 29 through an inductor 30, is connected across the other output junction of the rectifier bridges through the fixed resistors 31, 32. Smoothing capacitors 33, 34 are connected across the output circuits of each bridge. It will be apparent, therefore, that the discriminator output voltage, V , appearing across the terminals 23, 29, will have one sign when a guard signal is received by the limiter amplifier 10 and an opposite sign when a trip signal is received, and that magnitude of such output voltage is adjustable by means of the potentiometer 27.

The discriminator output voltage ($\pm V$) is applied to the potentiometer 35 of a two-stage D.C. amplifier 36, having two sections, namely, the upper section including the transistors 37, 38 and a lower section including the transistors 39, 40. A trip relay 41 has its operating coil 42 connected in the output circuit of the transistor 38 and a guard relay 43 has its operating coil 44 connected in the output circuit of the transistor 40. In the absence of a voltage applied across the input potentiometer 35, all transistors are biased to the nonconducting states and the relays 41 and 43 are in the illustrated, deenergized conditions. The trip relay 41 is provided with three sets of single-pole, single-throw contacts, with the movable arms of each contact set mechanically connected together for simultaneous operation in response to the energization and deenergization of the relay operating coil 42. Similarly, the guard relay 43 is provided with two sets of single-pole, single-throw contacts. Included in the diagram is an operating coil 45 of a power circuitbreaker, connected between a suitable source of power, such as the battery 46 and the normally-open contact set 47 of the trip relay 41. Those skilled in this art will understand that the circuit breaker is inserted in the primary winding of a power transformer located at the central station, such transformer supplying power over conventional, high-tension transmission lines to a receiving transformer located at a remote point. When the circuitbreaker operating coil is energized, the circuitbreaker opens, thereby removing power from the remote transformer. Obviously, the circuitbreaker operating coil is to remain deenergized at all times, except when a trip signal is received by the limiter amplifier 10 located at the central station.

When both the trip relay 41 and the guard relay 43 are in the deenergized condition, the signal lamp 48 is energized, the circuit being traced as follows; lead 49, lamp 48, lead 50, closed relay contacts 51, lead 52, closed relay contacts 53 and lead 54. This warns the operator of the absence of either a guard or a trip signal and indicates a requirement for checking the protection apparatus.

It will be noted that one side of the breaker-operating coil 45 is connected to the normally-open contact set 47, of the trip relay 41, and, therefore, such coil normally remains deenergized.

The input potentiometer 35, of the D.C. amplifier, is adjusted so that a greater portion of the discriminator output voltage ($\pm V$), must be delivered to the transistor 39 than to the transistor 37, thereby requiring more power to be delivered to the transistor 37 to cause conduction thereof. The fixed resistor 55 and the diode 56 form a biasing network preventing conduction of either transistors 37, 39 in the absence of an output voltage from the discriminator, that is, in the absence of a signal applied to the limiter amplifier 40. The resistor 57 and the diodes 58, 59 perform the same function with respect to the transistors 38 and 40. The resistor 60 and the capacitor 61 (connected to the collector electrode of the transistor 38), forms what may be termed a speed-up network to effect a rapid operation of the trip relay 41. When the transistor 38 is switched on by the transistors 37, the capacitor 61 momentarily shunts the resistor 60 resulting in a relatively large in-rush current through the relay operating coil 42. After the capacitor 61 becomes fully charged, a lower holding current (limited by the value of the resistor 60), is provided to retain the relay in the energized condition. The resistor 62 and capacitor 63 (connected to the collector electrode of the transistor 40), serve the same function with respect to operation of the guard relay 43. The capacitor 64, connected across the base-emitter of the transistor 38, and the capacitor 65, connected across the base-emitter of the transistor 40 constitute oscillation suppressors.

When a continuous guard signal is received by the limiter amplifier 10, the polarity of the discriminator output voltage (V), is such that the transistors 39 and 40 are in the conducting state, thereby resulting in the energization of the operating coil 44 of the guard relay 43. This effects a transfer of the relay contacts so that the contact set 66 closes and the contact set 53 opens. Since the circuitbreaker operating coil 45 is connected to the normally open contact set 47, of the deenergized trip relay 41, the actuation of the guard relay 43 has no effect thereon. However, the opening of the guard relay contact set 53 opens the circuit between the battery 46 and the "check" signal lamp 48. At the same time, the closure of the guard relay contact set 66 connects the "guard" signal lamp 67 across the battery 46. Thus, only the "guard" signal lamp is illuminated during all times that a guard signal is received by the apparatus, thereby indicating normal operating conditions.

Upon the receipt of a trip signal, the discriminator output voltage reverses in polarity. Immediately, the transistors 37 and 38 become conducting (thereby energizing the operating coil 42 of the trip relay 41) and the transistors 39 and 40 become non-conducting (thereby deenergizing the guard relay 43). When this occurs, the circuit breaker operating coil is energized thereby terminating the transmission of power to the remote apparatus at fault. It will be noted that the guard relay 43 must drop out and the trip relay 41 must pull in before the operating coil of the circuitbreaker is energized, the circuit being traced as follows: battery 46, coil 45, lead 68, now-closed contact set 47 of the energized trip relay, lead 52, now-closed contact set 53 of the deenergized guard relay and the lead 54. Such series connection of the normally-open contact set 47 and the normally-closed contact set 53 prevents operation of the circuitbreaker under all conditions, except when the trip signal is received. Upon the deenergization of the guard relay and the simultaneous energization of the trip relay, the "guard" signal lamp 67 is extinguished (since guard relay contact set 66 is now open) and the "trip" signal lamp 69 is illuminated through the now-closed contact set 76 of the trip relay.

While FIGURE 1 shows electrical circuitry for the

mutually-exclusive energization of a guard signal lamp 67, a trip signal lamp 69 and a check signal lamp 48, under the respective conditions of a guard signal, trip signal and no signal, it is apparent other contact and circuit arrangements may be utilized. In fact, additional sets of contacts can be provided on the guard and trip relays for lock-out relay operation, keying of the transmitters for read back operations, etc.

Reference, now, is made to the discriminator output curves of FIGURE 2, which show the relative noise power output affecting the operation of the trip and guard relays. The dotted line curve shows the relative output voltage of a standard discriminator whereas the solid line curve shows the relative output voltage of the discriminator tuned in accordance with this invention. As described hereinabove, the input potentiometer 35 (see FIGURE 1) is adjusted so that a higher discriminator output voltage is required to cause conduction of the transistor 37 in the trip portion of the D.C. amplifier 36 then is required to cause conduction of the transistor 39 which is in the guard portion of the amplifier. This is made evident in FIGURE 2 wherein the guard relay pull in and drop out voltage is indicated as +2.5, whereas the trip relay pull in and drop out voltage is indicated as -3.6, such voltage magnitudes being relative rather than absolute. Such relative adjustment of the discriminator output voltages at the guard and trip signal frequencies, combined with the specific tuning of the two discriminator circuits (namely, circuits 18 and 19 shown in FIGURE 1), greatly reduces the system's sensitivity to random noise. It will be noted that one of the discriminator circuits is tuned to peak below the guard signal frequency and that the other discriminator circuit is tuned to peak at the trip signal frequency. Between any two selected frequencies shown on the discriminator output curve, the area under the curve represents the power delivered to the output circuits when all frequencies between the two selected frequencies are present, as would be the case when random noise passes through the input filter of the apparatus. The shaded area under the solid curve, defined approximately by the frequencies from 1107 to 1305 cycles per second and 1407 to 1490 cycles per second represents power delivered to the output circuit by random noise frequencies between 1107 and 1490 cycles per second, but which noise frequencies do not affect the trip delay. On the other hand, the shaded area under the solid curve defined approximately by frequencies from 1305 to 1407 cycles per second represents the power delivered to the output circuit by random noise frequencies, between 1107 and 1490 cycles per second, which do affect the trip relay. This compares with the corresponding area under the dotted line curve (standard discriminator curve) wherein the power output affecting the trip relay is defined approximately by frequencies from 1305 to 1462 cycles per second.

Thus, it can be seen that, under conditions wherein random noise passes through the input band pass filter, the power output affecting the trip relay is significantly smaller in a discriminator tuned and biased according to this invention than the power output from a conventionally-tuned discriminator. In consequence, the operation of the trip relay is subject to considerably less disturbance from random noise, thereby reducing the possibility of false operations.

In addition to the specially tuned discriminator and the unbalance of the discriminator output voltage as applied to the D.C. amplifier, the possibility of false operation of the apparatus is further reduced by utilizing two sets of output relay contacts connected in series with the operating coil of the circuit breaker. As described hereinabove, one set of such relay contacts is closed when the guard relay is deenergized and the other set of contacts is open when the trip relay is deenergized. Thus, the guard relay must drop out and the trip relay must pull in before the circuit to the breaker operating coil is com-

pleted. The capacitance-resistance networks connected in the input circuits of the transistors which respectively operate the guard and trip relays, results in a rapid energization of the associated relay upon the receipt of a guard or a trip signal. Each relay is designed to have a maximum pull-in time of about 10 milliseconds, and when combined with a high speed circuit breaker, the power line will be disconnected within one cycle of the normal, 60-cycle line frequency, after receipt of the trip signal.

Although I have described the invention with specific reference to guard and trip frequencies deviating by 85 cycles from a normal center frequency of 1275 cycles, it is apparent the operating principles are applicable to any frequency-shift receiver with any band width and any adjacent channel rejection. Those skilled in this art will be able to make various changes and modifications to adapt the invention to specific applications under specific operating conditions. It is intended that changes and modifications of such character can be made without departing from the scope and spirit of the invention as recited in the following claims.

I claim:

1. Protective relaying apparatus of the class comprising a receiver for receiving guard and trip signals of two predetermined frequencies, discriminator means providing a D.C. output voltage which varies in sign in correspondence with the received signal, and control means operated by the said output voltage when a trip signal is received by the receiver, characterized in that the discriminator means comprises two tuned circuits, one circuit being tuned to peak at the trip signal frequency and the other circuit being tuned to peak below the guard signal frequency.
2. Protective relaying apparatus comprising,
 - (a) an A.C. amplifier responsive to first and second signals, which signals have predetermined different frequencies,
 - (b) a discriminator energized by the output voltages of the amplifier, said discriminator producing a D.C. output voltage having a sign depending upon the signal received by the amplifier,
 - (c) a pair of D.C. amplifiers, one amplifier providing an output voltage when the discriminator output voltage is of one sign and the other amplifier providing an output voltage when the discriminator output voltage is of reverse sign,
 - (d) a first relay having an operating coil energized by the output voltage of said one D.C. amplifier and a set of normally-open contacts,
 - (e) a second relay having an operating coil energized by the output voltage of said other D.C. amplifier and having a set of normally-closed contacts,
 - (f) a control member having an operating coil,
 - (g) a source of voltage, and
 - (h) circuit elements connecting the control member to the source of voltage through both said sets of relay contacts.
3. The invention as recited in claim 2, wherein the discriminator comprises,
 - (a) a first circuit tuned to peak at the frequency of the first signals,
 - (b) a second circuit tuned to peak below the frequency of the second signals.
4. Protective relaying apparatus responsive to guard and trip signals of predetermined different frequencies to effect selective actuation of a control member, said apparatus comprising,
 - (a) a limiter amplifier having an output transformer with two separate secondary windings,
 - (b) a filter connected in the input circuit of the limiter amplifier and having a band pass corresponding to the frequencies of the said guard and trip signals,
 - (c) first and second rectifier bridges,
 - (d) a first tuned circuit connected between the input

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- diagonals of the first rectifier bridge and one of said secondary windings, said circuit being tuned to peak at the frequency of the trip signal,
- (e) a second tuned circuit connected between the input diagonals of the second rectifier bridge and the other of said secondary windings, said circuit being tuned to peak below the frequency of the guard signal, 5
- (f) circuit elements connecting the output diagonals of the rectifier bridge to produce a D.C. output voltage having one sign when a guard signal is applied to the limiter amplifier and a reverse sign when a trip signal is applied to the limiter amplifier, 10
- (g) a first relay having a set of normally-closed contacts and an operating coil,
- (h) a second relay having a set of normally-open contacts and an operating coil, 15
- (i) a voltage source,
- (j) circuit elements connecting the said control member to the voltage source through both said sets of relay contacts, and 20
- (k) means energizing one of the other of said relay operating coils in correspondence with the sign of the said D.C. output voltage.
5. The invention as recited in claim 4, wherein the means energizing one or the other of said relay operating coils comprises, 25

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- (a) a first transistor normally biased to a non-conducting state,
- (b) circuit elements connecting the operating coil of the first relay in the output circuit of the first transistor,
- (c) a second transistor normally biased to a non-conducting state,
- (d) circuit elements connecting the operating coil of the second relay in the output circuit of the second transistor, and
- (e) circuit elements applying the said D.C. output voltage to the input circuits of both transistors.
6. The invention as recited in claim 5, wherein the second transistor is biased to the non-conducting state by a biasing voltage of greater magnitude than that of the first transistor.

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SAMUEL BERNSTEIN, *Primary Examiner.*