

April 26, 1949.

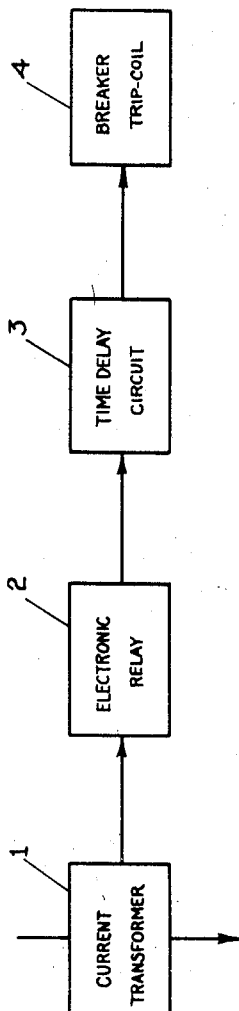
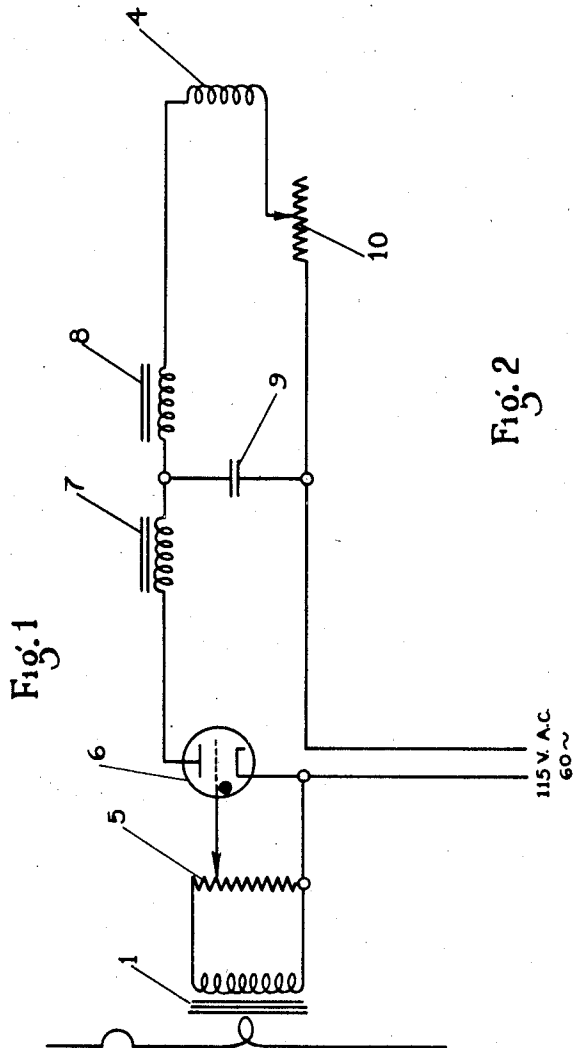
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2,468,418

TIME DELAY ELECTRONIC DEVICE

Filed Oct. 24, 1945

5 Sheets-Sheet 1



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TIME DELAY ELECTRONIC DEVICE

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5 Sheets-Sheet 2

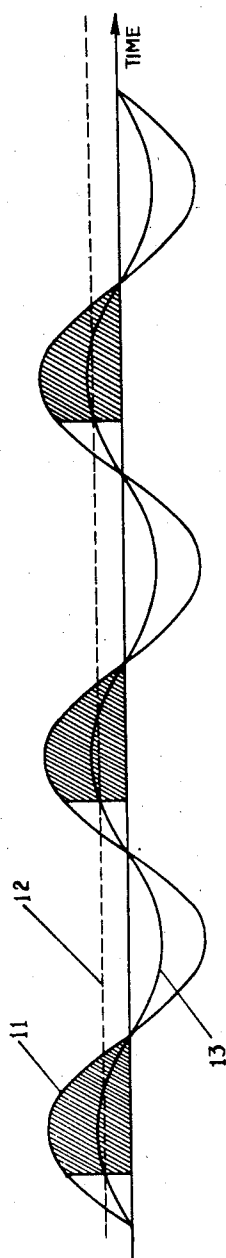


Fig. 3

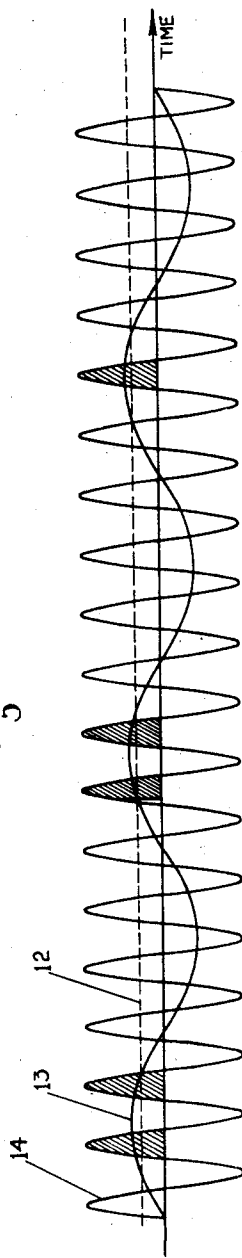


Fig. 4

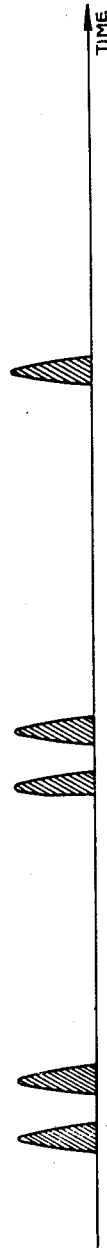


Fig. 4a

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5 Sheets-Sheet 3.

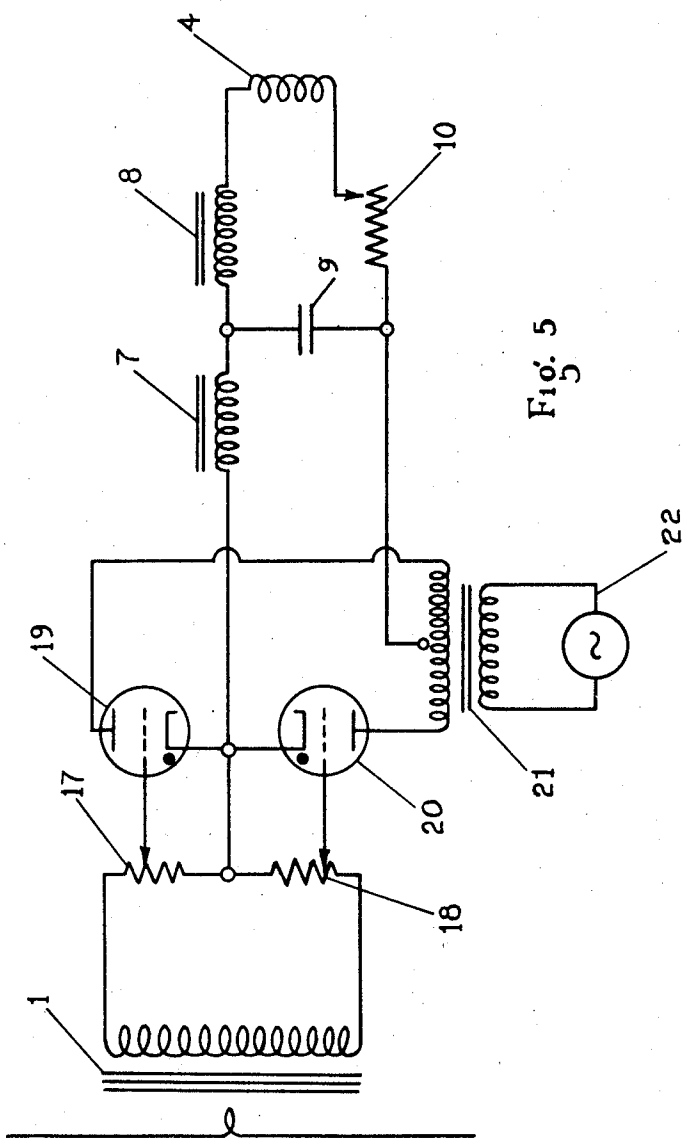


Fig. 5

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TIME DELAY ELECTRONIC DEVICE

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5 Sheets-Sheet 4

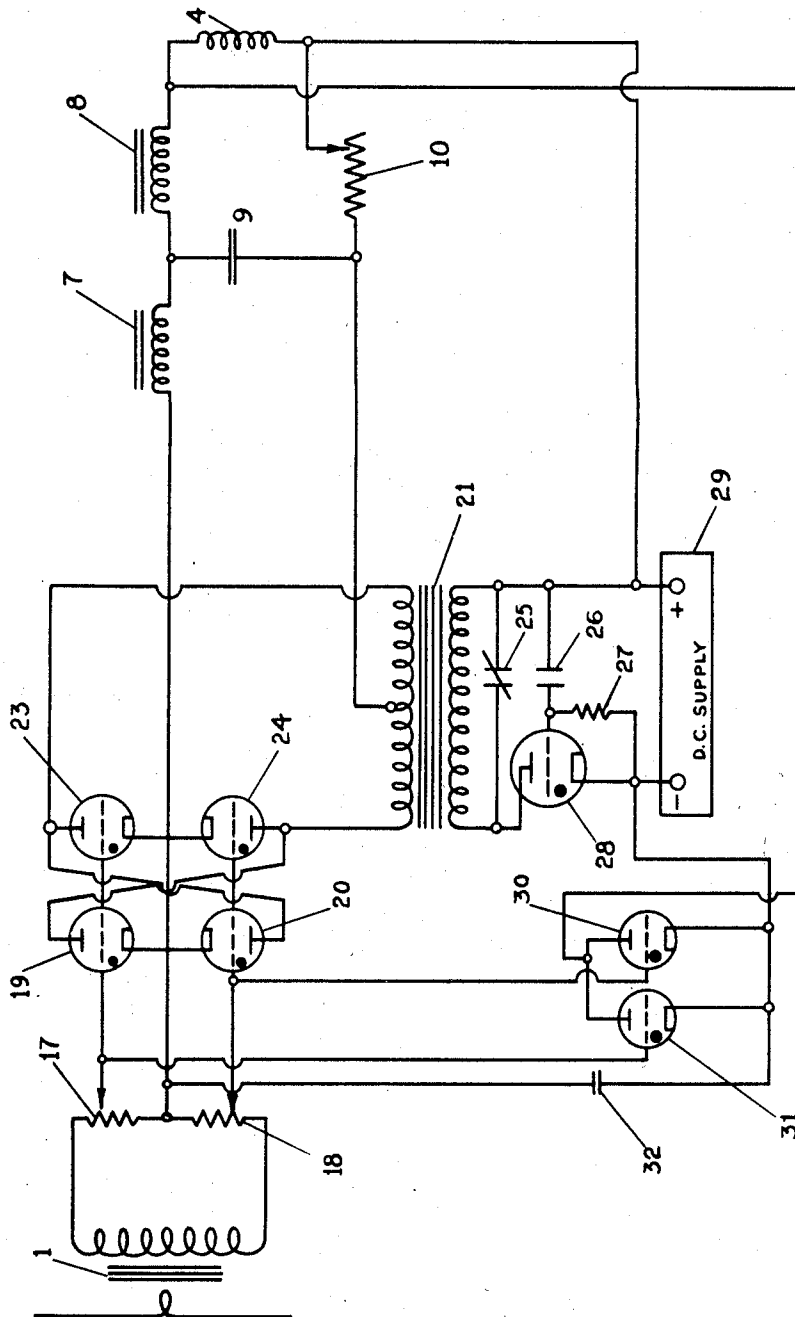


Fig. 6

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TIME DELAY ELECTRONIC DEVICE

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5 Sheets-Sheet 5

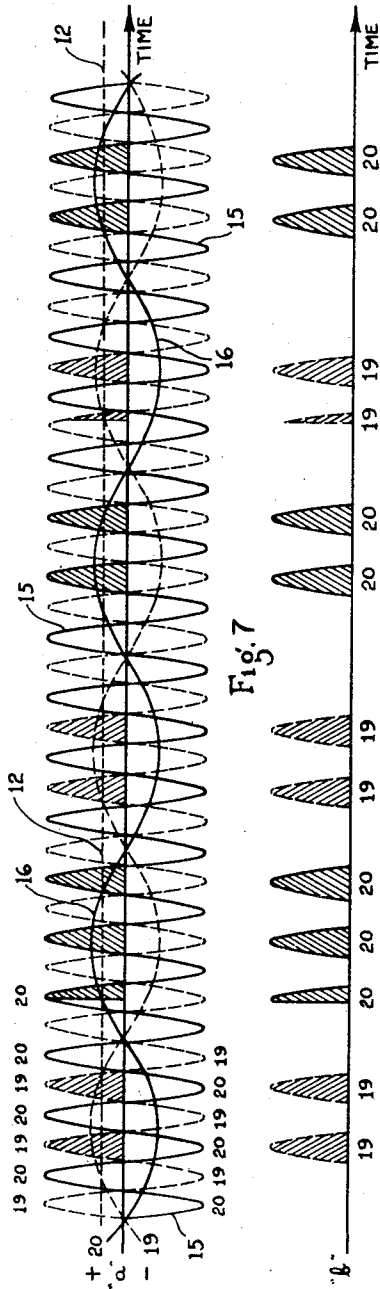


Fig. 7^a

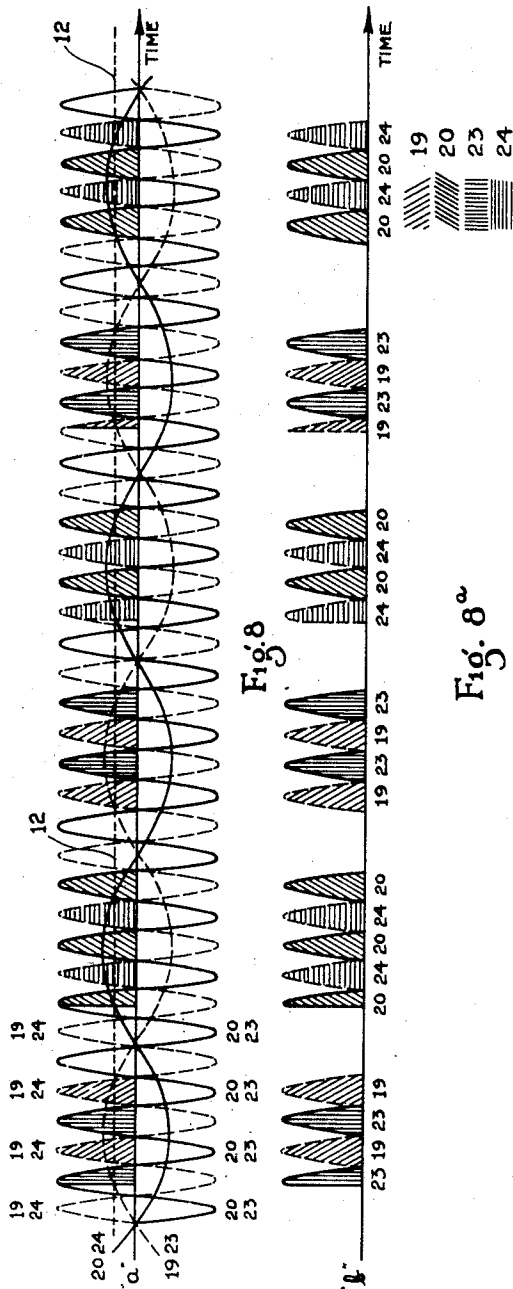


Fig. 8^a

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2,468,418

TIME-DELAY ELECTRONIC DEVICE

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Application October 24, 1945, Serial No. 624,175

6 Claims. (Cl. 175—294)

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My invention relates to time delay mechanism and circuits for circuit breakers, and, more particularly, it relates to the application of electronic circuits for achieving time delay in circuit breaker operations. Time delay mechanism heretofore employed embodied the employment of some mechanical means interposed between the armature of the overload magnet and tripping mechanism. In an alternative construction, time delay is secured by relay mechanism in the electrical circuit ahead of the trip magnet. The present type of relay mechanisms do not provide convenient adjustment of time delay for sequential operations due to the tendency, once a relay is energized, to carry its operation through to completion even though the circuit breaker nearer the fault has already operated to open the circuit. Moreover, the use of contacts are normally subject to the hazards of corrosion, maladjustment, wear and fitting.

In my present invention, these difficulties are avoided by the use of electronic tubes as relay means and by the use of electrical circuits as time delay elements.

According to my invention, the current which flows through the circuit which is to be protected is dropped in value by a suitable current transformer. The current in the secondary of this transformer is sent through a resistor across which there is developed a voltage drop. This voltage drop is proportional to the current in the circuit being protected. If this current goes to too high a value, the voltage drop across the resistor in question goes to a too high value, that is, it goes to a value which is sufficiently high to set off an electronic triggering circuit which is sensitive to voltage across this resistor. When this electronic relay becomes energized, the output it not immediately applied to the circuit breaker trip coil. Instead, the output is delayed by a time delay circuit, and is applied to the trip coil a fraction of a second later than the electronic relay is energized. Various types of electronic relay can be used in such a system. However, the type of relay which I prefer employs thyatron tubes.

A thyatron tube is sensitive to the voltage applied to the grid. If the voltage on the grid rises above a predetermined level, the tube becomes conducting. If the voltage on the grid remains

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below this level, the tube remains in a non-conducting condition. However, once the tube has become conducting, it remains conducting until the anode voltage has been removed or has been made negative.

Such tubes are commonly used with alternating voltage supplied to the anode circuit, so that once for every cycle the voltage becomes negative, and the grid circuit regains control of the current in the anode circuit.

It is well known that such types of thyatron control circuits are sensitive to variations in the phase of the voltage applied to the grid. In fact, the principle of phase variation constitutes one of the mechanisms by which such thyatron relay circuits can be operated. It is my purpose, however, to operate a relay which is sensitive to magnitude only and not to phase angles, since it is not desired that a circuit breaker should be sensitive to the phase angle of the current flowing through the breaker.

In order to prevent the electronic relay from being sensitive to the phase of the current which is controlling it, I use a frequency on the anode of the thyatron tubes considerably higher than the frequency of the circuit which is being controlled.

Thus, if the frequency of the circuit which is being controlled is of the neighborhood of 60 cycles, the frequency used on the anode of the thyatron tubes or electronic relay is of the order of 500 or 600 cycles. By thus using an elevated frequency on the anodes of the thyatron, I am able to make the relay independent of the phase of the voltage supplied to the electronic relay, so that the system becomes a true amplitude system.

Thus, an object of my invention is to provide a novel electronic relay system for achieving sequential operation in circuit breaker operations.

Another object of my invention is to provide a novel relay system which contains a time delay which can be readily adjusted by adjustment of electrical circuit elements. Still a further object of my invention is to provide an electronic relay and time delay circuit which can be used in circuit breakers in place of the customary type of contact making relay.

These and other objectives of my invention can best be understood by reference to the diagram in which

Figure 1 is a block diagram of the system.

Figure 2 is an extension in a schematic drawing.

Figure 3 shows certain wave shapes in connection with Figure 2.

Figure 4 shows wave shapes of a higher frequency in connection with Figure 2.

Figure 4a is a graph showing the amount of current flowing in the thyatron under the conditions shown in Figure 4.

Figure 5 shows a push-pull system.

Figure 6 shows a modification and extension of the system of Figure 5.

Figure 7 shows certain wave shapes in connection with the system in Figure 5.

Figure 7a is an analysis of Figure 7 showing the current flow for the system of Figure 5.

Figure 8 shows certain wave shapes in connection with the system shown in Figure 6.

Figure 8a is an analysis of Figure 8 showing the current flow for the system of Figure 6.

Making reference now to Figure 1, the current to be used as the control current passes through the primary of current transformer 1. The secondary of current transformer 1 is connected to the electronic relay tube 2. Relay 2 is so arranged that if the signal impressed upon it exceeds a predetermined value, the electronic relay will close. Closing of relay 2 sends a signal into the time delay circuit 3, and after a predetermined time delay of this circuit, a signal will appear into the breaker trip coil 4 which will set the breaker trip mechanism into operation.

The details of a simple system to follow this plan out are shown in Figure 2. Here the current transformer 1 is provided with a single turn on the primary and several turns on the secondary. The secondary is connected across to a resistor 5, so that the voltage drop across resistor 5 becomes proportional to the current in the primary of the current transformer 1. A tap on resistor 5 is used to connect to the grid of thyatron 6. Thyatron 6 has its plate energized by a suitable source of power such as the standard 115 volt, 60 cycle line.

The plate circuit is composed of the two inductors 7 and 8, capacitor 9, the breaker trip coil 4 and the adjustable resistor 10. This circuit comprises the time delay circuit, and it has such characteristics that when a connection is made between the anode and cathode of thyatron 6, in effect this time delay circuit is supplied with D. C. However, the current in the breaker trip coil 4 does not rise at once. Instead, time must be allowed for first the capacitor 9 to become charged through inductor 7 and also time must be allowed for the current in coil 4 to build up through adjustable resistor 10. It is this second part of the time delay which is used as the adjustment in the time delay. The smaller the resistance 10 the more time it will take for the current in the breaker trip coil 4 to build up to its ultimate value.

The operation of this whole circuit can best be understood by reference to Figure 3. In Figure 3 graph 11 shows the voltage applied from the power source to the anode of the thyatron 6. Line 12 shows the critical grid voltage of this thyatron, that is, this is the voltage below which the thyatron will not fire and above which the thyatron will conduct. Curve 13 of Figure 3 illustrates the voltage drop at resistor 5 applied to the grid of tube 6. As soon as the voltage shown by curve 13 rises above the critical value 12, conduction will start in the plate circuit of

the thyatron 6. This is indicated in Figure 3 by the shading under curve 11. During the time (along the horizontal) given by this shading, current will flow through the thyatron.

It is to be observed that this current is an intermittent current occurring during part of each cycle. This fluctuating current is smoothed out by the inductance 7 and condenser 9, these two elements carrying most of the alternating components of the current which passes through thyatron 6. The direct current component of this current passes through resistor 10 and breaker trip coil 4 and inductance 8, the value of this current being, however, less than enough to energize trip coil 4.

From this brief description, normal operations will now be understood. When the current in the primary of the current transformer 1 is of the allowable and safe value, the voltage drop across resistor 5 is below line 12 at all times and the thyatron is inactive. If now the current in the primary current transformer 1 increases due to abnormal circuit conditions, there results a sudden increase in the current in the secondary and a corresponding sudden increase in the voltage across the resistor 5 above the value represented by line 12 in Figure 3, and the voltage applied to grid of the thyatron is sufficient to fire the tube. With the grid at a sufficient voltage and an in-phase voltage applied to the plate, the thyatrons become conductive, and once every cycle a pulse of current flows through the thyatron 6.

These pulses of current pass through condenser 9 and inductance 7, each pulse increasing the potential charge in the condenser. Initially, the voltage charge on condenser 9 is insufficient to energize coil 4. However, as these pulses of current charge up condenser 9 to some definite value, current begins to flow through trip coil 4 and resistor 10. Current in this breaker trip coil 4 gradually increases until it reaches such a value that the coil is energized and the plunger in this breaker trip coil begins to move. The action in the breaker trip coil 4, then becomes cumulative so that the breaker is opened very quickly.

The lower the resistance value of resistor 10, the higher must be the voltage across capacitor 9 to produce a sufficient current flowing through breaker trip coil 4 to actuate the opening mechanism on the circuit breaker. Thus, a larger value of resistor 10 will provide a shorter time delay in this whole system.

One feature of this system is well worthy of notice—that is, as shown in Figure 3, the curve 13 does not rise very much above the line 12; nevertheless, the current flowing through the thyatron is a sizeable portion of the possible time during which current could flow. This illustrates the fact that the thyatron operation is almost discontinuous, that is there either is no current flowing through the thyatron or there is a very sizeable amount of current flowing through the thyatron. Thus, although it may be difficult to control the precise value at which the thyatron fires, nevertheless, when the thyatron does commence to conduct, it does so completely, so that there will never be any doubt that there will be a sufficient current flowing to operate the breaker trip coil after the adequate time delay.

Figure 3 is drawn with the phase of the voltage 13 the same as that of the anode plate voltage 11. If it should happen that these two phases were considerably different, the above described operation would not occur. For example, if the voltage 13 lagged 90 degrees behind the position

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shown in Figure 3, it would be seen that the point of crossing of the lines would be such that very little current, if any, would flow through the thyratrons. This would be a highly undesirable situation, and consequently, in order to avoid this phase error, circuits which yield the diagrams of Figure 4 have been developed.

Figure 4 differs from Figure 3 primarily in that it shows conditions secured with the anode plate voltages shown at a considerably higher frequency than the frequency of the current which is being controlled. Thus, in Figure 4, the anode plate voltage 14 is shown as a higher frequency current. The critical grid voltage 12 and the control grid voltage 13 remain the same. It is now to be noticed here that there are two full half cycles at the left of the Figure 4 during which time current flows and at the right of the figure there is one full half cycle during which time the current flows. However, in the middle of Figure 4 current flows for one full half cycle and a fraction. This condition as in Figure 3 is occasioned by the fact that in the middle of graph 4 the control grid voltage 13 does not rise above the critical grid voltage 12 until sometime after the anode plate voltage 14 has passed through zero. Whereas at the left of the figure, curve 13 happens to drop below curve 12 after the anode plate voltage 14 has become positive and has gone into the regions where conduction can occur for another full half cycle.

A circuit which would operate in this way might have some difficulty in that the amount of current which flows does so only during a relatively shorter period of time than was true in Figure 3. In order to overcome this difficulty, there is used with the system which gives the curves of Figure 4 another system which gives the curves of Figure 7. It is to be noticed here that the anode plate voltage (curve 15) is 180 degrees out of phase with the anode plate voltage (curve 14) in Figure 4. The critical voltage 12 remains the same, but the control grid voltage 16 likewise is 180 degrees out of phase with the control grid voltage 13 shown in Figure 4.

A circuit which can be used to accomplish the purposes shown in Figure 7 is shown in Figure 5. Here the secondary of transformer 1 is connected across a pair of resistors 17 and 18. This pair of resistors are of similar value, so that there is a center tap arrangement, and individual adjustments are made on each one of these resistors. The voltages from these taps are fed to the grids of a pair of thyratrons 19 and 20. The plate supply of these thyratrons is energized from source 22 (of higher frequency than the circuit being controlled) through a transformer 21. The output of this system is fed into the time delay circuit trip coil combination which is the same as that shown in Figure 2.

This circuit can then be described in terms of the curves of Figure 7. Tube 19 will operate in accordance with Figure 7 (dotted curves) whereas tube 20 will operate in accordance with curve in Figure 7 (solid curves).

Thus, during part of the cycle when the signal from the current transformer has a positive phase, the tube 19 will operate as is shown in Figure 7, dotted curves, during the shaded pulses or parts of the cycle of signal presented by alternator 22. Likewise, when the signal from the current transformer is negative, there will be a signal through tube 20 according to Figure 7, solid curves.

This is clearly illustrated in Figure 7 where the

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curves, representing the current flow through the thyratrons 19 and 20 of Figure 5, are marked with the reference numbers of their respective tubes.

Thus, the input supplied to the time delay network will consist of a series of pulses of the higher frequency supplied by alternator 22. It is to be noted that there will be a few gaps in this sequence of pulses as is shown by Figure 4a. In this figure there are shown those portions of the higher frequency supply from Figure 4, during which time current flows through the thyatron. The curve in Figure 4a should not, however, be considered to be exactly the curve of current, since the presence of the time delay circuit will alter the current somewhat from this particular curve. However, this curve does show those times during which current flows through the thyatron.

It is to be noted that should the current transformer drop to such a value that curves 13 and 16 do not cross the line 12, then there will be no current flow at all in the thyatron, and consequently, there will be no current flow through the breaker trip coil 4. Thus, it becomes evident that no matter what the particular shape of the current which results through the time delay circuit, ultimate current should be sufficient to cause the breaker trip coil 4 to operate when the current is flowing in accordance with the time limit set by Figure 4. The time delay as before will be controlled by the length of time it takes for condenser 9 to build up and then by the length of time it takes the current to build up in the resistor conductor combination 10, 4 and 8.

It now will be observed by reference to Figure 4 that the phase position of the signal from the current transformer, that is the phase position of curves 13 and 16 is comparatively immaterial in the operation of this system. As a matter of fact, the way this figure has been drawn there is no definite correlation between the frequency of curves 13 and 16, and the frequency of curves 14 and 15. Thus, there is no definite relationship between these two signals in any event. Consequently, no matter what the phase of the current from the current transformer has, the signal which will be transmitted to the time delay network will be similar to the one indicated by Figure 7a.

This, of course, arises from the fact that the frequency of the plate supply voltage for the thyratrons is considerably higher than the frequency of the current being protected.

Figure 6 represents a modification of Figure 5 in which several improvements over Figure 5 have been included. One of these improvements is the inclusion of another pair of thyratrons 23 and 24. These tubes act in such a manner as to fill in the gap left by thyratrons 19 and 20 and shown in Figure 7a.

The time during which current flows through the thyratrons or at least through one thyatron of the group is shown in Figure 8a. Here it is assumed that the signal coming from current transformer 1 is the same sort of signal as is shown in curves 13 and 16 in Figures 4 and 7.

Tracing these curves through Figure 8, it becomes evident that individual tubes are conducting during the time indicated by the shaded portion shown in Figure 8a. The numbers under each shaded portion indicate the tubes which are conducting during that particular time.

Thus, in the curves shown in Fig. 8a, the sequence of conduction is tube 23, 19, 23, 19. Then

there is a break during the time where the signal from current transformer 1 is lower than the signal indicated by the critical voltage 12 in Figures 4 and 7. As soon as the voltage passes through zero as the current from current transformer 1 passes through zero and becomes larger in the other direction than that required to produce a voltage drop in resistors 17 and 18 higher than the critical voltage 12, the other pair of tubes begin to fire.

Thus, the sequence is resumed in Figure 8a with tubes 20, 24, 20, 24, 20 firing. Again there is a break, and the sequence is resumed by tubes 23 and 19. Thus, the only break in conduction occurs during the time when the current from the current transformer is lower than the instantaneous current required to cause the relay to operate. That is, of course, exactly as it should be. Time delay is provided by exactly the same circuit which was used before, namely the conductor resistor capacitor combination 7, 8, 9, 10 and a breaker trip coil 4.

In Figure 6 a particular method of supplying the higher frequency to the anodes of the thyatron is shown. This is based on thyatron 28 and transformer 21. The primary of transformer 21 is tuned by a capacitor 25 to resonate at the appropriate frequency, that is, the frequency desired as the anode supply to the thyatrons 19, 20, 23, 24 in the relay proper. The combination of thyatron 28 along with resistor 27 and capacitor 26 and D. C. power supply 29 comprise the pulsing power supply which feeds the resonate circuit composed of primary transformer 21 and capacitor 25. Regulated pulses through the tank circuit are supplied through the thyatron 28, and this thyatron is controlled by the voltage fed in over capacitor 26 and resistor 27.

Another feature in this circuit is supplied through the thyatrons 31 and 30. These thyatrons provide instantaneous trip in case the current should rush much too high. Under these circumstances of a sudden inrush of current in the current transformer 1, the voltage on either 30 or 31 will rise above the value required to fire these tubes. In this event, D. C. power from the D. C. supply 29 will be conducted through one of these thyatrons and through the trip coil 4 without any interposition of time delay.

Two tubes are used here, one being controlled by each of the resistors 17 and 18, in order that no matter during which half of the cycle of the current in transformer 1 the inrush shall occur, the thyatrons will be able to pick it up and operate the breaker trip relay. Under the circumstances of using two thyatrons, this is possible since either one or the other will fire on a voltage which exceeds the control voltages of the thyatrons.

Capacitor 32 is interposed in the circuit in order that there shall be no difficulty arising from the interposition of the extra circuit which is in effect in parallel with the time delay circuit.

The circuit of Figure 6 has several advantages over the previous circuit. In the first place the current supplied to the time delay circuit is much more continuous than is supplied in Figure 5. In the second place the supply of the higher frequency current is automatically obtained through the thyatron 28 and the tuned circuit. This makes it unnecessary to have a special alternator to supply the higher frequency current. In addition, a feature is provided in which time delay is removed if the short circuit current exceeds a

higher limiting value than the value for which the time delay circuit is intended to operate.

It is further to be noted that the ultimate current in the circuit breaker trip coil under conditions of time delay operation can vary almost by a factor of 2 to 1 depending upon the strength of the current in the current transformer 1. This means that there is a wide range of inverse time delay action in the system. If the ultimate current in the current transformer 1 is just sufficient to operate the coil 4, then the full time delay of the time delay circuit is employed before the circuit breaker trip coil 4 will operate. On the other hand, if the current in current transformer 1 is much higher than this, then the current input from the thyatrons 19, 20, 23, 24 will be considerably more by reason of the fact that many more pulses will be transmitted through the thyatron system, that is, pulses of the frequency determined by the higher frequency oscillator 28. In the other extreme the current supplied by the thyatron system through the time delay circuit may be very much in excess of that required to operate the breaker trip coil 4, and, consequently, the circuit breaker trip coil 4 will operate considerably before the current has reached its ultimate value. In other words, it would take a much less time to operate than it did in the previously mentioned case.

Thus, as current in current transformer 1 increases, the effective time delay of the time delay circuit decreases even though the actual time constant of the time delay circuit may be of the same order of magnitude as it was before.

A condition somewhat in between these two is illustrated by the curves of Figure 4. In this circumstance, there is about a ratio of 65 to 35 percent during which the 65% time the thyatrons are conducting and during the 35% time the thyatrons are not conducting. Now making reference to Figure 4, it will be noted that if curves 13 and 16 should be of lower amplitude, so that they should intersect curve 12 just at the very peak of curves 13 and 16, the current supplied through the thyatron system would flow during only 1 or 2 half cycles of the higher frequency oscillator. This would constitute a minimum current supplied to the time delay circuit. On the other hand, the condition shown indicates a 65 to 35 ratio of current on, to current off, entering the time delay circuit.

If now, the signal from current transformer 1, that is signals 13 and 16 should be considerably greater than they are shown in Figures 4 and 7, it will now be clear that the current in the thyatrons will flow during a still greater proportion of time, so that the time ratio might approach something like 90% on to 10% off. This would mean then that the system automatically contains an inverse time delay feature, that is the stronger the current introduced into the current transformer 1, the less the time required to operate the breaker trip circuit.

The inclusion of the tubes 30 and 31 in Figure 6 gives the added feature that for very heavy current in Figure 1 there is no time delay whatsoever. The circuit operates instantaneously, and whatever time delay is present, is present in the breaker trip mechanism itself rather than in the electronic relay supplying the system. In Figure 6, of course, the D. C. supply could be conveniently obtained from a normal line frequency by conventional rectifier means. Likewise, the heaters of all of the thyatrons could

conveniently be supplied from a small transformer, or from any other available means.

Although I have described my invention above with respect to certain specific circuits, I prefer to have my invention described by the following claims.

I claim:

1. In a system for controlling the time of operation of a trip magnet of a circuit breaker protecting a circuit, a gaseous discharge tube having a cathode, anode and control electrode, a magnet whose time of operation is to be controlled connected in the anode circuit of said tube, electrical time delay elements connected in said anode circuit, circuit connections from the source of alternating current energy protected by the circuit breaker to said control electrode for controlling the breakdown of said tube, and a source of alternating current for providing operating power connected in said anode circuit, the frequency of said last mentioned source of alternating current being considerably greater than the frequency of said first mentioned protected source of alternating current energy, a further gaseous discharge tube having a cathode, grid and anode, circuit connections from said circuit being protected to the grid of said further tube and circuit connections including the anode cathode circuit of said further tube to the trip magnet for effecting instantaneous operation thereof in response to predetermined circuit conditions in said circuit being protected.

2. In a system for controlling the time of operation of a trip magnet of a circuit breaker protecting a circuit, a gaseous discharge tube having a cathode, anode and control electrode, a magnet whose time of operation is to be controlled connected in the anode circuit of said tube, electrical time delay elements connected in said anode circuit comprising inductance elements connected between said anode and magnet and a capacitance element connected in parallel with said magnet, circuit connections from the source of alternating current energy protected by the circuit breaker to said control electrode for controlling the breakdown of said tube, and a source of alternating current for providing operating power connected in said anode circuit, the frequency of said last mentioned source of alternating current being considerably greater than the frequency of said first mentioned protected source of alternating current energy.

3. In a system for controlling the time of operation of a trip magnet of a circuit breaker protecting a circuit, a gaseous discharge tube having a cathode, anode and control electrode, a magnet whose time of operation is to be controlled connected in the anode circuit of said tube, electrical time delay elements connected in said anode circuit, circuit connections from the source of alternating current energy protected by the circuit breaker to said control electrode for controlling the breakdown of said tube, a source of alternating current for providing operating power connected in said anode circuit, the frequency of said last mentioned source of alternating current being considerably greater than the frequency of said first mentioned protected source of alternating current energy, and a variable resistance in series with said magnet for controlling the time delay operation thereof, a further gaseous discharge tube having a cathode, grid and anode, circuit connections from said circuit being protected to the grid of said further tube and circuit connections including the anode cath-

ode circuit of said further tube to the trip magnet for effecting instantaneous operation thereof in response to predetermined circuit conditions in said circuit being protected.

4. In a system for controlling the time of operation of a trip magnet of a circuit breaker protecting a circuit, a gaseous discharge tube having a cathode, anode and control electrode, a magnet whose time of operation is to be controlled connected in the anode circuit of said tube, electrical time delay elements connected in said anode circuit comprising inductance elements connected between said anode and magnet and a capacitance element connected in parallel with said magnet, circuit connections from the source of alternating current energy protected by the circuit breaker to said control electrode for controlling the breakdown of said tube, a source of alternating current for providing operating power connected in said anode circuit, the frequency of said last mentioned source of alternating current being considerably greater than the frequency of said first mentioned protected source of alternating current energy, and a variable resistance in series with said magnet for controlling the time delay operation thereof.

5. In a system for controlling the time of operation of a trip magnet of a circuit breaker protecting a circuit, a gaseous discharge tube having a cathode, anode and control electrode, a magnet whose time of operation is to be controlled connected in the anode circuit of said tube, electrical time delay elements connected in said anode circuit, circuit connections from the source of alternating current energy protected by the circuit breaker to said control electrode for controlling the breakdown of said tube, a source of alternating current for providing operating power connected in said anode circuit, the frequency of said last mentioned source of alternating current being considerably greater than the frequency of said first mentioned protected source of alternating current energy, and a gaseous discharge tube having a cathode, an anode and control electrode, said magnet being connected to the anode of said last mentioned tube by-passing said time delay elements, circuit connections from said source of alternating current to said last mentioned anode and circuit connections from said protected source of alternating current energy to said last mentioned control electrode, said last mentioned tube discharging at a predetermined current value in said protected circuit for effecting instantaneous operation of said magnet.

6. In a system for controlling the time of operation of a circuit breaker trip magnet for a circuit breaker protecting a circuit, a first pair of gaseous discharge tubes each having a cathode, anode and control electrode, a second pair of gaseous discharge tubes each having a cathode, anode and control electrode, electronic time delay elements, a source of operating potential, output circuit connections for each of said first pair of tubes, each of said circuit connections including said magnet and time delay elements and including circuit connections in the anode of one of said first pair of tubes to one side of said source of operating potential and circuit connections from the other of said anodes of said first pair of tubes to the other of said source of operating potential, circuit connections from the control electrode of one of said first pair of tubes to the control electrode of one of said second pair of tubes, circuit

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connections from the anode of the other of said first pair of tubes to the anode of said one of said second pair of gaseous discharge tubes, circuit connections from the control electrode of said other of said first pair of tubes to the other of said second pair of tubes, circuit connections from the anode of said other of said second pair of tubes to the anode of the one of said first pair of tubes, and circuit connections from the circuit being protected to the control electrodes of all of said tubes.

CARL THUMIM.

REFERENCES CITED

The following references are of record in the file of this patent:

Number
1,552,321
1,728,745
1,762,811
1,819,999
1,871,787
1,938,742
1,985,051
2,293,570
2,295,297
2,344,633
2,399,322

12**UNITED STATES PATENTS**

Name	Date
Lea	Sept. 1, 1925
Brown et al.	Sept. 17, 1929
Charlton	June 10, 1930
Kearsley	Aug. 18, 1931
Goldborough	Aug. 16, 1932
Demarest	Dec. 12, 1933
Minkler	Dec. 18, 1934
Stibitz	Aug. 18, 1942
Schneider	Sept. 8, 1942
Pfleger	Mar. 21, 1944
Carlin	Apr. 30, 1946

FOREIGN PATENTS

Number	Country	Date
546,546	Great Britain	July 17, 1942