April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

Filed Feb. 17, 1944 10 Sheets-Sheet 1

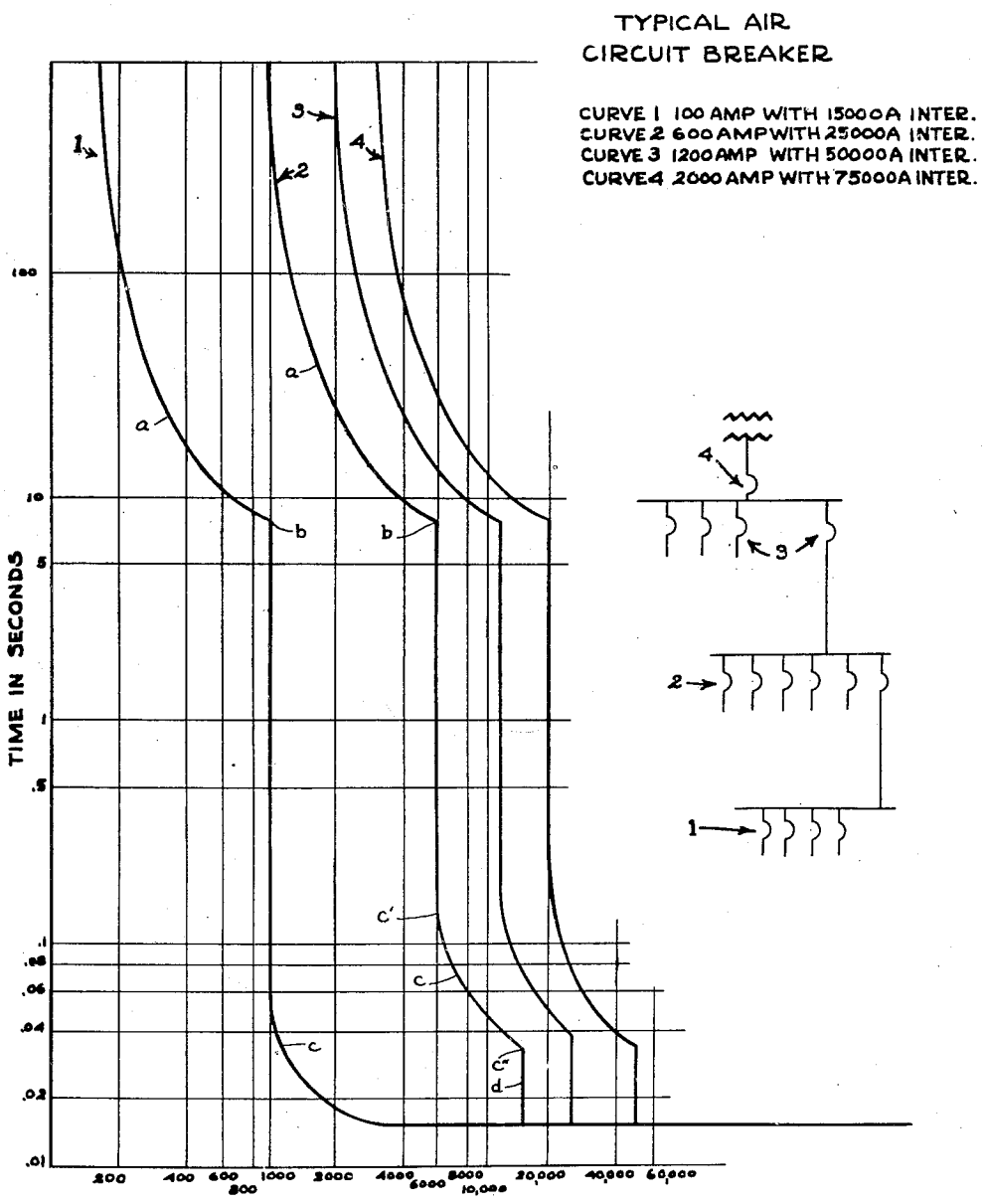


Fig. 1

INVENTOR.
HERBERT C. GRAVES JR.
BY Samuel Gatrolenko
Attorney.

April 6, 1948. H. C. GRAVES, JR 2,439,165

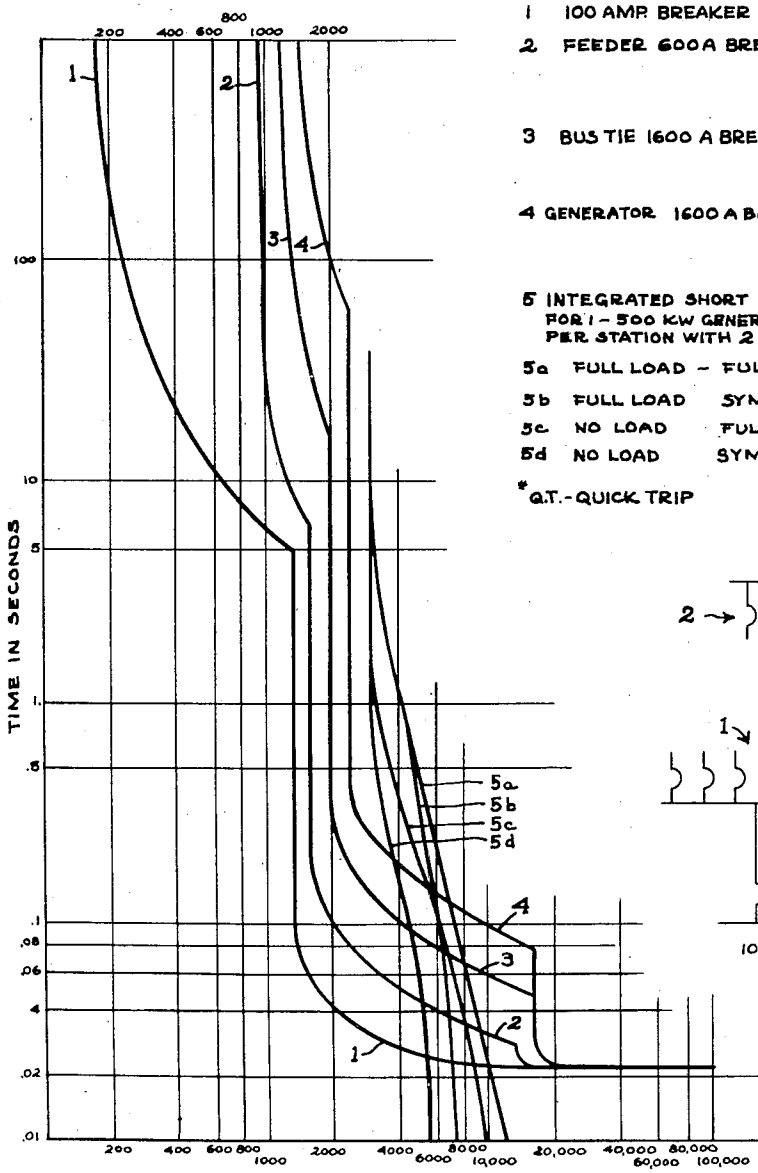
SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

Filed Feb. 17, 1944 10 Sheets-Sheet 2

CIRCUIT BREAKER
COORDINATION CHART
TWO GENERATING STATIONS

1 100 AMP BREAKER Q.T. * AT 1350 A.
INTER. CAP. 15,000 A
2 FEEDER 600 A BREAKER O.L. CAL. 600-1200 A
T.D. SETTING 900 A
Q.T. SETTING 1600 A
INTER. CAP. 25,000
3 BUS TIE 1600 A BREAKER O.L. CAL. 1200-2400 A
T.D. SETTING 1200 A
Q.T. SETTING 2000 A
INTER. CAP. 50,000 A
4 GENERATOR 1600 A BRKR. O.L. CAL. 1200-2400 A
T.D. SETTING 1400 A
Q.T. SETTING 2400 A
INST. SETTING 15,000 A
INTER. CAP. 50,000 A
5 INTEGRATED SHORT CIRCUIT CURRENT
FOR 1 - 500 KW GENERATOR, 2 GENERATORS
PER STATION WITH 2 GENERATING STATIONS
5a FULL LOAD - FULLY DISPLACED
5b FULL LOAD SYMMETRICAL
5c NO LOAD FULLY DISPLACED
5d NO LOAD SYMMETRICAL

*Q.T. - QUICK TRIP



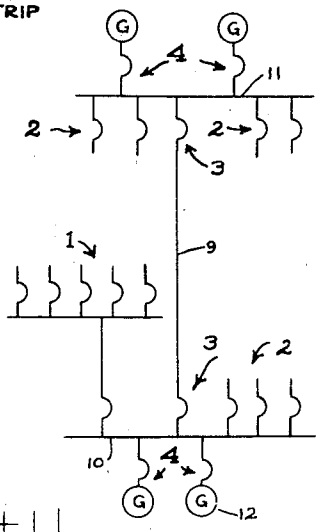


Fig. 2

INVENTOR.
HERBERT C. GRAVES JR.

BY Samuel Astrolenk
Attorney

April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

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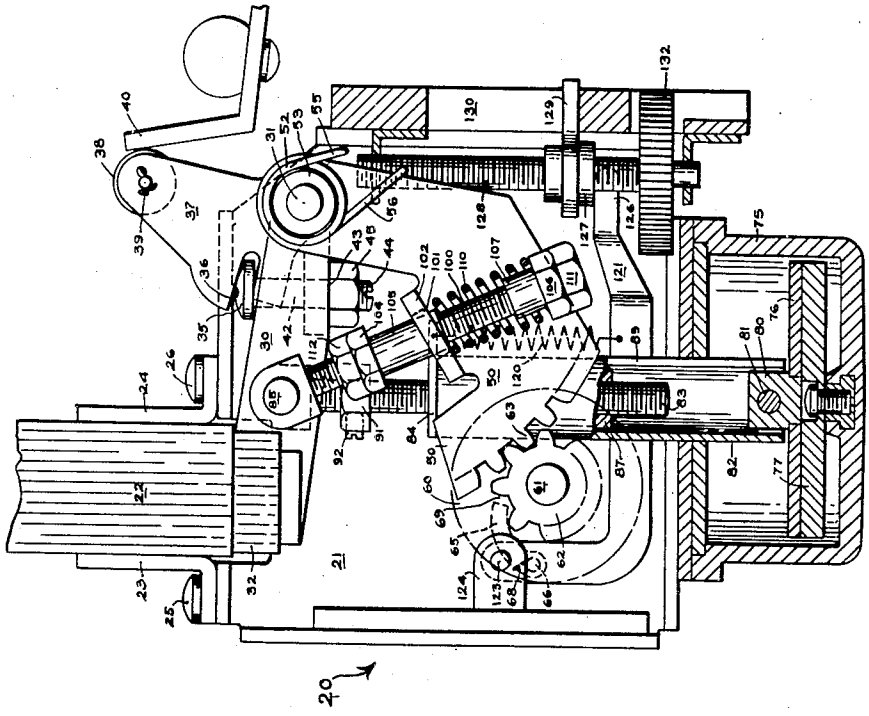


Fig. 6

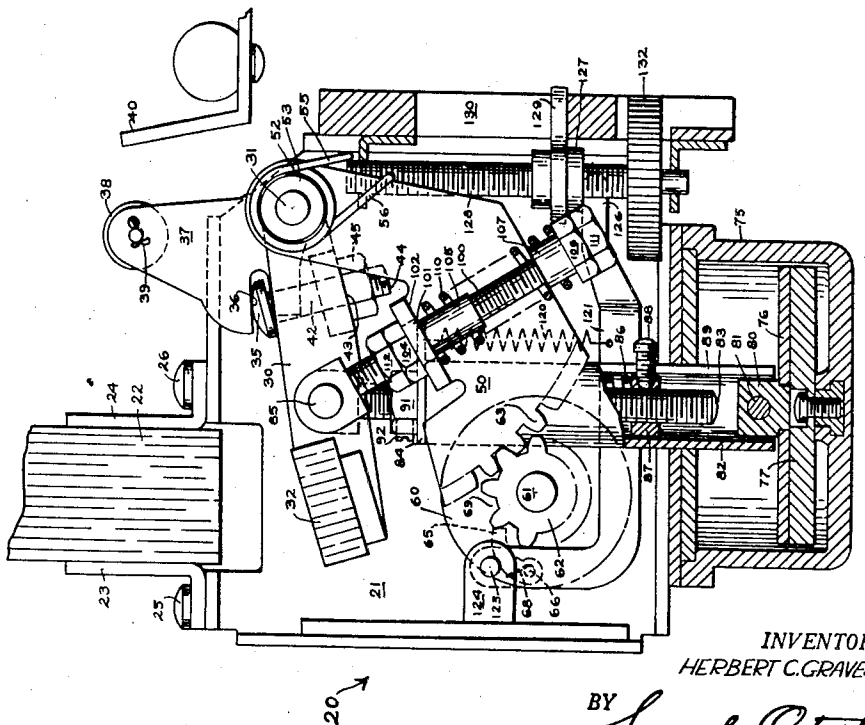


Fig. 3

INVENTOR.
HERBERT C. GRAVES JR.

BY Samuel Astrolink
Attorney.

April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

Filed Feb. 17, 1944 10 Sheets-Sheet 4

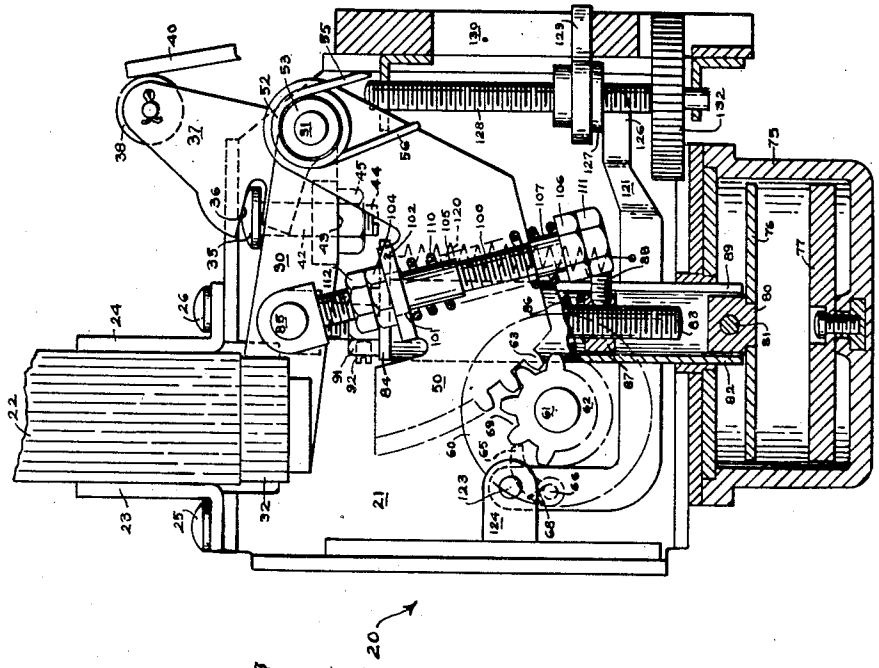


Fig. 4

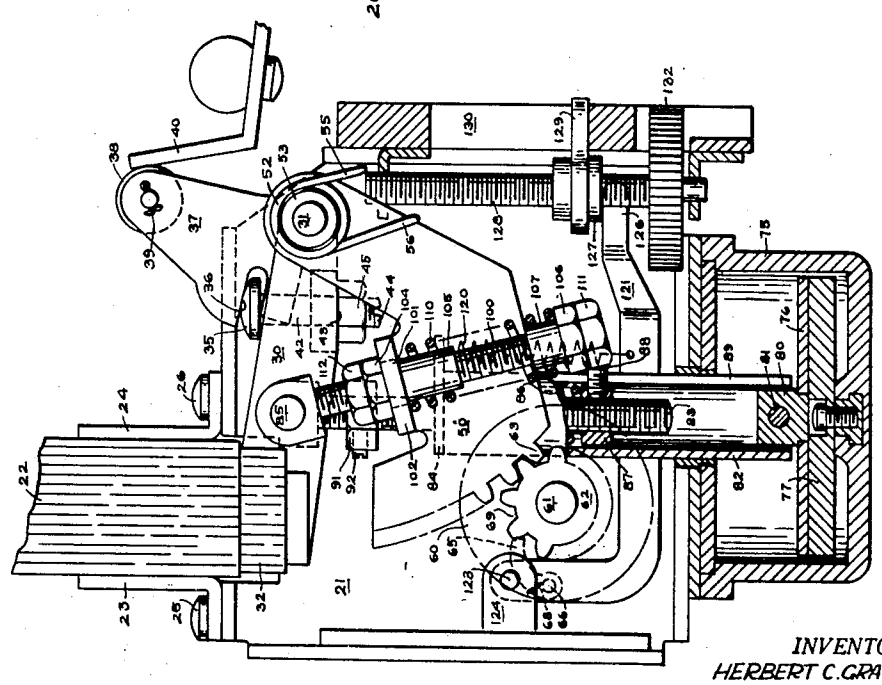


Fig. 5

INVENTOR.
HERBERT C. GRAVES JR.

BY Samuel Ostrolenk
Attorney

April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

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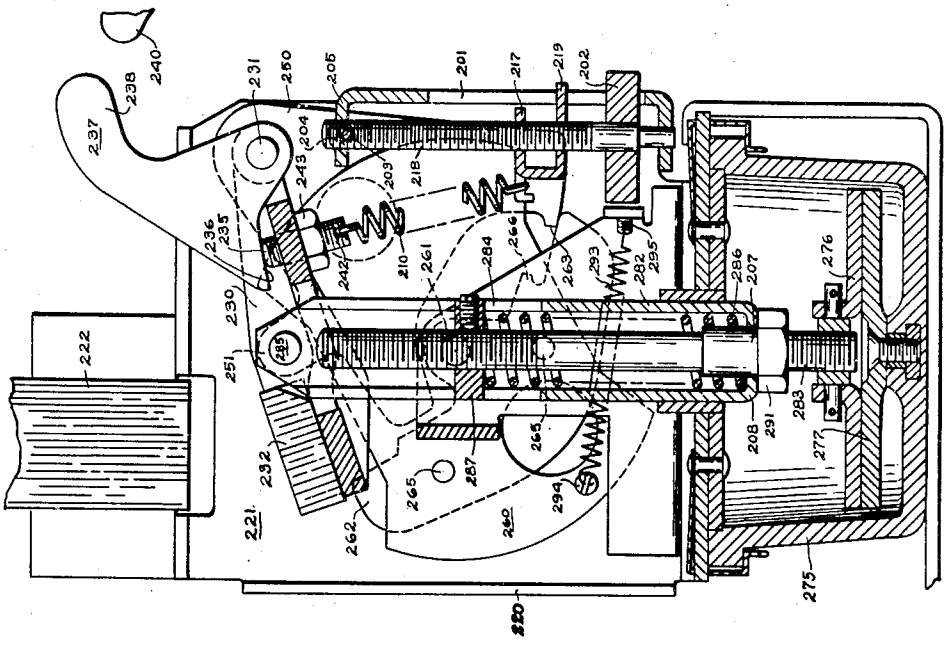


Fig. 7

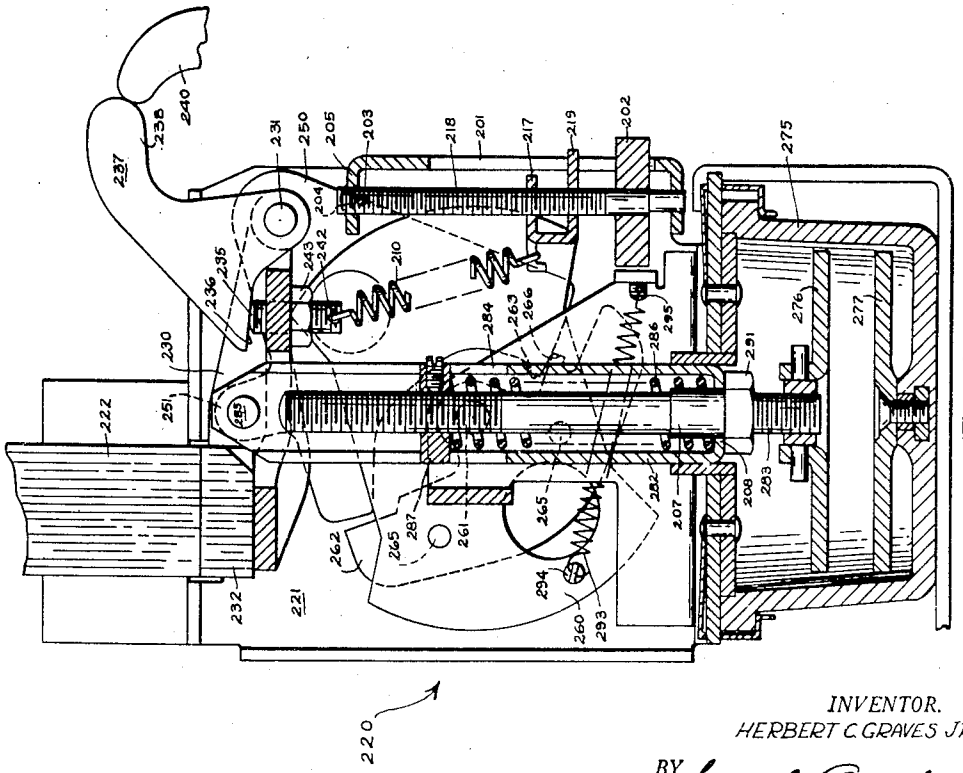


Fig. 8

INVENTOR.
HERBERT C. GRAVES JR.

BY Samuel Astrolenke
Attorney

April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

Filed Feb. 17, 1944 10 Sheets-Sheet 6

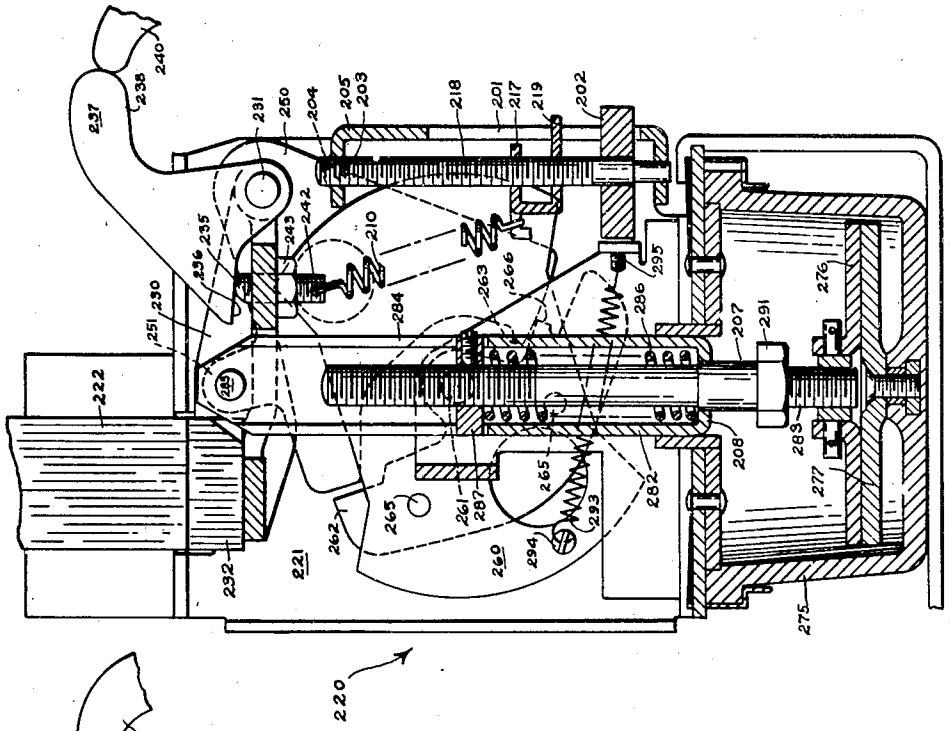


Fig. 10

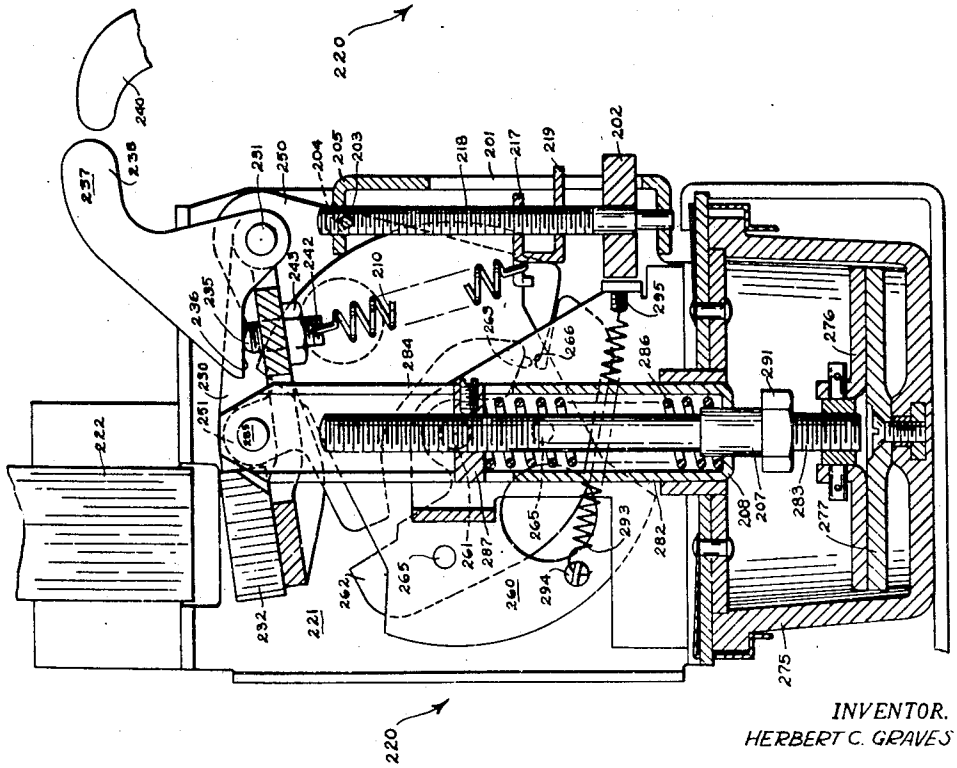


Fig. 9

INVENTOR.
HERBERT C. GRAVES JR.

BY Samuel Ostrolenk
Attorney

April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

Filed Feb. 17, 1944 10 Sheets-Sheet 7

Fig. 11

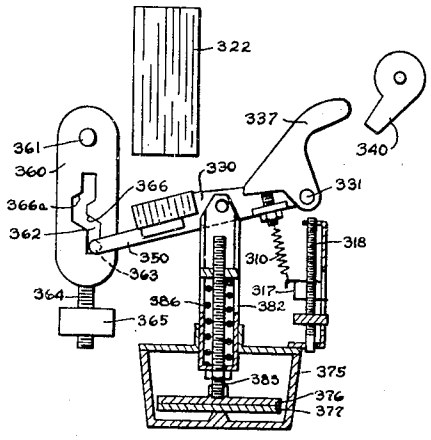


Fig. 12

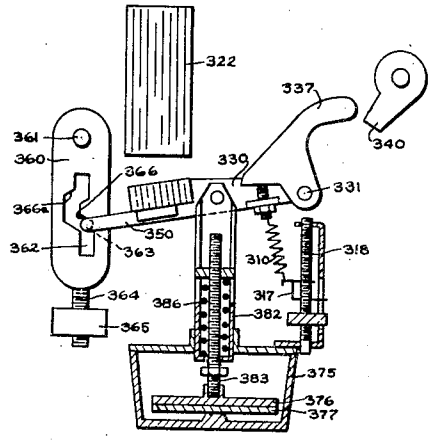


Fig. 13

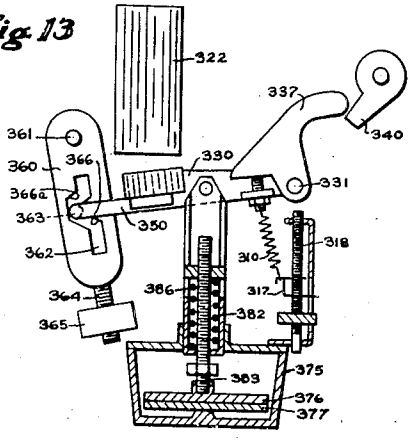
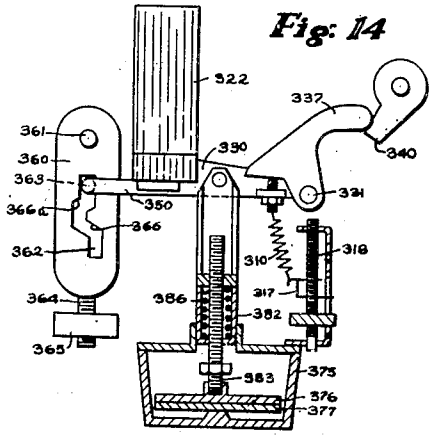


Fig. 14



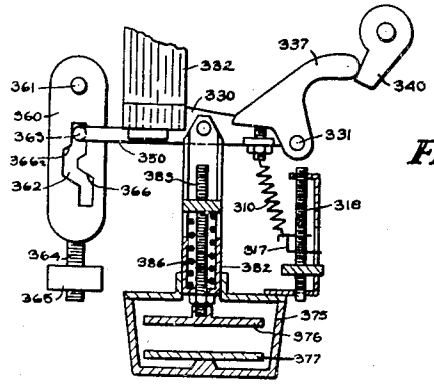


Fig. 15

INVENTOR.
HERBERT C. GRAVES JR.

BY Samuel Asterlitz
Attorney

April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

Filed Feb. 17, 1944 10 Sheets-Sheet 8

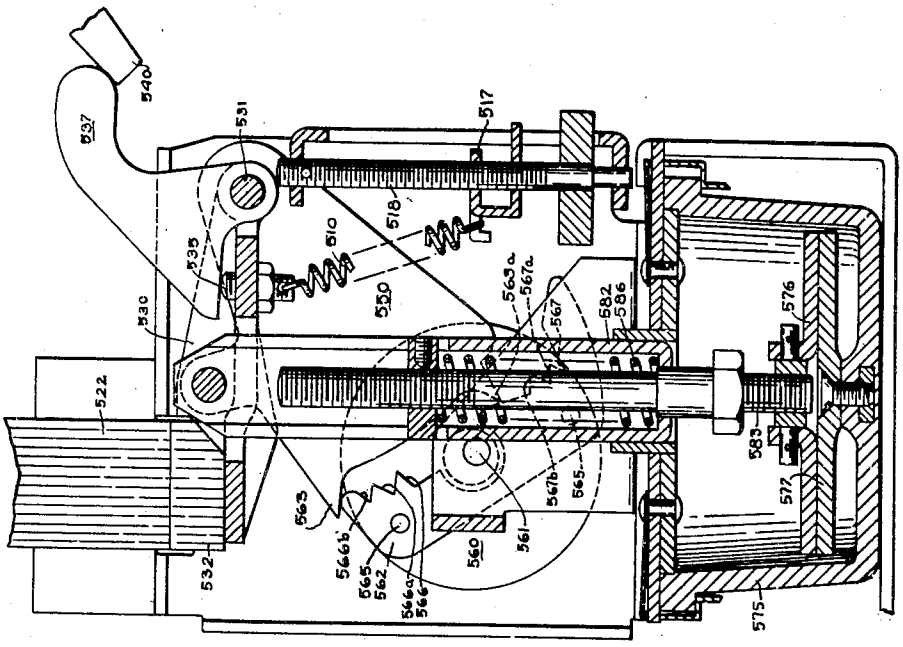


Fig. 17

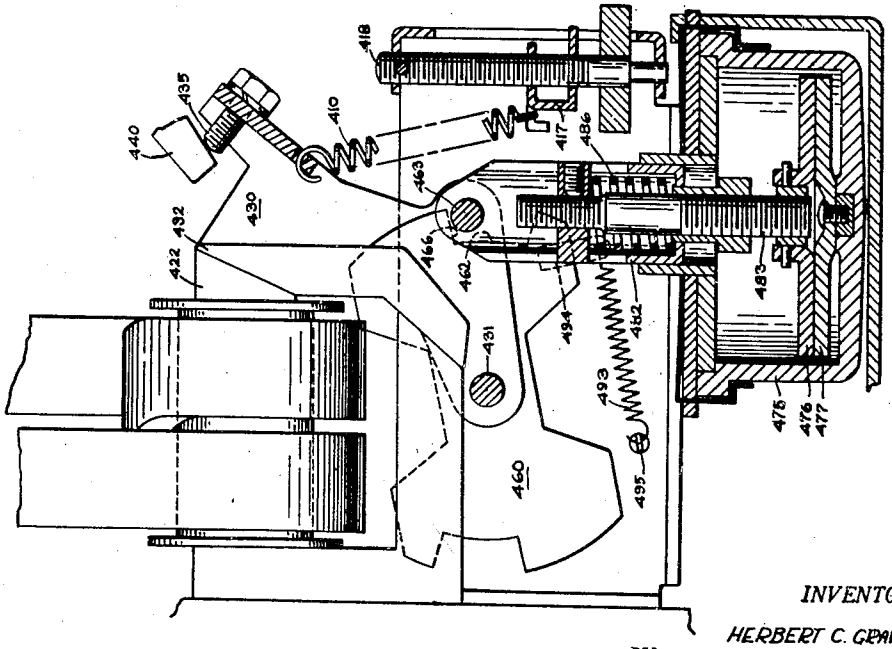


Fig. 16

INVENTOR.
HERBERT C. GRAVES JR.
BY Samuel Astrachan
Attorney.

April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

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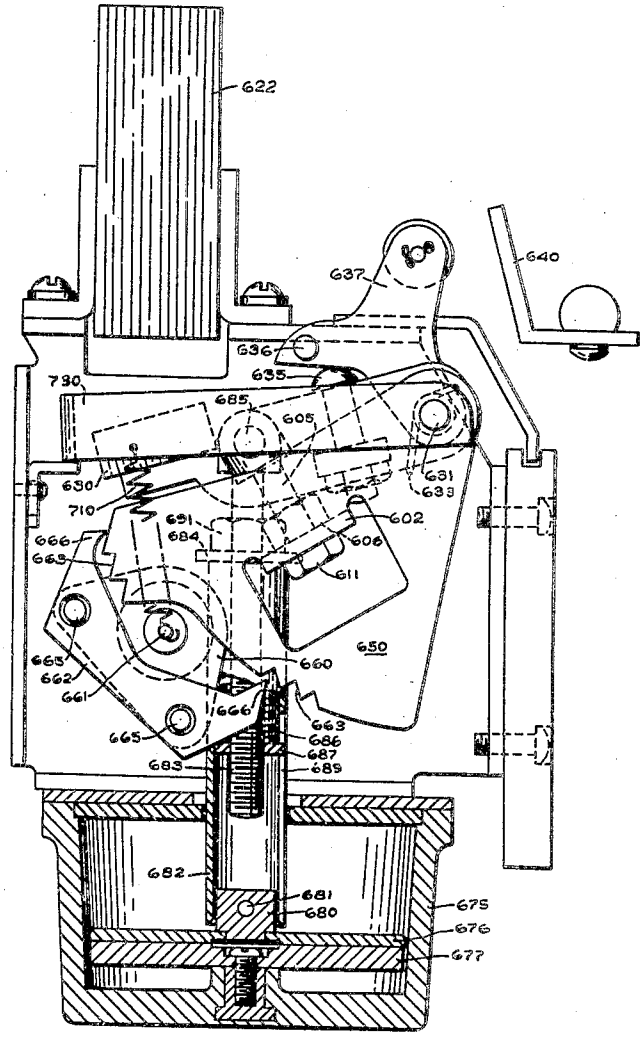


Fig. 18

INVENTOR.
HERBERT C. GRAVES JR.
BY Samuel Astorbuch
Attorney.

April 6, 1948. H. C. GRAVES, JR 2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

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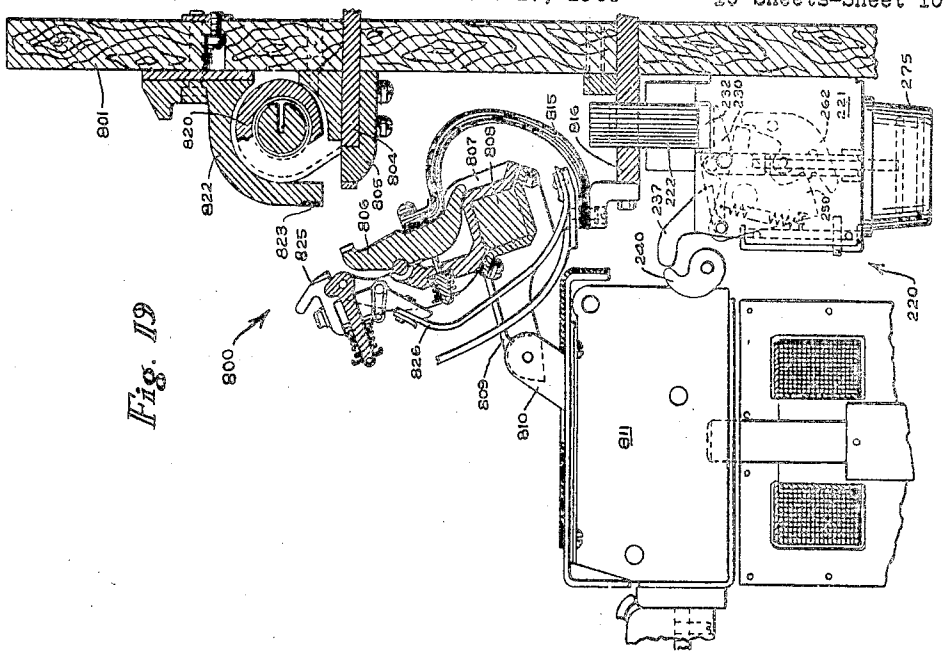


Fig. 19

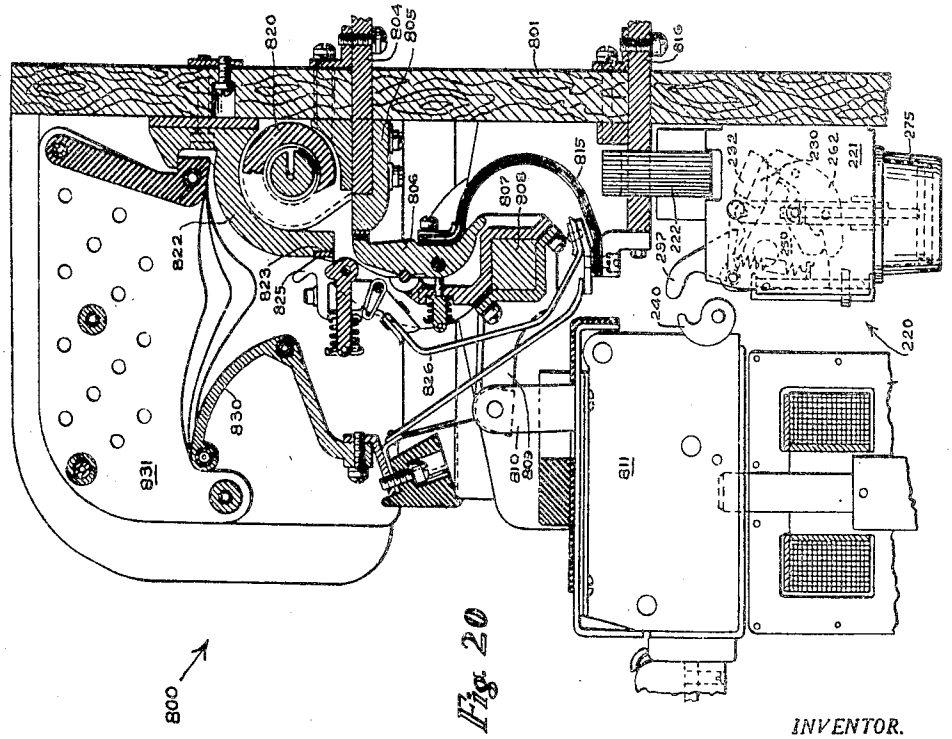


Fig. 20

INVENTOR.
HERBERT C. GRAVES JR.
BY Samuel Ostrolenk
Attorney

Patented Apr. 6, 1948

2,439,165

UNITED STATES PATENT OFFICE

2,439,165

SELECTIVE TRIPPING OF CIRCUIT BREAKERS IN A SYSTEM

Herbert C. Graves, Jr., West Chester, Pa., assignor to I. T. E. Circuit Breaker Company, Philadelphia, Pa., a corporation of Pennsylvania

Application February 17, 1944, Serial No. 522,725

16 Claims. (Cl. 175—294)

1

My invention relates to a novel system of circuit breakers arranged for sequential tripping over the entire protective tripping range of the circuit breakers including the short circuit current ranges, and more particularly relates to novel circuit breaker apparatus provided with direct acting overload devices which may be adjusted to secure sequential tripping with respect to other breakers in the system.

In distribution systems within, for instance, a large industrial plant, the power enters the plant through a main circuit breaker to the main distribution switchboard and is there fed out on a number of feeder circuits each protected by a circuit breaker. These feeders may each go to large loads. Some, or all, however, may go to additional distribution switchboards where they are again divided into smaller distribution circuits. Each of these circuits may in turn go to load centers or power panels for distribution of the energy to a multiplicity of loads.

Distribution systems of this type (of which a simplified diagrammatic illustration is hereinafter shown in the figures) are utilized not only in most industrial plants, but also wherever a large quantity of apparatus in a relatively compact unit must be operated from a central power source.

In such distribution systems, the fault current due to fault or short circuit conditions in one of the feeder circuits, or even in one of the load circuits, passes through several breakers in series and may result not merely in a tripping of the circuit breaker protecting that particular load, but in a tripping of each of the circuit breakers back of and in series with that particular circuit breaker back to the source, so that one of the main feeder breakers, or even the main breaker itself, may be tripped and thus disconnect the entire distribution system.

Accordingly, the primary problem to which this invention is directed is the construction and arrangement of such circuit breakers in a distribution system in such a novel manner that high speed selective tripping will occur, and so that the circuit breaker nearest the fault will be operative to clear an overcurrent, fault, or short circuit condition on the particular circuit it is protecting before the circuit breakers between it and the source can complete a tripping operation, and so that each circuit breaker in the system will be protected by the circuit breaker immediately behind it toward the source.

More specifically, I have invented a novel system in which the overload mechanisms of the

2

circuit breakers in the system are so adjusted that the smallest circuit breakers for protecting the individual loads have a higher speed trip characteristic than other breakers in series with them, up to their maximum interrupting capacity. At or below maximum interrupting capacity of these load breakers, the adjustment of the overload mechanism of the adjacent circuit breaker in series with the load unit breaker (toward the source) becomes quick acting to trip its associated circuit breakers quickly and, therefore, protects the smaller load breaker. The overload mechanism of this adjacent circuit breaker is in turn adjusted to trip its associated breaker faster than the next circuit breaker (toward the source) in the series circuit thereby preventing tripping of this next circuit breaker, at short circuit values approximately up to or below the maximum interrupting capacity of the preceding circuit breaker. This last circuit breaker is, in turn, tripped substantially instantaneously at short circuit currents of values substantially equal to or below the maximum interrupting capacity of the circuit breaker adjacent it toward the load.

In sequential tripping systems heretofore employed, the time separation between the various circuit breakers in the system has been effected by the provision of relays which have been set to various time delays and which, on operation, energize the shunt trip coils. Such systems are either very expensive and involved or can only provide sequential operation by timed intervals in the range of seconds since it is necessary in such a system that the relay first be energized sufficiently long to pull up its armature to close its contacts. When the armature has been moved to the energized position, and then only, does it energize the shunt trip coil which in turn must operate a second armature to operate the trip mechanism. Where instantaneous features were added, as was often the case, all circuit breakers in the sequence would open, thus losing continuity of service.

I have discovered that I can secure sequential tripping of circuit breakers in a power system not only in the overload current ranges such as may occur in motor starting circuits, but also in the range of short circuit currents where the tripping must be substantially instantaneous.

This I effect by providing overload devices having an inverse time ratio which may substantially simulate the heating conditions of a load such as a motor to provide a time delay trip for the protection of such a load. This is

followed by a quick trip protection at greater overload conditions such as at two to ten times th overload value of the particular breakers with a short inverse time or definite minimum time characteristic. In addition, a more definite ratio can be obtained by saturation of the magnetic circuit in the overload device.

Finally there is provided an instantaneous trip mechanism individual to each of said breakers. This latter is so arranged with respect to each of the other circuit breaker trip curves that each of the larger breakers (in a cascaded system) has substantially the same instantaneous tripping time as the next smaller breaker at the interrupting capacity of that smaller breaker.

At less than this interrupting capacity each of the quick trip mechanism, however, has a slightly lower tripping operation measurable in terms of a few cycles than the next smaller circuit breaker so that sequential tripping is still effected in such a short circuit current range close to maximum interrupting capacity of the breakers of the system.

Accordingly an object of my invention is to provide a novel system in which sequential tripping is secured in the short circuit current ranges and without substantial time delay in the tripping which would otherwise tend to damage the circuit breaker and the equipment being protected thereby, and also reduce interrupting capacity of the breakers.

A further object of my invention is to provide a novel power system in which the circuit breakers are all arranged to have characteristic curves for protecting normal overloads such as currents in motor circuits, in which sequential operation is secured and which also provides sequential operation at short circuit currents where very fast operations of the circuit breakers are necessary.

A further object of my invention is to provide a novel sequential tripping system in both the long time delay periods and quick trip operating periods.

In order to secure the sequential tripping at short circuit current values where extremely fast operations are necessary, I have discovered that I may, by the use of time delay mechanism such as inertia members in the overload devices, effect close timing between the overload devices of successive circuit breakers at short circuit values of current. This is due to the fact that the operation of the tripping mechanism of the circuit breaker is effected by a direct acting overload coil and that the inertia or other time delay devices are accurate for very short timing periods.

In one form of my invention there is interposed between the armature and the tripping mechanism of the circuit breaker an inertia mass which provides the inverse time delay in the movement of the armature towards the tripping mechanism. When however one of the circuit breakers having a slightly faster operation engages the tripping mechanism and the circuit breaker thereupon effects an opening of the system, the remaining armatures of the other circuit breakers in the system (each having been delayed by the mass in the manner herein described, for slightly longer periods) will not yet have reached the tripping position; and since the clearance of the fault by one circuit breaker will reduce the magnetic attraction exerted by one overcurrent magnet on the armature to the full load level or less, and since the armature

is normally restrained by a spring having a somewhat greater force than that exerted by the magnet at full load even at the reduced air gap, the armature will return without reaching the trip position.

Although the masses in the overload devices of each of these other circuit breakers will, through their inertia, continue to move forward, the energy stores in these masses is ineffective to perform any further action on the tripping mechanism since actual tripping is, as stated above, effected by direct action of the armature on the tripping mechanism and the armatures being of exceedingly light weight and being held back by comparatively powerful springs have been restored, as stated above, immediately upon the opening of the circuit by the next lowest breaker.

In other words, by a reliance on the use of a very light armature restrained by a comparatively powerful spring, there is at no time any substantial kinetic energy stored in the armature in its movement in response to the overload magnet.

Accordingly, a further object of my invention is to provide novel direct operating overload apparatus in circuit breakers to secure a novel sequential tripping system.

Still a further object of my invention is to provide restraining or time delay mechanism on the quick trip armature of the overcurrent trip magnet.

Still another object of my invention is to provide a sequential tripping system in which the circuit breakers directly operated from the armature have inertia members interposed between the armature and the tripping mechanism for providing inverse time action in the quick trip period and enable sequential tripping action in this period as well as in the overload period.

In selecting and constructing circuit breakers for installation on such a system in accordance with this invention, some or all of the following conditions are necessary:

1. Each main, feeder, sub-feeder, and load center breaker should preferably have a current carrying capacity equal to the carrying capacity of the cable or the load that it feeds.

2. The overload tripping device should have a time delay feature greater in current value and time than the normal operating surges that are imposed upon it, such as motor starting current. This is to prevent unnecessary tripping on harmless overloads. The time delay should have inverse characteristics, and be selective with the other breakers in series with it.

3. At current values greater than normal surges, each breaker should trip as quickly as possible to minimize any damage to the breaker itself or the cable or load which the breaker feeds.

4. But, at current values greater than normal surge values, there should be sufficient time delay in the short circuit device of the breakers in series, so that the breaker nearest the fault will open first. Only this breaker should open (if the fault current is within the interrupting capacity of this breaker) leaving the remainder of the system intact and feeding the load. Here selectivity is obtained by the higher speed selective device.

5. If the fault current is greater than the interrupting capacity of the breaker nearest the fault (as may happen in installations where

breakers are installed in "cascade") then, not only must the breaker nearest the fault open in the shortest time, but also the next breaker in series, which has a higher interrupting capacity. This breaker must open to aid and protect the first breaker, and must open quickly. If the second breaker in the series has insufficient interrupting capacity the process must continue back towards the main breaker until a breaker opens that can clear the fault. On these high values of current, the breakers must open quickly to limit any damage and only the necessary breakers should open. Here the high speed instantaneous element is effective to trip faster than either of the two timing elements.

6. On each of the trip features, calibrated adjustment should preferably be provided so that a breaker may be coordinated with the other breakers in the system in which it may be used.

In the foregoing conditions or requirements, the first three items have been known and are in substantial use. The features described in items 4, 5 and 6 set forth objects which my present invention is designed to provide and carry out.

These objects will become apparent from the following description and drawings in which:

Figure 1 is a schematic diagram of a group of circuit breakers in a typical distribution system together with a graph showing the tripping characteristics of each of the circuit breakers in the group.

Figure 2 is a schematic diagram of another typical distribution system where, in addition to the problem of the selective tripping of feeder breakers, there are presented the problems which arise from the utilization of two sources of power together with bus tie breakers; this figure also includes a graph showing the tripping characteristics of the breakers in the system.

Figure 3 is a side view showing the construction and operation of a time delay device for a typical circuit breaker in the distribution systems of Figures 1 and 2; the view of Figure 3 shows the relationship of all of the parts in the de-energized position of the circuit breaker tripping armature.

Figure 4 is a view corresponding to that of Figure 3 showing the position of the parts of the momentum absorbing device of Figure 3 after an overload has persisted long enough to break the film between the discs of the dashpot and the said discs have separated, allowing the armature to go to the closed gap position to trip the circuit breaker.

Figure 5 shows the position of the parts of the device of Figure 3 when the current is of sufficient value to bring the quick trip elements into play.

Figure 6 is a view corresponding to that of Figure 3 showing the position of the elements thereof, however, when there is an extremely heavy short circuit and no delay at all is desired.

Figure 7 is a view showing a modified form of momentum absorbing device for a circuit breaker showing the armature and associated parts in the unenergized or unattracted position.

Figure 8 is a view corresponding to that of Figure 7 showing the position of the elements for tripping after the dashpot discs forming a time delay have separated.

Figure 9 is a view corresponding to that of Figure 7 showing, however, the beginning of the quick trip stroke and illustrating the engagement of the momentum absorbing device.

Figure 10 is a view corresponding to that of Figure 7 showing the final tripping position of the device of Figure 7.

Figure 11 is a view of a further modified form of momentum absorbing device for utilization in connection with the present invention showing the parts thereof in the unenergized position.

Figures 12, 13 and 15 illustrate the successive steps of the operation of the device of Figure 11 for tripping an overload as the dashpot discs separate giving the time delay.

Figure 14 illustrates the quick trip position under heavy overcurrent conditions.

Figure 16 is a view of another modified form of momentum absorbing device for use in connection with the present invention.

Figure 17 is a view of another modified form of momentum absorbing device for use in connection with the present invention.

Figure 18 is a view showing a somewhat modified form of the construction of Figure 17.

Figures 19 and 20 are cross-sectional views partly in elevation showing the manner in which one of my tripping devices (that of Figures 7 to 10) may be incorporated in a circuit breaker structure.

Referring now to Figure 1, I have here shown a typical distribution system having a plurality of circuit breakers together with a graph showing the tripping characteristics thereof. In this distribution system, the electrical energy is distributed at a utilization voltage of 440 volts, the various interrupting capacities for each of the breakers are shown in the curves.

The power enters the main plant by the circuit breaker 4, and then passes to a main distribution switchboard whence it is fed out on a number of feeder breakers 3. These feeders may each go to large loads. Some, or all, however, may go to additional distribution switchboards where they are again divided into a plurality of small distribution circuits to which energy is fed out over the circuit breakers 2. Each of these circuits may in turn go to load centers or power panels for distribution of the energy over the circuit breakers 1 to a multiplicity of loads.

As above pointed out:

1. Each circuit breaker should have a continuous capacity approximately equal to the capacity of the cable or the load (whichever is smaller) that it feeds.

2. Unnecessary tripping on harmless overloads, occurring because of normal operating surges, should be avoided by an appropriate time-delay feature having proper inverse time characteristics.

3. Each breaker should trip as quickly as possible at current values greater than the normal surges.

4. It is essential, however, that at such current values greater than the normal surge values, there should be sufficient time delay in the overload devices of the breakers in series, so that the breaker nearest the fault will open first. Thus, should the fault occur in the load circuit protected by circuit breaker 1, this circuit breaker should be effective to clear that fault without causing a tripping of circuit breakers 2, 3 and 4. Consequently, breakers 2, 3 and 4 should have sufficient time delay so that breaker 1 will have an opportunity to clear the fault.

5. However, if the fault current is greater than the interrupting capacity of the breaker nearest the fault, then not only should the nearest breaker open, but also the next breaker in series which has a higher interrupting capacity. Thus, should the fault in a load circuit protected by circuit breaker 1 be greater than the capacity of

breaker 1, but less than the capacity of breaker 2, then not only should breaker 1 open immediately, but also breaker 2 should open as quickly as possible to protect not only the apparatus originally protected by breaker 1, but to protect breaker 1. If breaker 2 should have insufficient interrupting capacity for this purpose, then breaker 3 should open; and if breaker 3 should, in turn, have insufficient interrupting capacity, then breaker 4 should also open.

Thus, on extremely high values of current, the breakers must open quickly without any time delay to limit any damage; and yet, however, only the necessary breakers should open.

6. Calibrated adjustments should be provided on the trip features of each circuit breaker so that a circuit breaker may be coordinated with the other breakers in the system in which it may be used.

The graph of Figure 1 illustrates these operations in connection with the distribution system of Figure 1. Each of the circuit breakers in the distribution system has similar characteristics of operation, and a specific description of one of the curves for one of the circuit breakers should suffice to illustrate the operation of the remainder.

Thus considering curve 2 for circuit breaker 2, which is a 600 ampere circuit breaker with a maximum interrupting capacity of 25,000 amperes, the upper part of the curve *a* is the inverse time characteristic of the overload device. It is set at a high value to take care of starting motors directly across the line and other large surges frequently encountered in present day installations.

At ten times normal current or 6000 amperes at point *b*, the quick trip feature comes into play. This quick trip also has an inverse time feature, but the time delay value is very small, being of the order of one to six cycles of a 60 cycle wave. As shown, however, at portions *c* and *d* of curve 2, even this small time delay is defeated, and breaker 2 will open immediately at the value of the interrupting capacity (15,000 amperes) of the next smaller breaker (circuit breaker 1) to protect this next smaller breaker. (For safety, this instantaneous trip may be 80% of 15,000 or 12,000 amperes.)

This illustration of the operation of circuit breaker 2 in connection with curve 2 illustrates a main principle underlying the present invention—that is, that each circuit breaker is ordinarily arranged to open the circuit which it protects before the circuit breakers of greater capacity back of it in series come into operation. Where however the capacity of the circuit breaker nearest the fault is exceeded, the next circuit breaker of greater capacity back of it in series will come into operation, and so on, until a circuit breaker is reached which can clear the load.

Each circuit breaker is given time delay characteristics which enable it to come into operation at the appropriate times, in order to protect the circuits as well as the circuit breakers which follow it in series.

In each circuit breaker a quick trip operation may be provided in addition to the overload time delay, which has a short inverse or minimum time characteristic. This short inverse time delay functions to assure that any smaller breakers nearer the fault trip first and any larger breakers further from the fault trip later than any given breaker in the series.

Under very heavy currents, however, which completely exceed the interrupting capacity of the next smaller circuit breaker in series following a given circuit breaker, even the quick trip time delay is by-passed, and the given circuit breaker opens instantaneously without any delay whatever. This provides for immediate protection not merely of the original load and circuit, but also of the circuit breakers which follow in series after the given circuit breaker. Also, the instantaneous feature may increase the rupturing capacity of the breaker to which it is attached.

Thus in the system shown in Figure 1, the circuit breaker 1, as will be obvious, requires no instantaneous trip, but the quick trip is useful in order to quickly clear a fault before damage occurs and to make it selective with breaker 2 beyond 6000 amperes. Thus following curve 1 for circuit breaker 1, the section *a*, as above described, shows the operation of the circuit breaker under overcurrents which permit the time delay to operate.

Circuit breaker 1 is normally a 100 ampere circuit breaker with time delay up to ten times normal current; after which a quick trip is provided having a very short inverse time delay. Circuit breaker 1 has maximum interrupting capacity of 15,000 amperes.

Thus, following curve 1, it will be seen that at an overcurrent value of a little more than 200 amperes, it will take more than 100 seconds for the circuit breaker to trip. At an overcurrent, however, of 700 amperes, the circuit breaker will trip, should this overcurrent continue for only 10 seconds. At an overcurrent value of 900 amperes, the circuit breaker will trip, should this overcurrent continue for about 8 seconds. However, should the overcurrent value be 1000 amperes, or 10 times the normal rating, then the quick trip comes into play, as shown at curve *b* or *c*, and the circuit breaker will trip within .05 second or substantially three cycles.

At greater overcurrent values, the tripping operation will even be faster, as for example at 4,000 amperes in which case tripping occurs in .016 second or substantially one cycle.

At any of these values, breaker No. 1 has sufficient capacity to open the circuit. Accordingly, as shown by portion *c* of curve 2, circuit breaker No. 2 will not open due to the time delay which sufficiently delays the opening of the circuit breaker No. 2 so that circuit breaker No. 1 opens the circuit and renders the overload device of circuit breaker No. 2 ineffective before it can trip its circuit breaker. Thus, for example, at 4000 amperes, circuit breaker No. 1 opens in .016 second but circuit breaker No. 2 would take 10 seconds to open or 600 cycles.

However, at 15,000 amperes, as above pointed out, the interrupting capacity of circuit breaker 1 is exceeded, and it is necessary that the next circuit breaker open instantaneously. Consequently, the next circuit breaker 2 is provided with an instantaneous trip which comes into operation at 15,000 amperes. This point is indicated at portion *d* of curve 2.

The other elements of curve 2 correspond in operation to the previously mentioned elements of curve 1. However, it will be seen that even a quick trip operation *b* of curve 2 occurs with some small time delay over portion *c*, roughly, of the order of .15 second between *c'* and *c''*.

The instantaneous trip at 15,000 amperes is arranged, however, so that even the quick trip time delay is overcome, and the circuit breaker

opens in .016 second, and thus in less than a single cycle to protect circuit breaker 1.

Again, circuit breaker 2 has, as shown on drawing, a maximum interrupting capacity of 25,000 amperes. Consequently, it is necessary that circuit breaker 3 become instantaneous at this point.

Circuit breaker 3, as shown by curve 3, has an ordinary time delay for ordinary overcurrent surges, a quick trip, and a time delay on the quick trip, as above pointed out in connection with curves 1 and 2. Circuit breaker 3 also has an instantaneous trip *d* which comes into operation at 25,000 amperes to by-pass even the quick trip time delay and to make the operation of circuit breaker 3 instantaneous at 25,000 amperes, so that it too trips in about .016 second at this current value.

Similarly, since circuit breaker 3 has a maximum interrupting capacity of 50,000 amperes, circuit breaker 4 is arranged to be instantaneous at this value, as will be obvious from the graph of Figure 1; and thus circuit breaker 4 is instantaneous at any value from 50,000 to 75,000 amperes. The 75,000 amperes maximum interrupting capacity of circuit breaker 4 is designed to be greater than any possible current intensity which may occur in the entire distribution system.

The following specific examples are thus taken from the graph of Figure 1:

a. A fault condition in one of the circuits protected by a circuit breaker 1 of approximately 2,000 amperes.

Circuit breaker 1 will open within less than .02 second. The overload time delay of circuit breakers 2, 3 and 4 will not yet have permitted these circuit breakers to go into operations, and only circuit breaker 1 will be necessary to clear the fault.

b. A fault current of 10,000 amperes in a circuit protected by a circuit breaker 1—

Circuit breaker 1 will clear the fault within .02 second. The quick trip of circuit breaker 2 will have commenced operation, but the quick trip time delay will have been brought into action thus delaying the opening of circuit breaker 2 to about .05 second. Before .05 second has elapsed, circuit breaker 1, operating within less than .02 second, will have tripped open and cleared the fault, so that the quick trip time delay of circuit breaker 2 will thus have delayed the opening of circuit breaker 2 until the fault has been cleared, and the armature of circuit breaker 2 will then drop back without tripping circuit breaker 2. The quick trip time delay, as hereinafter pointed out, is essentially a momentum or energy absorbing device.

c. Assuming now a fault in the circuit protected by a circuit breaker 1 of 20,000 amperes—

Circuit breaker 1 will trip open within less than .02 second, but since its maximum capacity is 15,000 amperes, it will not serve to clear the fault. Simultaneously, circuit breaker 2, which becomes instantaneous at only 15,000 amperes, will be brought into immediate operation and will open within the same time of less than .02 second thus protecting circuit breaker 1. The quick trip of circuit breaker 3 will have been brought into operation, but the quick trip time delay will have slowed down the operation of the quick trip of circuit breaker 3, so that at 20,000 amperes it would take .05 second to open; but by the time .05 second has elapsed, circuit breakers 1 and 2 will have opened, thus clearing the fault by means of a circuit breaker having sufficient capacity to do so, and the momentum absorbing device on circuit breaker 3 will then have been sufficient to prevent the completion of the trip of circuit breaker 3.

d. Assuming a fourth current fault of 60,000 amperes in one of the feeders protected by circuit breaker 2—

Circuit breakers 2 and 3 would open instantaneously, as shown by the graph of Figure 1. However, since the maximum capacity of these circuit breakers is respectively 25,000 and 50,000 amperes, these circuit breakers will not be sufficient to clear the fault. Consequently, as shown in the graph of Figure 1, circuit breaker 4, which becomes instantaneous at 50,000 amperes, will immediately be brought into operation to clear the fault.

e. Assuming a 60,000 ampere fault in one of the individual circuits protected by circuit breaker No. 3 that is fed by the common bus of the circuit breaker No. 4—

In that event, the circuit breaker No. 4 individual to that circuit will open instantaneously. Similarly a 40,000 ampere fault in an individual circuit of one of the circuit breakers No. 3 would only cause that particular No. 3 circuit breaker to trip leaving the remainder of the system unaffected.

It is believed that these examples explain the operation of my system.

Thus, even though an overcurrent or short circuit condition occurs, at a value at which the quick trip of a principal circuit breaker is brought into operation—nevertheless, the provision of an energy absorbing device in the quick trip provides a very short time delay of the order of 1 to 12 cycles for the circuit breaker next in series to clear the fault—so that only those circuit breakers absolutely necessary to clear the fault will be brought into operation, and so that the others will remain closed.

Even this energy absorbing device which creates an extremely short time delay, as above pointed out, may be by-passed where the overcurrent or fault condition is of such value as to exceed the interrupting capacity of this or any other circuit breaker in series, in which case an instantaneous trip occurs.

The adaptability and flexibility of the sequention tripping arrangement described in Figure 1 makes it possible to apply this system in more complicated circuits. Since each of the characteristics of the tripping devices may be varied over wide ranges, many variations of the system and the settings may be made while nevertheless remaining within the principles of my invention.

In many systems, the normal surges may be small and the time delay may therefore be set for a much shorter period; or the quick-trip may be set at three times normal instead of ten times normal for closer protection.

In the above, I have given a more or less general application of my invention. In order to illustrate the kind of protective problems that may be solved in accordance with the principles of this invention, I have included Figure 2 which illustrates a special case. In Figure 2 the system includes, in addition to the problem of the selective tripping of feeder breakers, also the problem of two sources of power and bus-tie breakers.

Tripping of the feeder breakers is in the same manner as for the radial distribution system described in connection with Figure 1. Consequently, the curves with respect to breakers 1 and 2 need not be again reviewed.

In the case of Figure 2, however, the generators

feeding the system are relatively small and can supply only a limited amount of short circuit current. For that reason the quick trip and instantaneous trip of all the breakers in this system may be set for a lower current value than the distribution system shown in Figure 1.

For instance, in Figure 2 while the quick trip of breaker No. 1 is thirteen times normal, the quick trip of breakers Nos. 2 and 3 and 4 is less than twice normal as compared with ten times normal in the typical distribution system shown in Figure 1.

Likewise the instantaneous trip on breakers Nos. 2, 3 and 4 is set at approximately 15,000 to 20,000 amperes so as to be well within the short circuit current given by three generators feeding into a fault in the fourth generator.

Since normally the load is fed at each generator station and the bus tie is provided for emergency operation, the bus tie breaker has been selected to have a current capacity equal to one generator only and its overload calibration is set to 80% of one generator capacity.

Referring to the curves in Figure 2, the advantages of this system will become apparent if we assume various fault conditions and note the operation of the system:

1. A fault in the feeder protected by breaker No. 1 of less than its interrupting capacity of 15,000 amperes, will be opened by breaker No. 1 without disturbing any of the rest of the system.

2. A fault in the feeder protected by breaker No. 1 greater than 15,000 amperes and not exceeding 25,000 amperes will cause the opening of breaker No. 1 and breaker No. 2 leaving the remainder of the system unaffected.

3. A fault in the feeder protected by breaker No. 1 exceeding 25,000 amperes will be fed from three sources, from each of the two generator breakers No. 4 and the bus tie breaker No. 3. Even if the current should divide equally, all three of these breakers would open to clear the fault in approximately 6 cycles (60 cycle wave) leaving one generator station in operation.

4. Assuming a fault on bus 10 of any current value, then the two generator breakers No. 4 and the bus tie breaker No. 3 must open to clear the fault.

5. Assuming a fault on the bus tie 9 of any current value, then the breaker No. 3 receives twice as much current as any generator breaker which will result in the bus tie breaker No. 3 opening before the generator breakers No. 4. This will isolate the bus tie circuit without affecting either of the generator stations which will continue to feed their respective loads.

6. Assuming a fault in the generator 12 which will be fed by the other generator connected to the bus and also by the two generators over the bus tie, breaker No. 4 for generator 12 due to this high current, will open in advance of the other generator breakers or the bus tie breaker 3, and this generator will be isolated without interfering with the operation of the remainder of the system.

With these settings, it will be seen that all faults that may be expected on the system are cleared by the breaker nearest the fault and only the necessary breakers will be opened.

Thus, circuit breakers 2 protect the circuit breakers 1, as will be seen from the chart of Figure 2 in the manner previously described in connection with Figure 1. It will also be seen that circuit breakers 3 and 4 are respectively arranged

to protect the succeeding circuit breakers also in the manner previously described.

The short circuit current for one generator is plotted on the chart of Figure 2 as curve 5, with curves 5*a*, 5*b*, 5*c* and 5*d* of curve 5 showing the short circuit characteristics for the varying conditions indicated on the drawing. It will here be seen that the instantaneous settings of the circuit breakers are all such as to protect against the full short circuit current of all the generators in the system.

The element that makes this type of operation possible is the construction of the very short time delay used on the quick trip devices. Thus, in addition to the ordinary time delay which prevents the tripping of the circuit breakers as a result of normal current surges, there is an additional relatively minute time delay in the quick trip with an inverse characteristic and instantaneous trip device. Accordingly, where the overcurrent or short circuit condition is of sufficient intensity to overcome the time delay device and thus result in a quick trip without the interposition of the normal time delay, my invention contemplates that even the quick trip device be fitted with a time delay device resulting in a relatively minute delay in order to enable the selective operation above described to occur.

Where it becomes necessary, however, that absolute instantaneous operation be achieved, then my invention contemplates that even the relatively minute time delay of the quick trip device be overcome so that on greatly excessive overcurrent conditions or on full short circuits, all of the devices will be fully protected. Also this instantaneous trip increases the rupturing capacity of the breaker to which it is attached.

One form of such combination time delay-quicktrip-instantaneous device is shown in Figures 3 and 6.

In these figures only the tripping armature and its associated elements are shown. It will be understood, of course, that the tripping armature structure here shown is part of a complete circuit breaker and that the various devices secured to said armature may, with only obvious adaptations, be secured to cooperate with any type of tripping mechanism of a circuit breaker.

It must be understood that the minute time delay achieved in connection with the quick trip device must be a time delay which is of the very shortest duration possible which will serve to momentarily halt the armature, such as momentarily delaying the motion of the armature, to afford an opportunity for another circuit breaker to clear the overcurrent or short-circuit condition. If this relatively minute time delay is of too great a duration, then the circuit breaker does not fully protect the line and the load between which it is connected. If the time delay is too short, then the circuit breaker may be unnecessarily brought into operation. The time delay period selected therefore must be just that time period which is necessary to afford the next succeeding subsidiary circuit breaker time to clear the fault. This time delay should not be of any greater duration.

Obviously of course, as above pointed out, should the fault condition be such that the next succeeding subsidiary circuit breaker could not possibly clear the fault, then even this minute time delay should be removed. For this purpose the time delay on the quick trip device contemplated by this invention requires reliable operation at short periods of time, such as 1 to 12 cycles.

In Figure 3 the various parts of the time delay device are shown in the at-rest or de-energized position where no fault of any kind has occurred and where only normal current is flowing with no surges of any kind. The tripping device 20 is enclosed in any suitable housing 21 which may be secured in any appropriate manner to a circuit breaker panel or housing. The tripping magnet 22 (which is ordinarily energized by a series coil) is secured in appropriate position with respect to the housing in any suitable manner, as for instance by the angle brackets 23 and 24 which in turn are secured to the housing 21 by the bolts 25 and 26.

The tripping armature 30 is rotatably mounted on the pin 31 which in turn is secured between side plates of the housing. Armature 30 is provided at one end thereof with a plate 32 of a suitable magnetizable material which may readily be attracted by the magnet 22 on the occurrence of pre-determined fault conditions. The armature 30 is provided with an adjustable abutment 35 which bears against the undersurface 36 of the latch tripping member 37. Latch tripping member 37 is likewise rotatably mounted on the pin 31 and at its opposite end is provided with a roller 38 held in position in any suitable manner, as for instance by the cotter pin 39, which roller (as is shown in Figure 6) may be brought into engagement with the latch mechanism 40 of the circuit breaker itself in order to rotate this latch mechanism for the purpose of tripping the circuit breaker open.

Any suitable means (not shown) may be provided to retain the tripping member 37 in the normal position shown in Figure 3. Such means are commonly known and used in the art and may, for instance, comprise a coil spring (not shown) surrounding the pin 31 and bearing against the right hand surface of the tripping member 37. The abutment 35 is adjustable, as above pointed out, by reason of the fact that it constitutes the head of a bolt 42 which is threaded through the suitable tapped openings 43 in the armature 30 and which may be adjusted by means of the slot 44. It is held in the proper adjusted position by the lock nut 45.

The armature 30 has secured thereto (in the manner hereinafter described or in any suitable manner) a quick trip lever 50 which (in all cases except for the instantaneous trip) rotates with the armature 30 as it rises and falls. The quick trip lever 50 is itself rotatably mounted on the pin 31 and is secured to the armature 30 in such manner that for all purposes it is substantially a part thereof; except that when the instantaneous trip point is reached, as hereinafter described, the armature 30 may be freed from the quick trip lever 50. This manner of securement will be more specifically described in connection with the description of the operation of the tripping device at and above the instantaneous trip point.

The quick trip lever 50 cooperates with the elements hereinafter described to afford the minute time delay previously pointed out. Since this quick trip lever is itself intended to engage the momentum absorbing device or weight without affecting the armature setting itself, the quick trip lever is not intended to have any specific weight of its own. In other words, the quick trip lever 50 serves as a means for transmitting the driving force of the armature to a momentum absorbing weight and in an ideal situation trip lever 50 would itself be substantially weightless

so that only the momentum of the armature need be considered. This is important for the reason that the calibration of the circuit breaker depends on the mass and space relationship between the armature 30 itself and the magnet 22. An additional weight on the armature itself may well make this calibration difficult.

In order, therefore, to attain this substantially weightless condition of the quick trip lever 50, a coil spring 52 is provided which surrounds the bushing 53 on the pin 31. One end 55 of the coil spring bears against the inside wall of the housing 21 and the other end 56 of the coil spring 52 bears against the right hand surface of the quick trip lever 50.

The coil spring 52 is thus arranged so that it will substantially counterbalance the weight of the quick trip lever 50 so that the quick trip lever 50 will not itself act as a drag upon the armature 30 while the quick trip lever will nevertheless be able to transmit the momentum of the armature 30 to the momentum absorbing device.

The momentum absorbing device comprises a mass 60 which is rotatably mounted on the shaft 61. A spur gear 62 is also rotatably mounted on a shaft 61 alongside the mass 60. The gear teeth 63 in the quick trip lever 50 always mesh with the teeth of the spur gear 62. Consequently any movement of the quick trip lever 50 will result in corresponding rotation of the spur gear 62.

A pawl 65 is rotatably mounted on a stud 66 on the mass 60. The end of the pawl 65 is biased inwardly toward the center 61 in any suitable manner as for instance by the coil spring 68. A ratchet 69 is provided on the spur gear 62 alongside the gear teeth of the spur gear 62. It will be clear that this ratchet is so arranged that any upward movement of the quick trip lever 50 of Figure 3 which thus results in a counterclockwise rotation of the spur gear 62 will, through the ratchet 69 and the pawl 65, result in a similar counterclockwise rotation of the mass 60.

Immediately upon the removal of the overcurrent condition which resulted in a rise of the armature 30 and the quick trip lever 50, the quick trip lever and armature may fall back under the influence of the springs hereinafter described, without any interference from the mass 60. This is so because, on the clockwise rotation of the light spur gear 62, there is then no driving connection between the spur gear 62 and the mass 60 owing to the pawl and ratchet arrangement above described.

By means of the pawl and ratchet arrangement, a quick re-set of the armature is thus provided in the event that the quick trip time delay has been sufficient to enable another circuit breaker to clear the fault. The mass 60 which has thus absorbed the momentum of the armature 30 during the rise of the armature will therefore, because of the pawl and ratchet arrangement, not be effective to prevent the quick re-set. The time delay is thus achieved by reason of the fact that the initial momentum of the armature is transmitted directly to the mass 60 which must in turn be brought into motion.

After the mass 60 begins to rotate, then if the armature is still subject to the initial attraction of the magnet 22 (that is, if the fault has not by that time been cleared) then the armature continues to move upwardly continuing to rotate the mass 60 and trips the circuit interrupter. The time delay which is thus obtained in bringing the mass 60 into movement is of the order of 1 to 12 cycles. In that period of time any

subsidiary circuit breaker which is able to clear the load should have cleared the load so that the magnetic force on the armature exerted by the magnet should have been relaxed.

If the overload is not cleared in that short period of time, then the magnet is still effective to attract the armature to complete the tripping operation.

This quick trip time delay device is, of course, intended to operate only when the circuit conditions are such that the original time delay device has been nullified. In other words, referring back once more to Figure 2, and taking for instance circuit breaker 2 in that chart, the original time delay which has not thus far been described, is effective from 900 amperes to just short of 1600 amperes to effect the necessary time delay to avoid false tripping on normal surges. The quick trip setting is effective at 1600 amperes—that is, at 1600 amperes the original time delay is nullified, the circuit breaker tripping device operates as if there were no original time delay, and the quick trip relatively minute time delay which has just been described comes into operation. Subsequently, at 20,000 amperes the instantaneous setting is reached where even the quick trip relatively minute time delay is nullified.

The ordinary time delay which prevents false tripping on normal surges will be described first. This ordinary time delay comprises the dashpot 75, in which the sucker disc 76 connected to the armature in a manner hereinfater described engages the disc 77 at the base of the dashpot. The overload device does not permit movement of the armature so that the setting of the armature is not affected by overloads until the sucker disc releases. Thus after overload conditions the current may drop to 100% and the armature will not continue its travel to trip. The short time device is restrained at the first part of the stroke and releases from restraint at the last part of the stroke. It will also reset if the current drops to 100%.

The operation of the dashpot 75 which affords a time delay by reason of the fact that discs 76 and 77 cannot be separated until the oil film between them is broken, is well understood and requires no further description. The upper disc 76 is connected by means of an extension 80 and a pin 81 to the vertical sleeve 82. Rod 83 is slidably mounted in the sleeve 82 and extends through an opening in the top cover plate 84 of the sleeve 82 and is connected in any suitable manner to the pin 85 on the armature 30. A compression spring 86 is mounted between an adjusting washer 87 on the rod 83 and the underside of the top plate 84. The washer 87 may be vertically adjusted along the rod 83 to vary the compression of the compression spring 86 and once it is moved to the proper position may be maintained in a set position with respect to rod 83, by means of the set screw 88 which projects through a vertical slot 89 in the side of the sleeve 82.

A similarly adjustable washer 91 held in position by the set screw 92 may be provided on the rod 83 above the top plate 84 of the sleeve 82 to limit the downward movement of the rod 83 so as not to impose any additional counterclockwise rotative strain on the armature 30 and the quick trip lever 50.

The compression spring 86 is adjusted so that on normal surges it is substantially uncompressible. Thus for instance, referring again to circuit breaker 2 of Figure 2 the time delay setting begins to be effective at 900 amperes. At this point the discs 76 and 77 begin to separate and time delay is afforded by the time taken to break the oil film between discs 76 and 77. The force exerted on the armature 30 by the magnet at 900 amperes is not sufficient however to compress the spring 86. The spring 86 is adjusted however so that any force exerted by the magnet on the armature will not be sufficient to compress the spring 86 until the current value reaches or exceeds 1600 amperes. Accordingly, up to 1600 amperes the time delay device operates as if there were a single, solid bar connecting the armature with the sucker discs. Accordingly up to 1600 amperes the time delay is achieved only by the time taken to separate the sucker discs in the dashpot.

The compression spring 86, however, is so adjusted that at 1600 amperes the magnet 22 exerts sufficient force on the armature 30 to compress the spring 86. When such force is exerted which is thus sufficient to compress the spring 86, then the armature 30 rises even though the discs 76 and 77 stay together. The rod 83 is pulled up so that the washer 87 presses the spring 86 against the top plate 84 and the armature on such overcurrent conditions (in the example taken—1600 amperes or over) may thus rise toward the magnet as if the time delay dashpot 75 were not secured thereto, as illustrated in Figure 5. However, the spring tends to restore the armature to its original position if the current drops to 100% before the tripping motion is completed.

Accordingly, it is now seen how both the ordinary time delay and the quick trip time delay may be incorporated in a single unit. In the example taken (circuit breaker 2 of Figure 2) the time delay dashpot 75 is effective at any value from 900 amperes to 1600 amperes to slow the tripping operation so that normal current surges of short duration will not result in a tripping of the circuit breaker. At 1600 amperes the time delay dashpot 75 is in effect removed by reason of the fact that the spring 86 becomes compressible at that point. At that point, therefore, the quick trip time delay comes into operation. The armature 30 now moving up quickly and pulling up the quick trip lever 50 with it rotates the spur gear 62 and consequently rotates the mass 60. This operation results in the very short time delay, above described, and for the purposes above described.

It is obvious of course that the quick trip time delay element which includes the lever 50 and the mass 60 has no appreciable effect on the movement of the armature between 900 amperes and 1600 amperes (in the example taken—circuit breaker 2 of Figure 2). Here the rising of the armature under the time delay afforded by the separating of the discs 76 and 77 is relatively very slow and the mass 60 has no appreciable effect in slowing up this initially slow operation.

The quick trip as above pointed out comes into effect when the time delay 75 is mechanically shunted out by the compression of spring 86 and when the armature moves very quickly. The quick trip time delay acts in effect as a momentum absorber and timer to absorb the initial shock of movement of the armature 30 and thus effect a time delay of from 1 to 12 cycles. The quick trip time delay acts throughout the time delay period to delay the motion. If the magnet 22 continues to be energized sufficiently to attract the armature 30, the armature will nevertheless proceed with this delayed action through its course to effect a tripping operation.

Under certain conditions, as above described in connection with the discussion of Figures 1 and 2, it may be necessary even to obviate the relatively minute time delay afforded by the quick trip device so that a truly instantaneous trip is obtained. Accordingly the quick trip lever 50 is not directly and rigidly secured to the armature 30, but rather is so secured thereto that for all purposes up to the instantaneous trip point it operates with the armature while above the instantaneous trip point the armature is freed therefrom. For this purpose the means of connection between the quick trip lever 50 and the armature 30 comprises a threaded rod 100 which is pivotally secured in any suitable manner at one end to the pin 35. The opposite end of the rod 100 passes through an appropriate opening 101 in the cross-piece 102 on the quick trip lever 50 (the cross piece 102 may be simply secured to the upper surface of the quick trip lever 50 and extend normally thereto in order to provide for the opening 101; or in order to obtain a better balanced structure, two quick trip levers 50 may be used on either side of the armature 30 and connected together by the cross-piece 102).

The rod 100 is provided at its lower end with an adjustable nut 106 which carries a spring centering sleeve 107. Adjacent the other end of the rod 100 another adjustable nut 104 is provided which also carries a spring centering sleeve 105. The nut 104 is greater in diameter than the opening 101 in the bridging plate 102, while the sleeve 105 is smaller in diameter so that the said sleeve may readily pass therethrough. A compression spring 110 is captured between the upper surface of the adjusting nut 106 and the undersurface of the bridging plate 102, and is adjusted to the proper compression by appropriate rotation of the nuts 104 and 106.

When the proper compression of the spring 110 is obtained, then the nuts 104 and 106 are locked in position by the lock nuts 111 and 112. Compression spring 110 is so adjusted that for all current values up to the predetermined instantaneous trip point it is substantially incompressible; and thus for all current values up to that point the armature 30 and the quick trip lever 50 are essentially a single unit. Spring 110 is, however, so adjusted that at the instantaneous point, and above, the magnet 22 exerts sufficient force on the armature 30 to compress the spring 110.

Accordingly, above this instantaneous value the spring 110 may be compressed by the rise of the armature 30 so that the armature may operate free of the quick trip lever 50. Thus again referring to circuit breaker 2 of Figure 2, it is again pointed out that the time delay effected by the dashpot 75 is effective between 900 amperes and 1600 amperes. At 1600 amperes the spring 86 becomes compressible so that the dashpot 75 is mechanically shunted out. At 1600 amperes, however, the quick trip time delay becomes effective so that on rapid movement of the armature 30 the quick trip lever 50 brings the mass 60 into movement so that a relatively short time delay of 1 to 12 cycles is effected.

At 20,000 amperes which is the instantaneous trip point of breaker 2, Figure 2, the quick trip time delay is itself mechanically shunted out by reason of the fact that the spring 110 becomes compressible at that point. Accordingly the armature 30 may rise and if the quick trip lever 50 is even momentarily held back when the current is above 20,000 amperes the armature 30 may nevertheless rise although the quick trip lever is thus detained; and the armature 30 is thus freed from the quick trip lever by reason of the fact that the spring 110 is compressible as above pointed out.

As above pointed out, the spring 86 is adjustable so that different pick up settings for normal surges may be obtained. Likewise the spring 110 is adjustable so that different instantaneous trip points may be obtained. The armature itself is calibrated by means of the spring 120 which is attached at its upper end to an extension of the end plate 84 of sleeve 82 and at its lower end to the adjusting lever 121. That is, it will be obvious that the spring 120 need not necessarily be connected directly to the armature since the end plate 84 is connected to the armature through the sleeve 82, the rod 83, and the compression spring 86, and since the compression spring 86 is substantially incompressible at current values below the quick trip point.

Accordingly, initial calibration of the armature 30 is achieved by means of the spring 120 so that for all current values up to the quick trip point the spring 120 may be relied on to maintain the predetermined calibration of the circuit breaker tripping device. The fact that the spring 120 is connected, however, to the end plate 84 of the sleeve 82 makes it possible also to mechanically shunt out the spring 120 when quick operation is desired. Thus, when the time delay afforded by the dashpot 75 is mechanically shunted out by the compression of spring 86, the calibrating spring 120 is at the same time mechanically shunted out and the operation of the armature thereafter depends upon the quick trip lever 50 and the mass 60 or in certain cases on the compressibility of the spring 110. Thus, for quick trip or instantaneous operation the possibly complicating factor of the calibrating spring 120 is removed from the necessary calculations. But as above pointed out, up to the point where the quick trip is intended to become effective by compression of spring 86, the spring 120 serves as a calibrating spring which is a factor in controlling the rise of the armature 30. Also, change in calibration of one spring does not affect the other calibration.

The adjusting lever 121 is an angular member as may be obvious from Figure 3, which at one end is mounted on the pin 123 carried by the lug 124 in the housing 21, and at the other end carries an extension 126 which bears against the undersurface of the adjusting nut 127. Adjusting nut 127 is in threaded engagement with the adjusting rod 128. The adjusting nut 127 has an indicator 129 which extends therefrom outwardly through the slot 130 in the housing 21. The adjusting rod 128 is provided at its lower end with a thumb screw 132 so that the adjusting rod 128 may be rotated. Rotation of rod 128 by means of the thumb screw 132 will result in a movement upward or downward of the adjusting nut 127. This is so because the adjusting nut cannot rotate by reason of the fact that its indicating extension 129 is engaged in the slot 130. The movement upward or downwardly of the adjusting nut 127 will result in a corresponding rise or fall of the end 126 of the adjusting lever 121 and in a consequent adjustment of the calibrating spring 120. A suitable scale may be placed on the outside of the housing adjacent the slot 130 and parallel to the path of travel of the indicating extension 129 to indicate the extent of adjustment.

As above pointed out, Figure 3 shows the relation of the parts in the de-energized position,

that is, when the circuit breaker is either open or when it is carrying only normal load, so that the calibrating spring 120 is sufficient by itself to prevent a rise of the armature 30.

Figure 4 shows the relationship of all the parts after an overload has persisted long enough to break the film between the discs in the dashpot 75 and they have separated, allowing the armature to go to the closed gap position to trip the circuit breaker. As above pointed out, calibration of the time is secured by turning the dashpot in the usual manner. Calibration of the overload value is secured by changing the tension of the spring 120 as the indicating arm 129 is moved over the scale. The position of Figure 4 therefore, referring back once more to circuit breaker 2 of Figure 2, shows the condition where an overload between 900 amperes and 1600 amperes has persisted for a sufficiently long time to result in separation of the dashpot discs 76 and 77.

Figure 5 shows the position of all of the parts when the current is of sufficient value to mechanically shunt out the time delay dashpot 75 by compression of the spring 96 and thus to bring the quick trip into play. In this case the quick trip lever 50 has moved up with the armature. A time delay of short duration as above pointed out has been obtained by reason of the engagement of the gear teeth in the quick trip lever 50 with the spur gear 62 which in turn drives the mass 60. The pawl and ratchet arrangement above pointed out between the spur gear and the mass 60 provides for quick re-set if the overload is removed before the tripping position is reached.

Changing the momentum of the mass 60 changes the time setting.

The position shown in Figure 5 when related back to circuit breaker 2 of Figure 2 shows the condition of the circuit breaker when an overload occurs at current values between 1600 amperes and 20,000 amperes.

Figure 6 shows the position of the parts when there is a severe short circuit and substantially instantaneous trip is desired. In this case both the dashpot 75 and the quick trip momentary time delay are mechanically shunted out by the compression of spring 110. Again as above pointed out, only a very heavy short circuit current can cause the magnet 22 to exert sufficient force on the armature 30 to compress the spring 110. The position shown in Figure 6 when related to circuit breaker 2 of Figure 2 corresponds to a short circuit condition of over 20,000 amperes.

In the foregoing Figures 3 to 6, I have shown one physical embodiment of a combination time delay-quick trip-instantaneous trip circuit breaker tripping device which will be effective to carry out all of the principles set forth in connection with Figures 1 and 2.

As has been above emphasized, in order to obtain proper sequential cascading operation, each of the circuit breakers in the system should be provided with a time delay device to obviate false tripping on normal current surges of short duration with a means for obtaining a quick trip above such normal surges (for instance, at 10 times normal load) with means nevertheless for obtaining a very short time delay with the quick trip to prevent unnecessary tripping of circuit breakers; and with additional means to mechanically shunt out even the quick trip momentary time delay to obtain a truly instantaneous trip on very heavy short circuit currents.

The construction of the unit shown in Figures 3 to 6 accomplishes all of these functions and thus this unit may be used in the circuit breakers which have been discussed in connection with Figures 1 and 2. Many other arrangements for obtaining these results should of course now be obvious in view of the foregoing descriptions. In the following I have illustrated and described several preferred constructions which differ in some respects from the methods and means illustrated in connection with Figures 3 to 6.

In Figures 7 to 10 inclusive, I have shown another design of circuit breaker tripping device which may be utilized to accomplish substantially the same purpose except that the final instantaneous trip is not shown. The construction shown in Figures 7 to 10 therefore would be used when the circuit breakers are not connected in cascade but where selectivity is required. The design and operation of the quick trip time delay of Figures 7 to 10 has already been described in connection with the description of the shock absorbing devices in my application Serial No. 488,841 filed May 28, 1943, of which this is a continuation application.

Figure 7 shows the arrangement of the parts of the tripping device in the unenergized condition or in a position where the circuit protected by the circuit breaker is carrying the normal load for which it is designed. The tripping device 220 is contained in a housing 221 to the upper portion of which is secured in any suitable manner the pole piece 222 of the series overload magnet. The armature 230 is rotatably mounted on the pin 231 and is provided at its opposite end with a plate of magnetizable material 232 which may be attracted by the magnet.

The armature 230 is provided with an abutment member 235 which engages against the undersurface 236 of the striking member 237. The end 238 of the striking member 237, when the striking member is rotated clockwise by the armature 230, bears against the latch trip 240 of the circuit breaker. The abutment 235 constitutes the end of a threaded bolt 242 which may be rotated in a suitably tapped opening of the armature 230. The adjusted position of the abutment 235 is maintained by the lock nut 243.

A quick trip lever or striking member 250 is also rotatably mounted on the pin 231. Quick trip lever 250 is provided with an extension 251 through which the pin 235 passes to integrate the quick trip lever 250 with the armature 230. In order to provide for better balance of the structure there may be two quick trip levers 250, one on either side of the armature 230, with a similar duplication of the shock absorbing or weight members hereinafter described. This is in accordance with my disclosure in the above-identified application.

An abutment 262 is rotatably mounted on the pin 261 and is secured by means of a plurality of bolts 265, 265 to the mass 260. The quick trip lever or striking member 250 has a striking surface 263 which, when the armature is raised thus resulting in a clockwise rotation of the quick trip lever 250, bears against the surface 266 on the abutment 262. As shown in Figure 9, when the armature is attracted by the magnet, the surface 263 on the quick trip lever 250 strikes against the surface 266 on the abutment 262. These surfaces are so arranged that should the attraction of the magnet continue after they have met, the surface 263 may slide with respect to the surface 266 to rotate the abutment 262 in

a clockwise direction to permit the armature 230 to move to the trip position of Figure 10.

However, when the armature is attracted with sufficient force to overcome the effect of the ordinary time delay members hereinafter described, the quick trip lever 250 which is secured to and rotates with the armature strikes the abutment 262 with substantial force, that is, surface 263 strikes sharply against surface 266. The energy of movement of the armature 230 is thus transmitted to the abutment 262 and thus to the substantial mass 260 which is secured to and rotatable with the abutment 262. Consequently this energy of movement or momentum of the armature 230 is absorbed by the mass 260 which is brought into motion. This constitutes the shock absorbing feature of the invention described in my above-identified application.

Should the attraction exerted by the magnet 222 be continuous, however, so that the armature is continuously attracted even after the quick trip lever 250 has struck the abutment 262, then the members will continue from a position shown in Figure 9 to the full trip position in Figure 10.

The initial absorption of momentum of the armature by reason of the fact that the quick trip lever strikes against the abutment and brings the mass 260 into movement as shown in Figure 9 however, serves as a momentary time delay of the order of 1 to 12 cycles. Thus, should another circuit breaker in the circuit clear the fault which has thus initiated the movement of the armature within that 1 to 12 cycle period of time, then the time delay afforded by reason of the fact that the weight 260 absorbs some of the momentum of the armature, will be sufficient to prevent a tripping of the circuit breaker.

In that latter case, after the armature has given up its energy to the weight 260 and before the magnet can be effective to cause the armature to continue its movement, the excess current which has increased the force of the magnet will have been diminished so that the armature will then fall back.

The functions and operations of the various elements and the conformations of the abutment 262 have been described in my above mentioned application and reference is made thereto for a more particular description of all of the functions of the elements of the abutment 262. It is sufficient here to point out that in addition to serving as a shock absorbing member as described in my above mentioned application, the abutment 262 and its associated weight 260 serves as a momentary adjustable time delay element to permit effective sequential operation of the circuit breakers in the manner and for the purposes herein described.

Assuming that the device herein described is installed in a circuit breaker having a 600 ampere rating and an overload calibration of 600 to 1200 amperes, and assuming also that the time delay setting by the dashpot (hereinafter described) permits operation of the armature on overload conditions of extended duration beginning at 900 amperes, and assuming that the quick trip setting is for 1600 amperes; then in the manner hereinafter described the time delay dashpot is mechanically shunted out at 1600 amperes and the quick trip unit above described then operates in the manner just set forth.

The time delay elements which in the above example are intended to be effective between 900 amperes and 1600 amperes, correspond substantially to the time delay unit previously described in connection with Figures 3 to 6. In this case, as shown in Figure 7, the dashpot 275 is secured to the underside of the housing 221 in any suitable manner, and is provided with a stationary sucker disc 277 and movable sucker disc 276.

The movable sucker disc 276 is connected to a rod 283 which in turn passes up into a sleeve 282. The upper end of the sleeve 282 is pivotally connected in any suitable manner to the pin 285. The rod 283 is provided at its lower side with an adjustable nut 291, the position of which may be varied on the rod 283. The nut 291 also has a spring centering sleeve 207 extending therefrom upwardly into an opening in the lower portion of the sleeve 282. An adjustable nut 287 is also mounted on the rod 283 in threaded engagement therewith for adjusting purposes, and a compression spring 286 is held between the undersurface of the nut 287 and the annular flange 208 at the lower end of the sleeve.

As above described, the compression spring 286 is so arranged and adjusted that it is substantially incompressible for any overload up to the quick trip setting. Thus, taking the example above set forth, up to an overload of 1600 amperes, when the armature 230 is attracted by the magnet 222, the armature through the pin 265 pulls on the sleeve 282 which in turn through the compression spring 286 (which is uncompressible up to 1600 amperes) pushes on the adjusting nut 287 which in turn pulls on the rod 283 and thus pulls on the sucker disc 276.

The edge of the adjusting nut 287 is accessible through a slot 284 in the side of the sleeve so that it may be rotated to vary the compression of the spring 286 to vary the quick trip setting. Thus, it will be seen that in the device here illustrated, the time delay effected by the dashpot 275 will be effective up to an overload condition of sufficient intensity to compress the spring 286. When such overcurrent condition is reached (1600 amperes in the present example) then the compression spring 286 is compressed as shown in Figure 9, and the quick trip is permitted to operate.

The quick trip device after going through the relatively momentary time delay period illustrated by the meeting of the abutment surfaces of Figure 9, follows through to a full trip as shown in Figure 10 by further compressing the spring 286. Since this device is intended to be used with circuit breakers which are not cascaded, no instantaneous trip feature is shown. In order to modify this device to incorporate such an instantaneous trip feature, it would be necessary to remove the extension 251 of the quick trip lever 250 and to substitute therefor a spring connection between the quick trip lever 250 and the armature 230 in the manner previously described in connection with Figures 3 to 6.

Since, however, in a system which is not cascaded, each circuit breaker is necessarily arranged to be able to rupture the full short circuit current, an instantaneous trip feature which was necessary in the previous example to protect subsidiary circuit breakers is not necessary in an uncascaded system.

In this system the circuit breaker nearest the fault will respond most quickly and have sufficient capacity to clear that fault, no matter what its intensity may be, and the time delay on the quick trip should be effective to prevent remote circuit breakers from following through to trip after the fault has been cleared by the circuit breaker nearest the fault.

In this type of system which is not cascaded, it is obvious that the masses 260 will be of different sizes so that the circuit breaker nearest the fault will respond most quickly and so that more remote circuit breakers which will be subjected to a slightly greater momentary time delay will not be tripped open, and only those portions of the system are isolated as are necessary to fully clear the fault.

The armature of Figures 7 to 10 is provided with a calibrating spring 210 connected at one end to the abutment unit 242 of the armature and at the other end to the adjusting nut 217. The adjusting nut 217 is in threaded engagement with the adjusting rod 218. Rotation of the adjusting rod 218 will result in movement upward or downward of the adjusting nut 217, and consequently in a variation in the tension of the calibrating spring 210.

The adjusting nut 217 has an extension 219 which projects through a slot 201 in the housing, and which thus prevents the nut 217 from rotating and causes it to follow a longitudinal path upon rotation of the adjusting rod 218. The extension 219 also serves as an indicator of the calibration or setting of the calibrating spring 210, and an appropriate scale may be mounted alongside the slot 201 so that the various settings may be conveniently read off.

Adjusting rod 218 is provided with an adjusting hand-wheel 202 which may be manually grasped to rotate the same. The wheel 202 projects through an appropriate opening in the housing so that it may be readily accessible for changing the calibration of the armature of the circuit breaker. The adjusting rod 218 is provided adjacent its upper end with a pin 203 which registers with the groove 204 in the supporting flange 205. The tension of the calibrating spring 210 pulls the rod 218 up so that the pin 203 bears in the groove 204 and thus prevents false rotation of the adjusting rod 218.

In order to vary the calibration of the spring 210, it is necessary not only to rotate the adjusting disc or wheel 202, but first to depress the same in order to disengage the pin 203 from the groove 204. Thereafter an 180° turn of the wheel 202 may be made until the pin snaps into the groove once more. Successive similar 180° turns may be made in either direction in order to obtain the variation and adjustment above described.

In order accurately to position the weight 260 and the abutment member 262 with respect to the quick trip lever 250 so that the momentary quick trip time delay may function in the manner previously described, a light tension spring 293 is provided, one end of which engages the weight 260 by means of the screw 294 and the other end of which engages a stationary lug 295 secured to the housing of the device. This tension spring ensures that the weight and the abutment will be in the appropriate position to afford the proper momentary time delay by cooperation with the end of the quick trip lever 250.

As above pointed out, the device here shown is designed for use primarily in connection with a system which is not cascaded but nevertheless makes possible proper sequential operations in such a system in accordance with the principles previously set forth.

In Figures 11 to 15, I have shown another device which follows the principles of the device shown in Figures 7 to 10 for the purpose of ensuring appropriate sequential operation of circuit breakers in a system which is not cascaded.

In this device, the essential elements of the previous device described in Figures 7 to 10 are repeated. The magnet 322 is arranged to attract the armature 330, the said armature being rotatably mounted on the pin 331. The operation of the armature 330 with respect to the striking member 337 and the latch member 340 is the same as has been described in connection with the corresponding parts of Figures 7 to 10.

Similarly the arrangement of the calibrating spring 310, the adjusting nut 317, and the adjusting rod 318 is the same as that previously described in connection with the exactly similar members of Figures 7 to 10. Likewise the arrangement of the dashpot 375, the sucker discs 376 and 377, the rod 383, the compression spring 386, and the sleeve 382 is also exactly the same as that previously described in connection with Figures 7 to 10. That is, all the features of adjustment, calibration and ordinary time delay of Figures 11 to 15 correspond exactly with the similar features of the constructions shown in Figures 7 to 10.

The difference, which is obvious, is in the quick trip time delay feature which in this case includes the oscillating weight 360. The armature 330 is provided at the end opposite the pin 331 with an extension 350 carrying a pin 363 which passes through a slot 362 in the weight 360. The weight 360 is rotatably suspended from the pin 361 and may swing back and forth thereon. The weight 360 is also provided with adjustable means to increase the mass thereof and also to vary the natural period of oscillation thereof with respect to the pin 361. This means comprises a threaded extension 364 from the lower end of the weight 360 with an additional weight 365 mounted on the extension 364 in threaded engagement therewith and movable by rotation thereof along the extension 364 for the purpose immediately above mentioned. Change of this mass as will now be understood will change the time delay.

Figure 11 shows the condition of all of the parts when de-energized or when the circuit breaker in which the tripping device is mounted carries only the normal current for which it is rated.

Figures 12, 13 and 14 show successive phases in the quick trip device where the compression spring 386 in the ordinary time delay device is compressed by reason of the excessive current result in increased pull by the magnet on the armature. In these successive phases in Figures 12, 13 and 14, it will be seen that the weight 360 and its associated adjustably positioned mass 365 is successively oscillated to a plurality of positions during the course of the movement of the armature from the position of Figure 11 to the full trip position of Figure 14.

In Figure 15 the operation of the device for tripping on overload after the dashpot discs in the dashpot 375 have separated is shown. In this case the relatively slow movement of the armature is not to any appreciable extent interfered with in any way by the quick trip time delay effected by the weight 360. Thus, where the circuit breaker is subjected to a slightly excessive load of substantial duration (this load not being sufficient to result in a compression of the spring 386) the movement of the armature from the position of Figure 11 to the position of Figure 15 will depend on the separation of the discs 376 and

377 and the time required for the breaking of the oil film between these discs will determine the time delay in the case of such relatively small overload.

In the case of an overload requiring a quick trip, the time delay given by the dashpot 375 is mechanically by-passed by the compression of the spring 386; the quick trip is thus permitted to occur, and a short time delay by reason of the necessary oscillation of the weight 360 is obtained:

As the armature rises from the position of Figure 11 to the position of Figure 12 (with the spring 386 being compressed) the pin 363 on the armature strikes against the surface 366 on the interior of the slot 362. This results in a momentary halt for a relatively minute period in the movement of the armature while the weight 360 is swung from the position shown in Figure 12 to the position shown in Figure 13.

As the armature 330 continues to rise through the position shown in Figure 13, the pin now strikes against the surface 366*a* in the slot 362. This again results in a momentary halt for a relatively minute period of the movement of the armature 330 while the weight is swung back from the position shown in Figure 13 to the position shown in Figure 14 so that the armature may continue to move upwardly in the slot 362 as shown in Figure 14 to effect a full trip. The time delay thus obtained in the operation of the quick trip is that which is necessary to permit this vibration or oscillation of the weight 360 to permit the pin 363 on the armature 330 to move upwardly in the slot 362. This time, as above pointed out, is of the order of 1 to 12 cycles.

The device herein shown is one which is arranged for utilization (like the structure of Figures 7 to 10) in a system which is not cascaded. In order to modify this device so that it may be used properly in a cascaded system, an instantaneous trip which would by-pass the quick trip time delay is required. This instantaneous trip may well consist of a securement of the extension 350 to the armature 330 by means of a very strong coil spring which may be adjusted so that it will constitute a substantially rigid connection between the extension 350 and the armature 330 until some instantaneous trip point above the quick trip point is reached.

The adjustably positioned mass 365 is arranged and used so that the effective mass of weight 360 may be increased and also so that it may be adjusted to a position where no possible movement of the armature will conform to the natural period of vibration of the weight 360.

In Figure 16 I have shown a slightly modified form of quick trip time delay for use in connection with circuit breakers which are to be used in systems which are not cascaded to obtain proper sequential operation. In the embodiment here shown in Figure 16, the quick trip function and time delay device is shown in operation with the ordinary time delay device mechanically shunted out of the way. The dashpot 475 and its associated elements including the sleeve 482, the rod 483, the compression spring 486, and the sucker discs 476 and 477 correspond exactly to the similar elements shown in Figures 7 to 10 and 11 to 15.

Similarly the calibrating spring 410, the adjusting rod 416 and the adjusting nut 417 and their various associated elements correspond exactly to the similar elements also shown in Figures 7 to 10 and 11 to 15. The armature 430 is

rotatably mounted on the pin 431 so that its end 432 is in proximity to the pole 422 of the magnet so that it may readily be attracted by the magnet to effect a tripping operation under appropriate overcurrent or short circuit conditions.

The armature likewise is similar to those previously described in that it is provided with an adjustable abutment head 435 arranged to operate the latch member 440 to trip the circuit breaker when the armature 430 moves to the closed gap position. The armature 430 is provided with a pin 463 which registers with the slot 462 in the weight 460. The weight 460 is an evenly balanced weight which is also rotatably mounted on the pin 431. When an overcurrent condition is reached of such intensity as to result in the compression of the spring 486 (and thus to result in a mechanical shunting aside of the ordinary time delay) then the device is enabled to trip quickly. A quick trip time delay, however, is afforded by the fact that the pin 463 of the armature 430 moves against the abutting surface 466 in the cutout 462 of the weight 460.

The initial energy of movement of the armature 430 is thus transmitted through the pin 463 to the surface 466 of the weight 460; and the weight 460 is thus caused to rotate thereby momentarily at least slowing the operation of the armature. Should the fault condition be cleared by other circuit breakers in the system during this relatively very short period when the initial energy of movement of the armature is thus absorbed, then the armature will fall back. Should, however, the fault not be cleared during the momentary time delay afforded by the absorption of the momentum of the armature (of the order of 1 to 12 cycles) then the armature will be enabled to follow through under the continued attraction of the magnet 422 and actually drag the weight 460 with it to effect the full trip of the circuit interrupter.

The elements of the device shown in Figure 16 correspond in most essential respects with the device shown in Figures 7 to 10 and 11 to 15. This device also, as above pointed out, is of particular usefulness in connection with systems which are not to be cascaded. Appropriate means may be provided in the connection between the armature 430 and the weight 460, should that be necessary, to provide for an instantaneous trip. The instantaneous trip and the function and operation thereof have already been described in connection with Figures 3 to 6 and in view of the disclosure contained in connection with the aforesaid figures, the manner of incorporating such an instantaneous trip in the structure of Figure 16 should now be obvious.

In order to maintain the weight 460 in appropriate position for engagement between the pin 463 and the surface 466 to effect the time delay, a tension spring 493 is connected between a lug 496 on the weight 460 and a stationary member 495 on the housing wall. The design is such that the energy absorbed by the weight 460 will be absorbed by a stop and does not tend to trip the breaker. The armature itself is made light in weight.

In Figure 17 I have shown a modification of the construction of Figures 7 to 10 wherein substantially the same system is utilized for the same function. That is, the device is intended primarily for use in connection with the attainment of appropriate sequential tripping operations in a system which is not cascaded. In Figure 17 the device is shown with the quick trip in

operation and the ordinary time delay unit mechanically shunted aside. The quick trip has proceeded to a full tripping operation, thus showing that the fault condition which initiated the operation was not cleared during the momentary time delay obtained by the momentary absorption of the energy of the moving armature.

The dashpot 575, its sucker discs 576 and 577, the rod 583, the sleeve 582 and the compression spring 586 all correspond exactly in function and in operation to the similar members of Figure 7. Likewise the calibration spring 516, the adjusting nut 517, the adjusting rod 518 also correspond in function and in operation with the exactly similar elements of Figure 7. Also the armature 530, the striking member 537, the abutment 535 and the latch trip 540 correspond exactly and in function and in operation with the exactly similar members of Figures 7 to 10. Also the quick trip lever 550 is secured to the armature and operates therewith in exactly the same manner as previously described in connection with Figures 7 to 10. Also the abutment 562 which is secured to the weight 560 by means of the bolts 565 operate for the same purpose and in the same manner as described in connection with Figures 7 to 10 and members 560 and 562 rotatably mounted on the pin 561. The only difference is in the shape of the members of the elements of the quick trip lever 550 and the abutment 562 which cooperate with each other. These members are so shaped and arranged as to provide a species of escapement mechanism with an increased time delay period on the quick trip. That is, the extension 563 on the quick trip lever 550 first moves into engagement with the surface 566 on the abutment 562. This moves the abutment 562 counterclockwise and correspondingly rotates the mass 560 in the same direction. The extension 563*a* on the opposite end of the quick trip lever 550 then moves into engagement with the notch 567 on the opposite side of the abutment now resulting in a clockwise movement of the abutment 562 and the weight 560.

The extension 563 of the quick trip lever 550 on continued movement of the armature 530 now is brought into the notch 566*a* of the abutment 562 resulting once more in a counterclockwise rotation of the abutment 562 and weight 560; whereupon the extension 563*a* of the lever 550 moves in engagement with the notch 567*a* of the abutment 562 again resulting in clockwise rotation of the abutment 562 and weight 560. Thereupon the abutment 563 now moves into engagement with the notch 566*b* in the abutment resulting once more in counterclockwise rotation of the abutment and weight, whereupon the extension 563*a* of the lever 550 moves into contact with the surface 567*b* of the abutment resulting in clockwise rotation of the abutment and weight while the extension 563 of the lever 550 moves clear of the abutment.

By this means it will be seen that during the rise of the armature 530 an extended time delay on the quick trip is achieved by the escapement type operation of the abutment and weight wherein the abutment and weight must reverse their direction of movement several times during the movement of the armature and the initial energy of movement of the armature is successively absorbed so that rather than a time delay of the order of 1 to 12 cycles, an increased time delay which depends on the number of reversals

of movement of the abutment and weight is obtained.

This time delay, depending on the number of reversals of movement (and thus depending on the number of notches on each side) may extend for as much as 20 cycles and even more. As above pointed out, the unit shown in Figure 17 is not equipped with an instantaneous trip device and is therefore to be used preferably in a system which is not cascaded, that is, in a system where every circuit breaker in the system has capacity to clear any fault which may occur. However, this type of quick trip time delay may be of particular value when combined with other forms of time delay. Thus for instance in a system which is not cascaded, the main circuit breaker which controls many of the feeders may be provided with a quick trip time delay of the type shown in Figure 17. Moreover it will be obvious that it may be provided with an instantaneous quick trip device where desired.

The subsidiary feeder breakers may be provided with a quick trip time delay of the type shown in Figure 7; and the circuit breakers nearest the load may be provided with no quick trip time delay at all, so that these latter breakers will (after the initial dashpot time delay is mechanically shunted aside) be instantaneous under excessive overcurrent conditions. It will thus be seen that by this means absolute provision is made for proper sequential operation in a system which is not cascaded.

Should a fault occur in one of the load circuits, the circuit breaker nearest the load which has no quick trip time delay will trip instantaneously (provided the overcurrent is of sufficient intensity), the subsidiary feeder breaker will be subjected to the relatively short time delay (1 to 12 cycles) on the quick trip by means of the mechanism shown in Figure 7, while the main breaker will be subjected to the relatively longer time delay created by the mechanism shown in Figure 17. Consequently the breaker nearest the load will trip open and clear the fault before the other breakers operate.

Similarly should a fault of excessive proportions occur in a line protected by a feeder breaker (assuming still a system which is not cascaded) the feeder breaker having the quick trip time delay of Figure 7 will trip before the main breaker which has the relatively slower quick trip time delay of Figure 17.

Proper sequential operation in a system which is not cascaded can also be achieved merely by making more of the mass effective or by varying the number of teeth or notches in the escapement-like mechanism of the abutment of Figure 17, to provide for appropriate variations in the quick trip time delay or both. The structure shown in Figure 17 may be used on all circuit breakers (except the circuit breaker nearest the load) in such a system which is not cascaded with appropriate sequential operation being assured by variation in the number of notches in the abutment.

In Figure 18 I have shown a slightly modified form of inertia mass time delay which follows substantially the principles of Figures 7 to 10 and which includes the escapement principle of Figure 17.

The armature 630 is pivoted on the pin 631 and carries the abutment 635 which engages the striking member 637 to operate the latch trip 640. The armature 630 may be provided with a hold-

down spring similar to those shown in the previous figures.

The adjustable abutment 635 is directly mounted on the armature 630 so that when the armature 630 rises, the abutment 635 rotates the striking member 637 to effect a tripping operation. Torsion spring 633 restores the striking member 637 to its normal position when the armature has been released by magnet 622.

The adjustable abutment 635 is thus mounted because an additional armature 730 is also provided pivotal on the pin 631, which armature 730 must also be effective independently as hereinafter described, to trip the circuit breaker.

The armature 630 has secured thereto in any suitable manner and rotatable therewith the quick trip lever 650. Quick trip lever 650 is provided with a flange 602 through which a bolt 605 passes and which is secured to the flange 602 by the nuts 606 and 611. The opposite end of the bolt is pivotally secured to the pin 685 on the armature 630. The armature 630 and the quick trip lever 650 are thus integrated.

A weight 660 is rotatably mounted on the pin 661 and has secured thereto in any suitable manner, as for instance, by the rivets 665, 665, the abutment 662.

The notches 663 on the quick trip lever 650 engage alternately with the hooked extensions 666 on the abutment 662 as the quick trip lever 650 is rotated.

Thus, a species of escapement mechanism corresponding exactly to that shown in Figure 17 but reversed as to the parts, is achieved.

As the armature 630 is attracted by an excessive force exerted by the magnet 622, the successive engagement of the notches 663 and the hooks 666 causes a series of successive reversals of movements of the abutment 662 and the weight 660.

Consequently, when the armature 630 is attracted under an excessive overcurrent or short circuit condition, the said armature and the quick trip lever 650 are delayed in their movement toward the magnet by the necessity for bringing the mass 660 into movement, stopping it, reversing it, stopping it again, and so forth. The extent of the time delay is determined, of course, by the size of the mass 660 and by the number of notches 663.

Accordingly, if, while the armature 630 is moving toward the magnet 622, and another circuit breaker in the system clears the fault before the escapement-type mechanism 650—662 has permitted the armature to escape, the inertia mass of the weight 660 then, on the reduction of the attraction of the magnet 622, will stop armature 630 so that its spring may restore it before the tripping position is reached.

In the device of Figure 18, the armature 630 is under the influence only of the mass 660 and its hold-down spring and is designed to act on only excessive conditions with a relatively very small time delay.

The dashpot 675 is connected to the armature 630 in substantially the manner previously described in connection with other figures—that is, a threaded rod 683 is pivotally secured to the pin 685 on the armature 630 and passes downwardly into the sleeve 682.

Sleeve 682 is secured by means of the cross-pin 681 to the upwardly extending lug 680 of the upper sucker disc 676 of the dashpot 675.

Sucker disc 676 is in engagement with the lower sucker disc 677.

A nut 691, threaded on the portion of the threaded rod 683 which emerges from the top of the sleeve 682, restricts the movement of the rod 683 downwardly into the sleeve 682. The nut 691 bears against the upper plate 684 through the center of which the rod 683 passes.

A nut 687 on the rod 683 is adjustable upwardly or downwardly through the slot 689 in the side of the sleeve 682.

A compression spring 686 is captured between the nut 687 and the top plate 684.

At currents below a predetermined amount (two to ten times normal), the spring 686 is substantially incompressible, and the armature 630 is subjected to the time delay influence of the dashpot.

At predetermined value (for instance, more than ten times normal), the spring 686 becomes compressible so that the armature 630 may rise regardless of the fact that discs 676, 677 stay together and the quick trip time delay, resulting from engagement of members 650 and 662, comes into play. This, therefore, corresponds substantially in all respects to the devices previously described.

In addition, an additional armature 730 is pivotally mounted on the pin 631 and is held down by the fixed spring 710. The additional armature 730 is so formed that it will be attracted by the magnet only under excessive short circuit conditions and thus is a U-shaped member, the major portion of which lies only within the outer boundaries of the magnetic field of the magnet 622.

The armature 730 is in addition held down by the powerful spring 710 which is connected to the pin 661. The spring 710 is arranged so that the armature 730 will be attracted only under excessive short circuit conditions approaching the interrupting capacity of the circuit breaker. When the armature 730 has been attracted by the magnet 622, due to an excessive short circuit condition, it cooperates with the striking pin 636 in the striking member 637 to rotate the striking member in a clockwise direction so as to effect a tripping operation.

Consequently the dual overload condition is provided so that should it be necessary to bypass even the quick time delay of members 650 and 662, an additional armature 730 performs the function of ensuring an instantaneous trip.

Thus in the construction of Figure 18 the dashpot time delay ensures appropriate inverse time delay elements for current surges of from two to ten times normal. The quick trip time delay ensures a momentary time delay at current values between, say ten times normal and those somewhat below the interrupting capacity of the circuit breaker. The instantaneous trip is provided by armature 730 at values just below the interrupting capacity of the circuit breaker. The instantaneous armature 730 may, of course, be so arranged that it will operate at values just below the interrupting capacity of the next smaller circuit breaker below it in a cascaded system.

In Figures 19 and 20 I have shown a circuit breaker 800 with the novel selective time delay elements of my invention incorporated therein.

In this case, I have shown the elements of Figures 7 to 10 in the housing 220 mounted at the lower end of panel 901 on which the circuit breaker is mounted.

In Figure 20, the circuit breaker is shown in the closed position with the elements of the time de-

lay device in a position which correspond to that of Figure 7.

In Figure 19, I have shown the circuit breaker in the tripped position with the elements of the time delay device in the housing 220 in the positions which correspond to that of Figure 8.

The circuit breaker is here shown only as a representative commercial circuit breaker which may be controlled by my time delay device. This circuit breaker is the KB type circuit breaker of the assignee of the present invention and is more fully described in applications Serial No. 339,687, filed June 10, 1940, now Patent No. 2,348,228, issued May 9, 1944 and Serial No. 339,682, filed June 10, 1940, now Patent No. 2,390,735, issued December 11, 1945.

Current enters through the upper back connection stud 304, then passes to the main stationary contact 305, then to the main movable contact 306 mounted on the operating arm 307 which, in turn, is mounted on the rotatable bar 308.

Bar 308 is operated by the crank 309 which, in turn, is operated by the link 310 from the operating mechanism 311.

The circuit breaker may be tripped by rotating the latch trip lever 240 by means of the striking member 237 of the tripping device.

Current passes from the main movable contact through the pigtail 315 to the lower back connection stud 316.

The magnet 222, mounted on and energized by the lower terminal, acts on the armature 230 in a manner previously described.

The circuit breaker herein shown also comprises other elements including the blow-out coil 320 through which current passes from the upper back connection stud 304 to the arcing horn 322 then to the stationary arcing contact 323; thence current passes through the movable arcing contact 325 mounted on the movable contact carrying arm 307, then through the pigtail 326 to the lower terminal 316. A suitable arcing horn 330 for the movable arcing contact 325 and a suitable arc chute 331 are also provided.

It may thus be seen that the inverse selective time delay elements of my device may readily be mounted in existing commercial circuit breakers with a minimum, if any, adaptation of the circuit breaker itself.

With the other methods shown in all of the other figures, proper sequential operation in a system which is not cascaded can be obtained simply by varying the momentum absorbing weights so that different weights in different circuit breakers of the system will absorb more or less of the initial energy of movement of the armature to create variations in time delay.

Thus in that case, any one of the systems herein described may be used throughout in a system which is not cascaded with the heaviest weight on the main circuit breaker quick trip time delay, the lightest weight on the quick trip time delay of the circuit breaker nearest the load circuit breaker, and with no quick trip time delay on the load circuit breaker. Of course, the foregoing systems, especially that described in connection with Figures 3 to 6, may also be used in connection with cascaded circuit breakers in which case each circuit breaker not only protects the particular circuit in which it is connected, but also the next subsidiary circuit breaker or set of circuit breakers in the manner above described.

In the foregoing I have described my invention

and the method achieved thereby in connection only with specific preferred embodiments and in connection with specific operative examples of the system and the method. Many variations and modifications of the physical embodiments of my invention and of the systems and methods which are the essence thereof should now be obvious to those skilled in the art. Accordingly, I prefer to be bound not by the specific disclosures herein, but only by the appended claims.

I claim:

1. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a time delay mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second time delay mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, the long time delay and the short time delay of each of said circuit breakers being different from that of other circuit breakers in said system for effecting sequential trip in the long and short time delay periods.

2. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker operable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to operate said tripping mechanism, and a second mechanism individual to each of said circuit breakers and interposed between the armature mechanism of its associated electromagnet and said tripping mechanism for effecting a short time delay of the order of cycles in the operation of said armature mechanism to operate said tripping mechanism when said electromagnet is energized by short circuit currents.

3. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker en-

gageable by the armature of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long titme delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and an inertia mechanism having a time delay characteristic individual to each of said circuit breakers and interposed between the armature of its associated electromagnet and tripping mechanism for effecting a short time delay of the order of cycles in the operation of its armature mechanism to engage and operate said tripping mechanism.

4. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having interrupting capacities different from other breakers in said system and each of said circuit breakers having individual cooperable contacts and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, the long time delay and the short time delay of each of said circuit breakers being different from that of other circuit breakers in said system for effecting sequential trip in the long and short time delay periods.

5. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the fault currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long inverse time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short inverse time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, the long inverse time delay and the short inverse time delay of each of said circuit breakers being

different from that of other circuit breakers in said system for effecting sequential trip in the long and short inverse time delay periods.

6. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a time delay mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second time delay mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism.

7. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second mechanism individual to each of said circuit breakers and mechanically in parallel with said long time delay mechanism for effecting a short time delay of the order of cycles in the operation of said armature mechanism to engage and operate said tripping mechanism when said electromagnet is energized by short circuit currents.

8. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a time delay mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second mechanical escapement time delay mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short

time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, the long time delay and the short time delay of each of said circuit breakers being different from that of other circuit breakers in said system for effecting sequential trip in the long and short time delay periods.

9. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a time delay mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second time delay mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, the long time delay and the short time delay of each of said circuit breakers being different from that of other circuit breakers in said system for effecting sequential trip in the long and short time delay periods, said second time delay mechanism being constructed to permit instantaneous operation of said armature mechanism for effecting instantaneous operation of said trip mechanism in response to short circuit currents of predetermined value.

10. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having interrupting capacities different from other breakers in said system and each of said circuit breakers having individual cooperable contacts and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, the long time delay and the short time delay of each of said circuit breakers being different from that of other circuit breakers in said system for effecting sequential trip in the long and short time delay periods, each of said individual short time delay mechanisms being constructed to delay the operation of its associated armature mechanism to engage its associated tripping mechanism for a sufficient time to permit tripping operation of the next smaller circuit breaker up to the maximum interrupting capacity of said smaller circuit breaker.

11. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having interrupting capacities different from other breakers in said system and each of said circuit breakers having individual cooperable contacts and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker engageable by the armature of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its electromagnet is energized by overload currents for effecting a long time delay of the order of seconds in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, and a second mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, the long time delay and the short time delay of each of said circuit breakers being different from that of other circuit breakers in said system for effecting sequential trip in the long and short time delay periods, each of said individual short circuit time delay mechanism having current-time characteristics such that it permits its armature mechanism to operate its associated trip mechanism over the entire current range and up to the maximum interrupting capacity of its circuit breaker in shorter time than any of the remaining larger capacity circuit breakers in said system.

12. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having interrupting capacities different from other breakers in said system and each of said circuit breakers having individual cooperable contacts and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker operable by the armature of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to operate said tripping mechanism, the short time delay of each of said circuit breakers being different from that of other circuit breakers in said system for effecting sequential trip in the short time delay period, and means individual to each of said circuit breakers for operating its associated armature in response to predetermined fault currents to effect instantaneous tripping of its associated contacts at or below the interrupting capacity of the next smaller circuit breaker.

13. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual operable contacts and a current responsive mechanism energizable in accordance with current flowing in its associated circuit breaker, a tripping mechanism individual to each circuit breaker directly operable by said current responsive mechanism for effecting a tripping of the contacts of the associated circuit breaker, said current responsive mechanism having a time delay characteristic of the order of cycles in the operation of its associated tripping mechanism when energized by currents from a range of ten times up to the short circuit interrupting capacity of said circuit breaker, and time delay mechanism associated with each circuit breaker having a time delay characteristic in the operation of the tripping mechanism of the order of seconds in response to currents of overload ranges flowing in its associated breaker, the time delays of each of said breakers being different from that of other breakers in said system up to the full short circuit available at each of said circuit breakers, said current responsive mechanism of each said circuit breaker being restorable to their non-operated position following the opening of the circuit by another of the circuit breakers in the system while its associated circuit breaker carries up to full load current.

14. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts, and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker and directly engageable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a time delay mechanism individual to each of said circuit breakers and comprising an inertia member acting on said armature for delaying the operation of the tripping mechanism and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to engage and operate said tripping mechanism, the short time delay of each of said circuit breakers being determined substantially entirely by said inertia member and being different from that of other circuit breakers up to the full short circuit available at the circuit breakers in said system for effecting sequential trip in the short time delay periods, the construction of the time delay mechanism being such that the armature of each of said circuit breakers is restorable to its non-operative position while the circuit breaker carries full load following the interruption of the circuit by another of the circuit breakers in the system.

15. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having interrupting capacities different from other breakers in said system and each of said circuit breakers having individual cooperable contacts and an individual electromagnet energizable in accordance with the currents flowing in its associated circuit breaker, each

electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker operable by the armature of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a mechanism individual to each of said circuit breakers and operable when its associated electromagnet is energized by short circuit currents for effecting a short time delay of the order of cycles in the operation of the armature mechanism of its associated electromagnet to operate said tripping mechanism, the short time delay of each of said circuit breakers being different from that of other circuit breakers in said system for effecting sequential trip in the short time delay period, and means individual to each of said circuit breakers for operating its associated armature in response to predetermined fault currents to effect instantaneous tripping of its associated contacts at or below the interrupting capacity of the next smaller circuit breaker.

16. In an electrical system having a plurality of circuit breakers connected in series, each of said circuit breakers having individual cooperable contacts and an individual electromagnet energizable in accordance with current flowing in its associated circuit breaker, each electromagnet having an armature mechanism, a tripping mechanism individual to each circuit breaker and directly engageable by the armature mechanism of its associated electromagnet for effecting a tripping of the contacts of the associated circuit breaker, a time delay mechanism for delaying the operation of the tripping mechanism when said electromagnet is energized by currents over a range of the order of 10 times normal up to the short circuit interrupting capacity of said circuit breaker, the time delay of the operation of the tripping mechanism in response to the energization of said electromagnet by said short circuit currents being of the order of cycles, the short time delay of each of said breakers being different from that of other breakers in said system up to the full short circuit available at each of said circuit breakers and being substantially the same for currents in excess thereof, the armatures of each of said circuit breakers being restorable to their non-operated position following the interruption of the circuit by another of the circuit breakers in the system while its associated circuit breaker carries up to full load current.

HERBERT C. GRAVES, JR.

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