

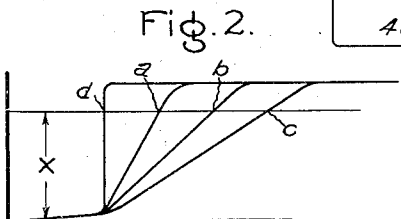
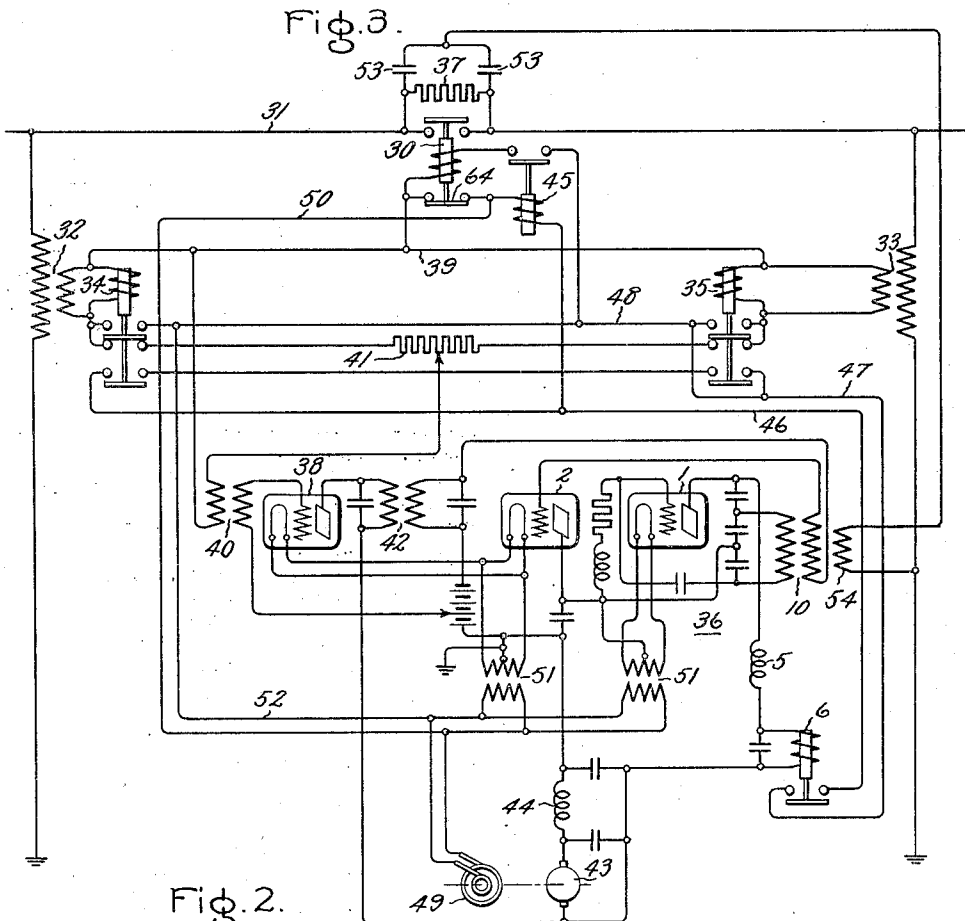
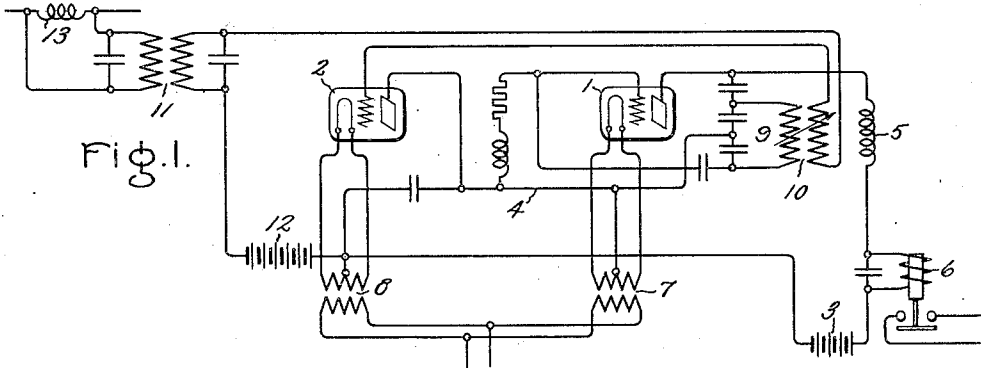
Sept. 24, 1935.

E. D. COOK

2,015,591

CONTROL CIRCUIT

Original Filed Aug. 8, 1928 2 Sheets-Sheet 1



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2,015,591

CONTROL CIRCUIT

Original Filed Aug. 8, 1928 2 Sheets-Sheet 2

Fig. 4.

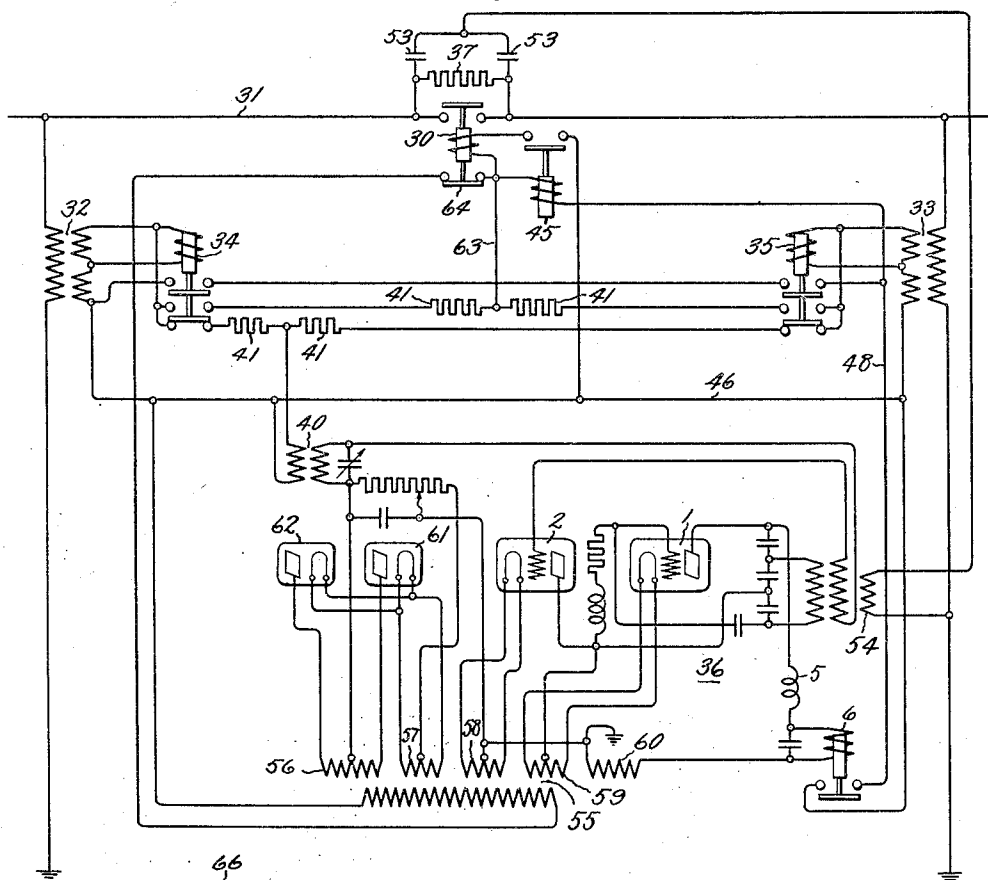


Fig. 5.

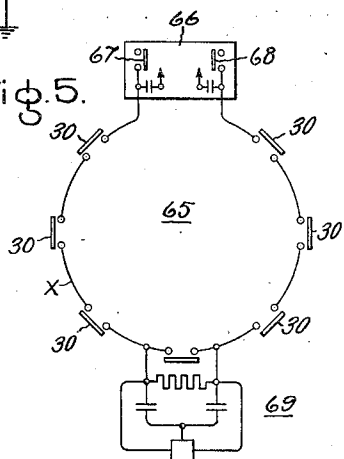
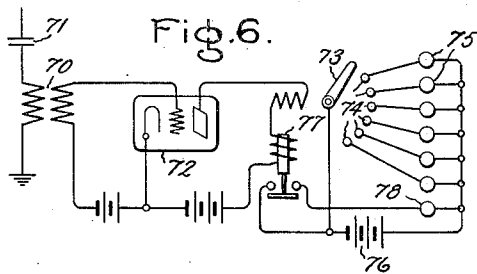


Fig. 6.



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UNITED STATES PATENT OFFICE

2,015,591

CONTROL CIRCUIT

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Original application August 8, 1928, Serial No.
298,321, now Patent No. 1,876,449. Divided and
this application December 1, 1931, Serial No.
578,391

12 Claims. (Cl. 177—352)

My present application is a division of my co-
pending application, which matured into Patent
No. 1,876,449, entitled Control circuits and which
is assigned to the same assignee as my present
application.

My present invention relates to control circuits
and more particularly to automatically operating
circuit closing devices.

In Patent No. 1,696,566, issued December 25,
1928, of Emmett F. Carter, is disclosed an electron
discharge oscillation generator, the operation of
which is controlled in response to a control po-
tential which is produced by voice, or other signal,
waves. This result is effected by utilizing a sec-
ond electron discharge device connected in the
anode circuit of the oscillation generator, the
grid of the second device being normally biased
negatively to a value such that insufficient anode
current flows to permit the generator to produce
oscillations. By applying the control potential
to the grid of this second, or control electron
discharge device, the anode current, and hence,
the operation of the oscillation generator may
be efficiently and reliably controlled.

In accordance with one aspect of my present
invention a coupling between the grid circuit of
a control electron discharge device, which is uti-
lized in the manner taught by the above men-
tioned application, and the circuit of the oscilla-
tion generator, is provided whereby oscillations
produced by the generator are supplied to the grid
of the control device. Control potential is ap-
plied to the grid of the control device in the usual
manner. When the control potential which is
applied to the grid of the control device is of an
order such that the impedance of that device is
reduced sufficiently to permit anode current to
flow in sufficient magnitude to permit the produc-
tion of oscillations, the oscillations produced are
supplied back upon the grid of the control de-
vice. This, in turn, further reduces the imped-
ance of the control device and increases the anode
current and the amplitude of the produced oscil-
lations, this accumulative, or regenerative action
continuing until the normal operating conditions
of the generator are reached. Dependent upon
the degree of coupling employed, as will later be
explained, the oscillation generator will then
continue in operation, notwithstanding that the
control potential is removed from the grid of the
control device, until, by suitable means pro-
vided for the purpose, its operation is interrupted.

As thus arranged the circuit has very important
advantages in connection with the operation of
electrical devices, such as relays, switches and

the like. My present invention has for one of its
objects to provide means whereby a system of the
type indicated above, may be utilized not only in
the operation of circuit interrupters, such as are used in power
transmission lines and particularly to the auto-
matic reclosing of such circuit interrupters when
power is applied to the line and in response to line
conditions.

A further purpose of the invention is to provide
means whereby the oscillatory circuits provided,
as indicated above, may be utilized not only in
the operation of the circuit interrupter but also
in producing signaling operations at a remote
point indicating the condition of the switches.

A further object of my invention is to provide
an automatic reclosing circuit breaker which op-
erates in response to circuit impedance variations
of extremely small magnitude whereby the circuit
is capable of efficiently discriminating between
impedances of the order of magnitude of full load
impedance on the power line in which the circuit
breaker is used and a very slightly lower imped-
ance which may be due to a fault on the line.

Still a further object of my invention is to pro-
vide a circuit interrupter of the type indicated
which is responsive to impedance conditions on
the line in either direction from the circuit break-
er when power is applied to the line from the op-
posite direction.

The novel features which I believe to be char-
acteristic of my invention are set forth with par-
ticularity in the appended claims. My invention
itself, however, both as to its organization and
method of operation, together with further ob-
jects and advantages thereof may best be under-
stood by reference to the following description
taken in connection with the accompanying draw-
ings in which Fig. 1 represents a portion of the
circuits employed in accordance with my inven-
tion; Fig. 2 represents certain operating char-
acteristics thereof; Figs. 3 and 4 disclose circuits
of this form employed in an automatic reclosing
circuit breaker; Fig. 5 indicates a transmission
line to which my invention is applied; and Fig. 6
represents an indicating device which may be
employed in connection therewith.

Referring to Fig. 1, of the drawings I have
shown at 1 an electron discharge device of the
usual three element type which is connected in
any well known manner to produce oscillations.
Connected to the anode circuit of the device 1
is a second electron discharge device 2 which is
also of the three element type. The anode cir-
cuit of these devices extends from the negative
side of a suitable source of potential 3 through

the cathode conductors of the discharge device 2, space between the cathode and anode of the device 2, conductor 4, space between the cathode and anode of the device 1, choke coil 5, actuating winding of relay 6 to the positive side of the source of potential 3. The cathodes of the discharge devices 1 and 2 are energized by means of alternating current applied to the transformers 7 and 8 respectively. Connected between the grid and anode of the discharge device 1 is the usual oscillatory circuit 9. This oscillatory circuit is coupled to the grid of the control device 2 through a circuit extending through the secondary winding of a transformer 10, the primary winding of which comprises a part of the oscillatory circuit 9, secondary winding of a transformer 11, source of biasing potential 12, to the cathode of the control device 2. The source of potential 12 is of an order such that a negative potential is impressed upon the grid of the control device sufficient to preclude the flow of current in the anode circuit, or at least sufficient to maintain this current at a value such that no oscillations are produced by the device 1.

The primary winding of the transformer 11 may be connected to any suitable source of control electromotive force. If the device is to be used in connection with the operation of overload circuit breakers this primary winding may be connected in shunt with an impedance 13 which is connected in series with the line to be protected. In such application of the system the relay 6 may be used to control the actuating winding of the circuit breaker.

As thus arranged when the potential across the impedance 13, and hence across the secondary winding of the transformer 11 increases beyond a certain value current will be caused to flow in the anode circuit of the devices 1 and 2 and oscillations will be produced by the device 1. These oscillations will be supplied through the transformer 10 to the grid of the control device 2. This in turn additionally reduces the impedance of the device 2 and further increases the flow of anode current, thereby increasing the amplitude of the oscillations produced. This accumulative or regenerative action will continue until the anode current has built up to its normal value and the oscillation generator 1 operates under normal conditions.

In the operation of my device it has been found that with a certain relatively close coupling between the windings of the transformer 10 at a certain critical value of the control potential a very slight change in voltage across the impedance 13 will cause the anode current to build up practically instantaneously to its normal value, that is, substantially square line action of this current may be had. In this manner relay 6, which may require a comparatively large current, may be reliably operated in almost instantaneous response to a very slight variation in the voltage across the impedance 13. With this coupling after the relay 6 has been operated it will be maintained in its energized condition by the regenerative connection between the oscillatory circuit 9 and the grid of the device 2.

With a degree of coupling less than the above mentioned certain relatively close coupling, the rate of increase of anode current with respect to the increase of applied control potential will be dependent upon the degree of coupling employed. This characteristic of the device is illustrated in Fig. 2 in which curves *a* and *b* represent

the increase in anode current when the degree of coupling is less than that above mentioned, the curve *c* represents the static characteristics of the circuit and curve *d* represents the increase in anode current when the degree of coupling is either equal to or greater than that above mentioned. If the lesser degree of coupling be employed the anode current will decrease when the control potential is removed and the production of oscillations will cease whereas if a coupling corresponding to curve *d* be employed oscillations and hence the increased anode current will continue to flow notwithstanding that the control potential is removed.

In Fig. 3 I have shown a circuit arrangement of the type shown in Fig. 1 as applied to the automatic reclosing of circuit breakers when power is applied to the line and in response to the conditions of the line. Since my device has the property of sensitive discrimination between potentials such as may be caused to result from varying impedance of the line it has particular utility in this connection.

Referring to Fig. 3, I have shown a circuit interrupter 30 which is included in a transmission line 31. The transmission line 31 may comprise a part of a loop circuit such as that shown in Fig. 5, which is later to be described, and has the characteristic that power may be supplied through the line in either direction. A suitable impedance 37 is connected in shunt with the contacts of the interrupter 30 so that a portion of the line potential is supplied to that part of the line on the opposite side of the interrupter from which the power is applied. Connected in shunt with the line 31, or between the line and ground, and upon opposite sides of the circuit interrupter 30, are a pair of transformers 32 and 33 which may comprise the usual distribution transformers of the system. Connected in circuit with the secondary winding of these transformers are the usual load circuits, not shown, and also the actuating windings of relays 34 and 35 respectively. These relays are arranged to control the energization and operation of the circuit 36 which is provided as indicated above for operating the circuit interrupter 30.

It is thought that this form of my invention will best be understood by reference to its operation. If it be assumed that power is supplied to the transmission line 31 at a point to the left of interrupter 30 it will be seen that full voltage is applied to the relay 34 and that this relay is actuated thereby. Upon operation of this relay power will be supplied to an alternating current motor 49 through a circuit extending from the upper terminal of the secondary winding of transformer 32, through the lower contacts of interrupter 30, conductor 50, alternating current motor 49 and upper armature and upper contacts of relay 34 to the lower terminal of the secondary winding of transformer 32. The alternating current motor 49 drives a direct current generator 43 to energize the anode circuits of devices 1, 2 and 38, the cathode circuits of these devices being energized through transformers 51 the primaries of which are connected in shunt with the alternating current motor 49.

The potential which appears across the secondary winding of transformer 33 is dependent upon impedance conditions on the line 31 beyond the transformer 33 and upon the circuit which is connected to the secondary winding of the transformer. If a heavy load, such as that of a lighting circuit, is connected to the line either through

transformer 33 or other transformers to the right of switch 30 this potential will be very small and will approach that which would exist if a short circuit, or other low impedance fault, had occurred on the line. In accordance with my invention the circuit 36 is operated in response to the potential of this secondary winding to close the interrupter. By utilizing a coupling between the windings 10 which is greater than the critical coupling mentioned the circuit may be made to discriminate between a low impedance fault, and the low impedance condition caused by a heavy load connected to the line notwithstanding that the impedances of the line under these conditions are but slightly different.

If a short circuit, or other low impedance fault condition, exists upon the line beyond the transformer 33, or on the secondary load circuit of the transformer 33, potential which appears across the secondary winding of this transformer will not be sufficient to cause the production of oscillations and hence no further operation will result. If the impedance on the line beyond the interrupter 30, however, be but slightly greater as would be the case if a large load were connected to the line then sufficient potential will appear across the secondary winding of the transformer 33 to cause the operation of the equipment 36 and hence the closing of the circuit interrupter 30, this operation being as follows: The potential which appears across the secondary winding of the transformer 33 will be impressed upon the grid of an amplifier 38 through a circuit extending from the upper terminal of the transformer 33 through conductor 39, primary winding of transformer 40, a portion of resistance 41, upper armature and its lower contacts of relay 35 to the lower terminal of the secondary winding 33. It will be understood that this potential is not sufficiently great to cause the actuation of the relay 35. This potential is amplified by the device 38 and supplied through transformer 42 and secondary winding of transformer 10 of the discharge device 1 to the grid of control device 2, these circuits being as indicated in Fig. 1. Oscillations will be produced by the device 1 and supplied to the grid of the device 2, causing full anode current immediately to build up in the anode circuit of these devices. This circuit extends from the negative side of the source of potential 43 through smoothing reactor 44, space between the cathode and anode of the discharge device 2, space between the cathode and anode of discharge device 1, choke coil 5, relay 6 to the positive side of the source of potential 43. Relay 6 will then be energized closing a circuit which extends from the upper terminal of the secondary winding of the transformer 32 through conductor 39, lower contacts of the circuit interrupter 30, actuating winding of relay 45, conductor 46, contacts of relay 6, conductor 47, conductor 48 and upper armature and its upper contacts of relay 34, to the opposite side of the secondary winding of transformer 32. Relay 45 will then be operated closing a circuit which extends from the upper terminal of the secondary winding of the transformer 32 through the actuating winding of circuit interrupter 30, contacts of relay 45, conductor 48 and the upper armature and its upper contacts of relay 34 to the lower terminal of the secondary winding of transformer 32. Thus the actuating winding of circuit interrupter 30 will be energized and the switch will be actuated to its closed position. Upon actuation of the switch 30 to its closed position its lower contacts are opened,

thereby deenergizing the alternating current motor 49 and deenergizing the anode and cathode circuits of the devices 1 and 2.

After the circuit interrupter 30 has been actuated to its closed position full potential will be applied across the primary of transformer 33, thereby actuating the relay 35 to its upper position. This operation interrupts the circuit of the primary of transformer 40 at the upper armature and lower contacts of relay 35 such that the high potential of the secondary winding of transformer 33 is not impressed upon this transformer. The interrupter 30 may be retained in its closed position, and operated to its open position, by any of the usual expedients which are well-known in the art.

If we assume that the interrupter 30 is in its open position and that power is supplied from the right-hand end of the line, relay 35 will be energized and relay 34 will be in its lower position. In closing its upper contacts relay 35 completes the circuit for the motor 49, which extends from the upper terminal of the secondary winding of transformer 33 through conductor 39, lower contacts of interrupter 30, conductor 50, alternating current motor 49 and the primary winding of cathode transformers 51 in parallel, conductors 52 and 48, upper armature and its upper contact of relay 35 to the lower terminal of the secondary winding of transformer 33. The cathodes of the discharge devices will then be energized and the motor 49 will drive the direct current generator 43 to supply power to the anodes of the different discharge devices. If the impedance of the line at the left of interrupter 30 be sufficiently great potential will be applied through the upper armature and its lower contacts of relay 34, a portion of resistance 41 and transformer 40 to the grid of the amplifier 38, such that when amplified and applied to the control device 2 through transformer 42 the device 1 will produce oscillations and cause the energization of the relay 6. The interrupter will then be operated to its closed position as before thereby deenergizing the circuits of the devices 1, 2 and 38. Operation of relay 34 will then protect the transformer 40 from the high potential of the secondary winding of transformer 32.

It will be noticed that the device 1 produces oscillations until the circuit interrupter has been closed. These oscillations may, if desired, be supplied as carrier currents to the transmission line by any suitable means. As illustrated this means comprises a pair of coupling condensers 53, which are connected to the transmission line 31 on opposite sides of the interrupter 30. One terminal of each of these condensers is connected through the winding 54 which is in inductive relation with the oscillatory circuit of the oscillation generator 1 to ground. Thus during a predetermined time interval prior to the operation of the circuit breaker, high frequency oscillatory currents are supplied to the transmission line for transmission in either direction. These currents may be received at a remote point to indicate that the circuit breaker has operated. The interval during which these currents are produced may be made as long as desired by any suitable time delay mechanism which may be associated with the relay 6, for example, to retard its operation. If for some reason, as due to an inoperative condition of the switch 30 such as might result from faulty toggle mechanism, or the like, the circuit interrupter does not close after the relay 6 has been operated, it will be seen that carrier cur-

rents will be continuously supplied to the line, thereby indicating, in a manner later to be described, that the switch is in faulty condition.

Figure 4 is a modification of the circuit shown in Fig. 5. In this figure it will be noted that the transformers 32 and 33 are of the double secondary type. It will further be noticed that the circuits of the electron discharge devices 1 and 2 are energized by means of alternating current which is supplied through a transformer 55 having a plurality of secondary windings 56, 57, 58, 59 and 60. The winding 56 is utilized to energize the anode circuit of two asymmetrically conducting electron discharge devices 61 and 62, which are connected to supply direct current biasing potential to the grid of the control device 2. The winding 57 supplies heating current to the cathodes of these devices. The windings 58 and 59 supply heating currents to the cathodes of the devices 2 and 1 respectively and the winding 60 supplies potential to the anode circuits of these devices. Thus the anode circuit of the devices 1 and 2 extends from the cathode conductors of the device 2 through the space between the cathode and anode of this device, cathode conductors of the device 1, space between the cathode and anode of the device 1, choke coil 5, relay 6, and winding 60 to the cathode conductors of the device 2.

The operation of this form of my invention is as follows: If it be assumed that power be received from the left-hand end of the circuit 31 and that the main contacts of the interrupter 30 are open the relay 34 will be energized. This relay will complete an energizing circuit through the lower contacts of interrupter 30 for the primary of transformer 55. Potential will be supplied, as before, through resistance 37 to the opposite end of the circuit and a portion of this potential will appear across the secondary winding of the transformer 33. This potential will be supplied through the lower contacts of relay 35 and transformer 40 to the grid of the control device 2. If the impedance conditions beyond the transformer 33 are such that the main contacts of the interrupter 30 may properly be closed this potential will be sufficiently great to cause sufficient current to flow in the anode circuits of devices 1 and 2 to cause the device 1 to produce oscillations and the relay 6 to be operated. The operation of the relay 6 completes a circuit extending from the lower terminal of the secondary winding of the transformer 32, through conductor 46, contacts of relay 6, conductor 48, actuating winding of relay 45, conductor 63, lower armature and its upper contacts of relay 34 to the upper terminal of the secondary winding of transformer 32. Relay 45 will then close its contacts, thereby energizing, through an obvious circuit, the actuating windings of the interrupter 30, causing this interrupter to close its main contacts and to open its auxiliary contacts 64, thereby interrupting the supply of energy to the transformer 55, and the operation of the oscillator 1. The interrupter 30 will then be maintained in its closed position by mechanical or other means customarily employed in connection with switches utilized for this purpose.

When power is supplied from the right-hand end of the circuit it will be apparent that the operation of devices 1 and 2 is the same except that their operation is dependent upon line conditions beyond the transformer 32.

It will be noticed that the oscillation generator of this figure is similarly provided with an

output winding 54 which is adapted to apply high frequency currents through condensers 53 to the line for transmission in either direction.

Since the anode circuit of the oscillation generator is supplied with alternating potential it operates only during the portion of the alternating current cycle during which the anode is at positive potential. Accordingly if the line impedance in the direction opposite to that from which power is supplied is such that oscillations are produced by the device 1 but this impedance is reduced, as due to trouble on the line, before sufficient time interval has elapsed to permit closing of the interrupter 30 the operation of the device 1 will be interrupted and the interrupter 30 will not be closed.

In Fig. 5 I have shown a transmission circuit in connection with which my invention has particular utility. The transmission line comprises a loop 65 extending from a power station 66. Power may be supplied to either end of the loop through interrupters 67 and 68 located at the station. Distributed about the loop are a plurality of interrupters 30, associated with each of which is apparatus 69 which may be of the type indicated in either Figs. 3 or 4. Located at the station and associated with each end of the loop 65 is a high frequency responsive circuit, such as is shown in Fig. 6. The circuit is of any well-known construction employing an electron discharge detector 72 which is connected to the line through a transformer 70 and a coupling condenser 71. Either the primary or secondary of this transformer, or both may be tuned to the frequency of oscillations produced by the generators in the different devices 69. Connected in the output circuit of the electron discharge device 72 of the receiving circuit is the actuating winding of an ordinary step by step selector switch having an armature 73 which is adapted to be actuated over a bank of contacts 74 by means of a suitable ratchet and pawl arrangement of well-known form. Each contact 74 is connected in circuit with a suitable signal lamp 75, and source of potential 76, such that when the armature 73 engages any one of these contacts a corresponding lamp 75 will be lighted. Also connected in the anode circuit of the rectifier 72 is a relay 77 which is adapted when energized to close the circuit of a signal lamp 78 for a purpose later to be indicated.

Let us assume that a fault has occurred in that section of the loop circuit 65 which is indicated by an X in the drawings and that all of the interrupters are in their open position. The operator at the station 66, desiring to ascertain in what section the fault lies will first close the switch 67 and supply power to the left-hand end of the loop circuit. Since the impedance condition between the first and second interrupters 60 from this end of the line are proper, one interrupter 30 will be closed. Since a fault exists in the next section the next interrupter will not close with the result that only one high frequency impulse will be supplied to the receiving apparatus associated with the left-hand end of the loop at the station 66. The armature 73 of the selector switch of this apparatus will engage its first contact and cause the first one of the lamps 75 to be lighted. The operator will then close the switch 68 which is associated with the opposite end of the line. Since the impedance conditions in all of the sections to the right of the section marked X are correct four of the switches 30 will be closed and the selector which is asso-

ciated with the right-hand end of the loop will engage its fourth contact, thereby energizing a corresponding lamp. The operator is then informed that the fault lies between the second and third interrupters from the left. If for any reason any of the switches 30 do not close notwithstanding that the impedance conditions in the direction opposite from that in which power is supplied is correct, then high frequency currents from the oscillation generator associated with that switch will be continuously supplied to the line causing the relay 77 to be continuously energized and the lamp 78 to be lighted. Thus for example if the operator observes that the third lamp in the bank of lamps 75 is lighted and that the lamp 78 is also continuously lighted he will know that the mechanism of the third switch from the end of the line at which power is supplied is faulty. If the lamp 78 were not lighted the operator would be informed that the difficulty lies in the line section beyond the next switch rather than in the switch itself.

If power is supplied at both ends of the loop circuit and the entire line is in good condition all of the switches will be closed. When the last switch closes, due to the fact that power is supplied at both sides of the switch, it will be seen that both of the relays 34 and 35 will be energized and will close their upper contacts. Resistances 41 prevent the occurrence of a short circuit on transformers 32 and 33 when this occurs. When these relays operate the circuit of the primary winding of the transformer 40 is interrupted and the high potentials which exist upon the transformer windings 32 and 33 will be prevented from causing the circuit 36 to operate. The interrupter 30 will then be closed directly. The circuit of the actuating coil of relay 45 extending in the case shown in Fig. 3 from the upper terminal of the secondary winding of transformer 33 to auxiliary contact 64 of the switch 30, actuating winding of relay 45, lower armature and contacts of relay 34, lower armatures and contacts of relay 35, upper armature and its upper contacts of relay 35 to the lower terminal of the secondary winding of transformer 33. Relay 45 will then be operated to connect the actuating winding of the interrupter 30 in shunt with the secondary windings of transformers 32 and 33.

In the circuit shown in Fig. 4 the above operation will be accomplished as follows: The actuating winding of the relay 45 will be energized through a circuit extending from the upper terminal of transformer 33 through the lower armature and its upper contacts of relay 35, conductor 63, actuating winding of relay 45, upper armature of relay 35, upper armature of relay 34 and conductor 46 to the lower terminal of the transformer 33. Relay 45 will then be actuated to connect the actuating winding of interrupter 30 in shunt with the secondary windings of transformers 32 and 33.

While I have shown particular embodiments of my invention it will, of course, be understood that I do not wish to be limited thereto since many modifications, both in the circuit arrangement and in the instrumentalities employed, may be made without departing from the spirit and scope of my invention as set forth in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In combination, a power transmission line, a circuit interrupter included in said line having

an actuating winding, means for energizing said winding thereby to actuate said interrupter in variable time response to energy received over said line in either direction said means including a self oscillatory circuit, means for varying the rate at which oscillations in said oscillatory circuit build up, and means utilizing the variable rate of building up of said oscillations to vary the time of response of said interrupter.

2. In combination, a power transmission line, a circuit interrupter included in said line, means for producing electrical oscillations in combined response to energy received over said line in a certain direction and to the operating condition of said line in the opposite direction from which energy is received, means for accelerating the rate of building up of said oscillations, and means for operating said interrupter in response to the oscillations produced, whereby said interrupter is operated in rapid response to said energy received over the line from said certain direction dependent on the condition of the line in the opposite direction.

3. In combination, a power transmission line including a plurality of circuit interrupters, means for actuating each interrupter in combined response to energy received over said line from a certain direction and to the operating condition of the line in the direction opposite to that from which energy is received, said means including means for supplying continuous carrier current to the line during the period required for operation of said last means for transmission in the direction from which energy is received, and means responsive to said carrier current for indicating the operation of said interrupters.

4. In combination, a power station, a transmission line extending from said station including a plurality of circuit interrupters located at intervals along said line, means at the power station for supplying energy to the line, means located at each interrupter which is responsive to energy received from the station and to the operating condition of the line beyond the interrupter for initiating the operation of the interrupter and for supplying continuous carrier energy to the line, means for interrupting the supply of carrier energy after the interrupter has been operated and means at the power station responsive to said carrier energy for indicating the number of interrupters, which were operated and for indicating an inoperative condition of any interrupter.

5. In combination, a power station, a line comprising a loop extending from said station, a plurality of switches located at spaced intervals around said loop, means located at each switch which is responsive to energy received over the line in either direction and to the operating condition of the line in the direction opposite to that from which energy is received for operating the interrupter and for supplying a single carrier impulse to the line for transmission in either direction, and means located at the station responsive to carrier impulses received from the line for indicating the operation of the switches.

6. In combination, a power transmission line, an interrupter included in said line, an impedance connected in shunt with said interrupter, means including an electron discharge oscillation generator for actuating said interrupter, means responsive to energy received from either direction over said line for energizing said oscillation generator and for causing said generator to produce oscillations in response to potential on the

line on the side of said interrupter opposite to that from which power is received thereby to cause the operation of the interrupter.

7. In combination, a power transmission line, an interrupter included in said line, an impedance connected in shunt with said interrupter, an electron discharge oscillation generator having a control element, means for supplying potential from the line on either side of said interrupter to said control element, means responsive to energy received over said line in either direction for interrupting the supply of potential from the direction in which energy is received to said control element whereby said generator operates in response to potential on the line on the opposite side of said interrupter from which energy is received to which said last means responds, and means for operating said interrupter in response to the oscillations produced.

8. In combination, a power transmission line including a plurality of circuit interrupters, means for actuating each interrupter in combined response to energy received over said line from a certain direction and to the operating condition of the line in the direction opposite to that from which energy is received, said means including means for supplying a carrier current impulse to the line for transmission in the direction from which energy is received when each interrupter is operated, whereby when power is supplied to the line at one end thereof a number of carrier current impulses are supplied to said line for transmission toward said end dependent upon the number of interrupters operated.

9. In combination, a power station, a transmission line extending from said station including a plurality of circuit interrupters located at intervals along said line, means at the power station for supplying energy to the line, means located at each interrupter which is responsive to energy received from the station and to the operating condition of the line beyond the interrupter for initiating the operation of the interrupter and for supplying carrier energy to the line, and means for interrupting the supply of carrier energy after the interrupter has been operated, whereby when power is supplied to the line at one end thereof a number of carrier im-

pulses are supplied to said line dependent upon the number of interrupters operated and carrier energy is continuously supplied to said line upon failure of any interrupter to complete this operation initiated by the second recited means.

10. In combination, a transmission line having a number of circuit interrupters located at spaced intervals therein, means associated with each interrupter responsive to energy from one direction and to the operating condition of the line in the opposite direction for operating the respective interrupter and for supplying a carrier energy impulse to the line for transmission in the direction from which energy is received and for supplying a continuous carrier impulse to said line upon failure of the associated interrupter to operate, whereby when power is supplied to the line at one end thereof a number of impulses are transmitted toward said end dependent upon the number of interrupters operated and a continuous impulse is transmitted upon failure of operation of an interrupter and means at said end responsive to said carrier energy to produce an indication dependent upon the number of impulses received and to produce a different indication in response to receipt of continuous carrier energy.

11. The method of indicating the condition of a plurality of remote automatic reclosing circuit breakers connected at intervals in a line which comprises supplying power to said line, thereby causing each of said breakers to operate, supplying carrier energy to the line during the interval required for operation of each breaker, and indicating the number of impulses supplied to the line.

12. The method of indicating the condition of a plurality of remote automatic reclosing circuit breakers connected at intervals in a line which comprises supplying power to said line, thereby causing each of said breakers to operate, supplying carrier energy to the line during the time interval extending between initiation and completion of operation of each breaker, and indicating the duration of said carrier energy impulses supplied to the line and the number of said impulses.

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