

E. E. F. CREIGHTON.
PROTECTIVE DEVICE.

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1,266,558.

Patented May 21, 1918.

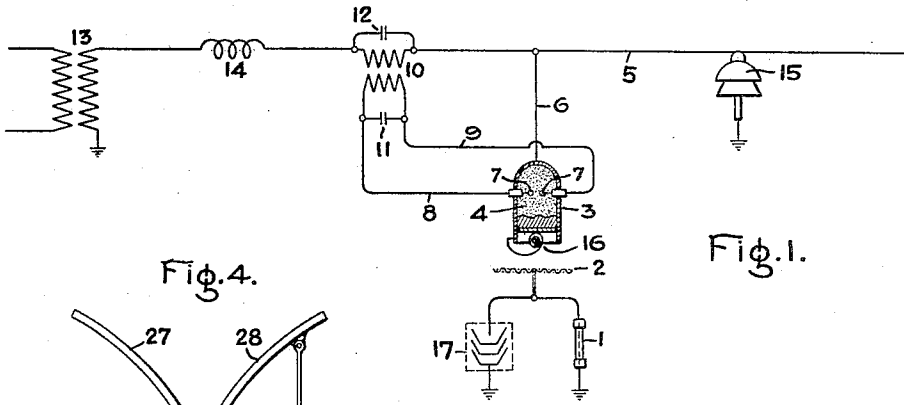


Fig. 1.

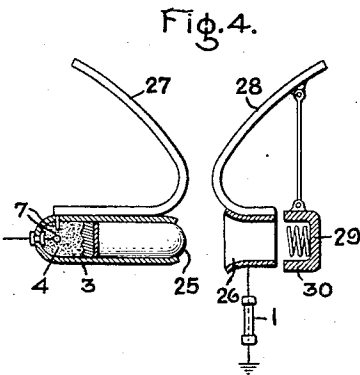


Fig. 4.

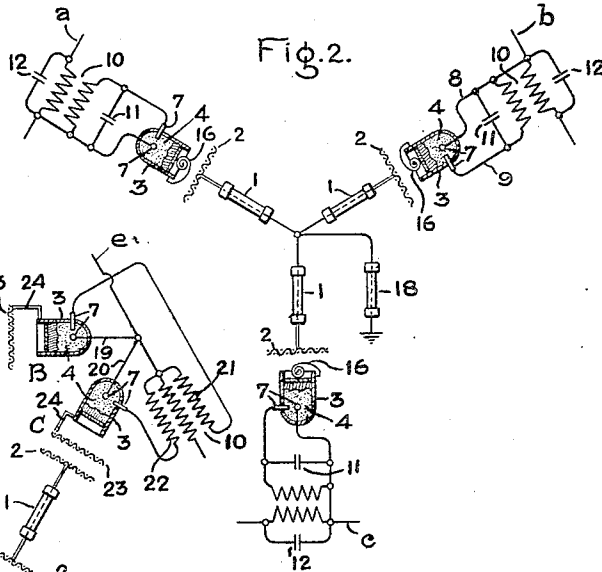


Fig. 2.

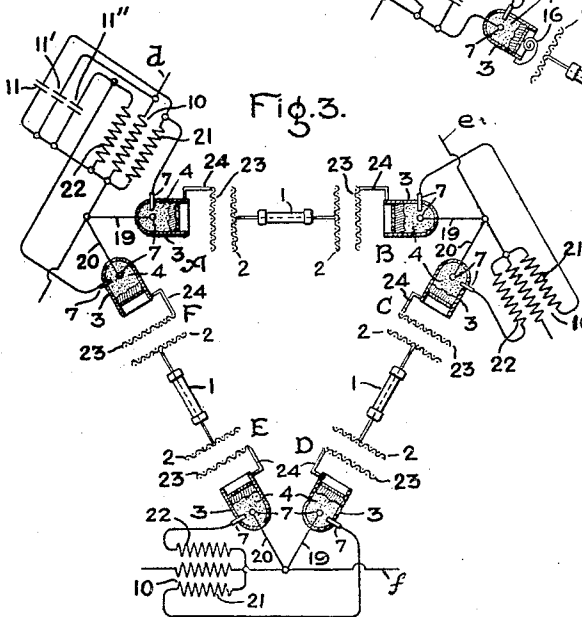


Fig. 3.

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UNITED STATES PATENT OFFICE.

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PROTECTIVE DEVICE.

1,266,558.

Specification of Letters Patent.

Patented May 21, 1918.

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To all whom it may concern:

Be it known that I, ELMER E. F. CREIGHTON, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Protective Devices, of which the following is a specification.

My invention relates to protective devices for power transmission systems and more particularly to protective devices for maintaining continuity of service on transmission lines under short circuit conditions.

The object of my invention is to generally improve protective devices for transmission systems and more specifically to provide a novel and improved protective device which will maintain continuous service on a transmission line upon the occurrence of faults such as short circuits.

The novel features which I believe to be characteristic of my invention will be definitely indicated in the claims appended hereto. The features of construction and mode of operation will be understood by reference to the following description taken in connection with the accompanying drawings which show the preferred embodiments of my invention and in which:—

Figure 1 shows diagrammatically a protective device embodying my invention and applied to a single conductor. Fig. 2 shows diagrammatically my protective device applied to a Y-connected system. Fig. 3 shows it applied to a delta connected system, and Fig. 4 is a view partly in section of a slightly modified form of device embodying my invention.

My novel protective device is applicable for maintaining continuity of service on systems of distribution upon all conditions of short circuit, not only short circuits between one conductor of the system and another conductor but also short circuits between one or more conductors and ground.

In the particular form of device shown in Fig. 1 a ground connection or path is made, preferably through a fuse 1 to a good conducting surface, such as a metallic screen 2. Mounted in alinement with the screen 2 and

separated therefrom by a suitable air gap is a chamber or cartridge 3 containing an explosive material 4 and connected to the conductor 5 to be protected by a connection 6. In carrying out my invention I may use the explosive material 4 to operate mechanical means to bridge the gap to the screen 2 in the path to ground from the conductor, as will be explained more in detail herewith, or I may use a special character of explosive material forming highly conductive gases which complete the path to ground. This material 4 may be any suitable explosive material such as smokeless and black powders or fulminate of mercury. If I desire to utilize the conductivity of the gases formed from the ignition of the material 4, I prefer to add a small quantity of a material, preferably magnesium powder forming, when ignited, a highly conductive gas. For igniting the explosive material 4, a spark gap is provided within the cartridge 3 between electrodes 7 which are embedded in the explosive material. These electrodes 7 form terminals of wires 8 and 9 comprising the secondary circuit of a current transformer 10 which controls the discharge of the spark gap, the wires 8 and 9 being suitably insulated from the cartridge 3. The transformer 10 is connected to the conductor 5 with the primary and secondary of the transformer being shunted by a capacity or a device having a condenser action such as condensers 11 and 12 respectively, the function of which will be explained later. Between the transformer 10 and the source of power, such as transformer 13, is placed a power limiting reactance 14, the object of which will be described later.

The operation of my protective device, as shown in Fig. 1, may be described as follows: Under normal operations upon the conductor 9, the potential induced in the secondary circuit of transformer 10 is insufficient to cause a discharge across the gap. When, however, a short circuit occurs between phases or between one phase and ground, such as an arc around the insulator 15, a sudden change of magnetic flux in the primary of current transformer 10 is

produced which induces a very high electromotive force in its secondary circuit. This greatly increased electromotive force existing between the electrodes 7 causes a discharge of the spark gap with a consequent ignition of the explosive material 4, in cartridge 3. If a material such as magnesium powder is incorporated with the explosive material the explosion shoots a flame of hot and highly conducting gases from the cartridge 3 against the screen 2. The contact of these hot conducting gases upon the screen 2 closes a normally open or normally inoperative power shunting circuit, between the conductor 5 and earth, a conducting path which is of low resistance. This conducting path or normally open power shunting circuit is from conductor 5 through connecting wire 6, cartridge 3 and the conducting gases to the screen 2 and through fuse 1 to ground. The explosion in cartridge 3 thereby closes a shunt circuit for the power on conductor 5 and forms a low resistance path to ground which is in shunt to the path to ground formed by the accidental arc at the insulator 15. The formation of this low resistance shunt path to ground in shunt to the power on the conductor immediately extinguishes the accidental arc and removes the short circuit as due to the shunt of the power the potential at the accidental arc is lowered to a value insufficient to maintain the arc. When the accidental arc is extinguished, the current rush to ground over the power or current shunting path causes the expulsion of fuse 1 to blow thereby interrupting this shunt path and causing the conductor 5 to return to its normal condition. In order to insure a good conducting path to ground through the fuse 1, when an explosive forming highly conductive gases is not used, I utilize the percussion of the explosion to mechanically complete the current or power shunting circuit. One way in which this may be accomplished is to use a metallic ribbon in the form of a spring 16 which is secured to the cartridge 3 and extends into the path of the explosion from the cartridge. Due to the percussion of the explosion, the metallic spring 16 is unwound and projected into contact with screen 2 to complete the shunt path.

An essential characteristic of my protective device is its great rapidity of action, the whole operation above described of shunting out the short circuit and returning the line to normal condition occurring within $\frac{1}{4}$ to $1\frac{1}{2}$ cycles of the generator frequency. This is much quicker than can be produced by any purely mechanically operated switch. As every hundredth of a second after the accidental short circuit takes place adds greatly to the volume of the arc, it is of

great importance to extinguish the arc in the early period of its development before it becomes an arc of persistent character. It might be noted that the quicker the short circuit arc is extinguished, the easier it is to extinguish and therefore the shorter the time required to extinguish it. A purely mechanically operated switch cannot operate quickly enough to shunt the short circuit arc and return the line to normal condition without synchronous apparatus on the line requiring an extraordinarily heavy current to pull it back in step or without causing it to actually drop out of step thus necessitating shutting down the line and re-synchronizing. With my novel device, the operation of clearing the line of trouble and returning it to normal operating condition takes such an exceedingly short time, that synchronous apparatus in the line remains practically unaffected and the short circuit arc is extinguished in the early period of its development.

It has been found that high frequency surges upon the line due to lightning or switching, will cause sufficient potential difference between electrodes 7 in the transformer secondary circuit to cause a spark discharge and hence a false operation of the device unless proper precautions are taken. To meet these conditions, and render the transformer selective to produce a spark potential only upon conditions of short circuit, I provide a capacity such as condenser 11 in shunt to the secondary winding of transformer 10 or condensers 11 and 12 in shunt to both the secondary and primary windings respectively of the transformer. When one condenser 11 is used in shunt to the secondary winding of the transformer, I use a condenser the capacity of which is so proportioned in relation to the inductance or number of turns of the primary winding that currents of high frequency above a certain predetermined frequency are by-passed or absorbed through the condenser 11 without producing a spark potential across the spark gap between electrodes 7. I prefer to use, however, two condensers 11 and 12 in shunt to the secondary and primary windings respectively of transformer 10.

The capacity of condenser 12 is so proportioned to the number of turns or the inductance of the primary winding that a major portion of currents above a predetermined frequency will pass through the shunt circuit including condenser 12 while the major portion of currents below the predetermined frequency will pass through the primary winding. A path of relatively low impedance is therefore formed through the condenser 12 only for currents of a frequency in excess of the predetermined frequency. The capacity of condenser 11 is so

proportioned in relation to the relative impedance of the paths through the primary winding and through the condenser 12 that currents of a frequency above the predetermined amount which are induced in the secondary winding are by-passed or absorbed by the condenser 11 without producing a spark potential across the spark gap. A high frequency surge will not be entirely by-passed through the condenser 12 but some of the high frequency current will leak through the primary winding which may be called the residual current due to the surge. This residual current will be transformed and produce a voltage in the circuit of the secondary winding and the object of this condenser 11 is to absorb this residual current which is always above the predetermined frequency.

By so proportioning the condensers 11 and 12 in the novel manner above described, I render the transformer 10 selective to cause a discharge across the spark gap between electrodes 7 only in response to abnormally heavy currents having a frequency above the predetermined frequency which is the frequency of the generator. The normal working current will pass through the primary winding and have no effect on the spark gap as this current is of low value and low frequency and the potential induced therefore in the secondary winding is not sufficient to produce a spark potential. Upon the occurrence of transient electric waves such as a high frequency high current surge upon the conductor, the greater part of the high frequency current is by-passed through the condenser 12, due to the sensibility of a condenser to increase in frequency, while the smaller portion passes through the primary winding and is induced in the secondary winding and absorbed by the condenser 11 in the secondary circuit.

To limit the current from a transformer due to a short circuit, I provide a reactance 14 in the conductor 5 which acts to protect the power transformer 13 from the detrimental effects of excess currents and incidentally of high frequency surges traveling along the conductor 5.

It has often been found expedient to provide a capacity, or a device having a condenser action, preferably an electrolytic condenser or lightning arrester 17, in shunt to the expulsion fuse 1, to prevent the tendency toward reformation of the accidental arc due to an electromagnetic kick of potential when the fuse 1 blows. It has sometimes occurred in practice that upon the rapid extinguishment of the accidental arc by the blowing of the expulsion fuse 1, there is produced an electromagnetic kick of potential on the conductor 5 which by being above the normal voltage, may reestablish

the accidental arc. It is therefore advisable to provide an apparatus which will remove this electromagnetic kick of potential which is in reality a high frequency surge, produced by the sudden changes of flux in the transformers 10 and 12. I provide therefore an electrolytic condenser 17 in parallel with the expulsion fuse to form an easy path to ground for any high frequency currents produced by the electromagnetic kick.

In Fig. 2 I have shown the application of my novel protective device to the protection of a grounded Y-connected system of distribution, the conductors corresponding to the three phases being designated by *a*, *b*, and *c*. In a Y-connected system three of my novel protective devices are used, one connected in the secondary circuit of the current transformer 10 for each conductor, the circuit through each protective device terminating at a common or neutral point, which point is connected to ground through an expulsion fuse 18 similar to fuse 1. A ground on either conductor *a*, *b*, or *c* or a short circuit between the conductors will, as has been before described, cause the explosion of the cartridge 3 corresponding to the faulty conductor or conductors, thus forming a shunt path to ground from the faulty conductor or conductors through fuse or fuses 1 and the common fuse 18. Either one or both fuses will blow and the fault will be cleared from the system so quickly that the healthy conductors of the system are unaffected and synchronous apparatus remains in step.

In Fig. 3 is shown the application of my novel protective device to the protection of a delta connected system having conductors *d*, *e* and *f* corresponding to the three phases of the system. For a delta connected system, six of my protective devices, A, B, C, D, E and F are used. Devices A and B are connected between conductors corresponding to phases *d* and *e*, devices C and D between conductors corresponding to phases *e* and *f* and devices E and F between conductors corresponding to phases *f* and *d*. Protective devices A and F are both operated in response to conditions on conductor *d*, one electrode 7 of each protective device being connected by conductors 19 and 20 respectively to conductor *d*. The other electrode 7 of each of the protective devices A and F is connected to one of the secondary windings 21 and 22 respectively of the transformer 10 shown in this instance, as an auto-transformer. In order to economize space I have shown condensers 11, 11' and 11'' in shunt to only one transformer, that corresponding to conductor *d* but it is to be understood that each of the windings of each transformer are likewise shunted by condensers. The spark gaps of both pro-

protective devices A and F are thereby controlled by similar conditions on conductor *d*. In like manner the spark gaps of protective devices B and C and of D and E are controlled by similar conditions on conductors *e* and *f* respectively. The two protective devices between each pair of conductors are provided with a common expulsion fuse 1 and an extra screen 23 between each cartridge 3 and screen 2. These screens 23 are connected to cartridges 3 by metallic connections 24. The object of this screen 23 connected to the cartridge 3 is to insure a good connection from the cartridge 3, as some of the explosive material 4 as it leaves the cartridge, is often still in an unignited condition producing in the cartridge poorly conductive gases. The screen 23 is therefore placed a sufficient distance from the cartridge to be in the path of the highly conductive gases after all particles have become ignited.

By my arrangement of protective devices and connections I am able to protect my system and maintain continuity of service upon the occurrence of either single or three phase short circuits as will be apparent from the following description. Assume that a single phase short circuit exists, that is a short circuit between any two conductors, for example, between conductors *d* and *e*. Then due to the rush of current to the fault a sudden change of flux occurs in the transformers 10 of both conductors *d* and *e* which induces a high electromotive force in both the secondary windings 21 and 22 of each transformer. Due to the increased electromotive force in the circuit through winding 21 of each transformer, a potential difference exists between the electrode 7 of protective devices A and B sufficient to break down their respective spark gaps and cause a discharge simultaneously of their cartridges 3 through their screens 23 and 2 to their common fuse 1. In like manner, a similar increase of potential is induced in the secondaries 22 of each transformer 10 which causes cartridges 3 of protective devices F and C to discharge. It is apparent that a short circuit between conductors *d* and *e* will cause four protective devices A, B, C and F to simultaneously discharge. The discharge of devices C and F produces no current through their fuses 1 as there is no way of completing a conducting path unless their corresponding devices D and E should simultaneously operate. The simultaneous discharge of devices A and B, however, forms a low resistance path between conductors *d* and *e* through the common expulsion fuse 1 which is in shunt to the accidental short circuit. This shunt path reduces the potential across the conductors at the accidental short circuit to an

amount which is insufficient to maintain the arc and it is therefore extinguished. Thereupon the excess current passes between the conductors *d* and *e* by means of the shunt circuit and causes fuse 1 to blow which clears the lines of trouble and returns conditions to normal. This action of my protective system, as has been before pointed out, takes place within $\frac{1}{2}$ to $1\frac{1}{2}$ cycles at generator frequency and only the conductors in which the trouble exists are affected, the remaining conductors operating under normal conditions.

Upon the occurrence of a three phase short circuit it can be readily seen from the above description that all six protective devices will operate and form shunt circuits between each pair of conductors, subsequently blowing all three fuses 1 to clear the circuit. It is thus apparent that by my novel arrangement of protective devices, I am able to efficiently protect my system from any character of short circuit and by an examination of the devices it can be easily determined what character of short circuit existed on the line.

Of course it will be understood that when a fuse blows in my protective devices to clear the line, it is necessary to replace this fuse by a new one. The replacing of new fuses for those blown may be done automatically by any suitable device which can be arranged to perform this function.

Fig. 4 shows a modified form of protective device in which the explosive force of the material 4 is utilized to mechanically complete the shunt path to ground. In this device I use an elongated form of cartridge 3 filled with explosive material 4 and provided with a spark gap between electrodes 7. The cartridge also contains a metallic bar 25. In alinement with the metallic bar and separated therefrom by a suitable air space is a metal tube 26 which is connected to ground through an expulsion fuse 1. Mounted upon cartridge 3 and tube 26 in metallic connection therewith, are arcing horns 27 and 28 respectively. Suspended from one horn 28 in alinement with tube 26 is a heavy metallic member or buffer 29 provided with a spring 30.

This device operates as follows: When the explosive material 4 is ignited, it shoots the bar 25 across the gap between the cartridge 3 and tube 26, the bar 25 passing through tube 26 and coming to rest by striking against spring 30 of the buffer 29. The bar is of such a length that it bridges the gap between the cartridge 3 and tube 26 for an instant and thus connects the faulty conductor to ground through the fuse 1.

My invention may be embodied in many other forms than those shown and described and I therefore do not wish to be restricted

to the precise construction shown, but intend to cover by the appended claims all changes and modifications which are within the scope of my invention and will be apparent to those skilled in the art.

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

1. In combination with an electric conductor, a normally inoperative power shunting circuit connected to said conductor, a cartridge in said circuit containing explosive material, means for exploding said cartridge upon the occurrence of predetermined conditions on said conductor, and means for rendering said power shunting circuit operative in response to the explosion of said cartridge.

2. In combination with an electric conductor, a normally open power shunting circuit connected to said conductor, a cartridge in said circuit containing explosive material, means for igniting the explosive material in said cartridge in response to a fault occurring on said conductor, and means whereby said power shunting circuit is closed by the explosion of said cartridge and the fault on said conductor thereby removed.

3. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge included in said path, means for exploding said cartridge in response to conditions of short circuit on said conductor, and means for closing said current shunting path in response to the explosion of said cartridge.

4. A protective device for a transmission line comprising a normally open circuit connected to each conductor of said transmission line each circuit arranged when closed to shunt the power from its conductor, an explosion cartridge in circuit operative to close its normally open circuit when exploded, and means responsive to a short circuit on any conductor for causing the explosion of the cartridge corresponding to the faulty conductor whereby the short circuit on said conductor is removed without affecting the other conductors.

5. In combination with an electric conductor, a normally open current shunting path connected to said conductor, a cartridge included in said path, explosive material in said cartridge forming when ignited highly conductive gases, means for igniting said explosive material to explode said cartridge in response to conditions of short circuit on said conductor, and means coöperating with said highly conductive gases for closing said current shunting path.

6. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an ex-

plosion cartridge included in said path, means for exploding said cartridge in response to conditions of short circuit on said conductor, and means operative in response to the explosive action of said cartridge for closing said current shunting path.

7. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge included on said path, means for exploding said cartridge in response to conditions of short circuit on said conductor, and mechanical means rendered operative by the explosive action of said cartridge for closing said current shunting path.

8. In combination with an electric conductor, a protective device comprising a cartridge connected to said conductor and filled with explosive material, a spark gap within said cartridge capable of breaking down to ignite said explosive material, means for supplying a spark potential to said spark gap in response to conditions of short circuit on said conductor, and a normally opened circuit closed by the explosion of said cartridge to form a low resistance path in shunt to said short circuit.

9. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosive cartridge operative when exploded to close said current shunting path, a spark gap within said cartridge, means including a transformer for selectively causing the discharge of said spark gap in response to conditions of short circuit on said conductor, and means operatively related to said transformer for rendering its action selective.

10. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge operative when exploded to close said current shunting path, a spark gap within said cartridge, means including a current transformer for selectively causing the discharge of said spark gap in response to conditions of short circuit on said conductor, and devices having a condenser action shunting the primary and secondary of said transformer for rendering its action selective.

11. A protective device for an electric conductor comprising an explosion cartridge, explosive material within said cartridge adapted when ignited to produce highly conductive gases, a normally open current shunting path connected to said conductor including said explosion cartridge, a spark gap within said cartridge, a transformer connected to said conductor operative to supply a spark potential to said spark gap in response to conditions of short circuit on said conductor, and means whereby said

highly conductive gases formed as said cartridge is exploded act to close said current shunting path to remove said short circuit.

12. A protective device for an electric conductor comprising an explosion cartridge, a normally open current shunting path connected to said conductor including said cartridge, a spark gap within said cartridge, a transformer connected to said conductor operative to supply a spark potential to said spark gap in response to conditions of short circuit on said conductor, and mechanical means operative in response to the explosive action of said cartridge for closing said current shunting path and removing said short circuit.

13. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge included in said path, explosive material in said cartridge forming when ignited highly conductive gases, means cooperating with said high conductive gases to close said current shunting path, a spark gap within said cartridge arranged when discharged to ignite said explosive material, and a transformer operative to control the discharge of said spark gap in response to conditions of short circuit on said conductor.

14. In combination with an electric conductor, a protective device comprising a cartridge of explosive material, means for igniting said explosive material upon the occurrence of a fault upon said conductor, means for establishing a low resistance circuit in shunt to said fault in response to the ignition of said explosive material, and a circuit opening device in said shunt circuit operative to open said circuit and return said conductor to normal.

15. A device for maintaining continuity of service on a transmission system under conditions of short circuit comprising a cartridge of explosive material, means for exploding said cartridge upon the occurrence of a short circuit upon said system, means for closing a low resistance path in shunt to said short circuit in response to the explosion of said cartridge whereby said short circuit is removed, and circuit opening means in said shunt path operative to return said system to normal condition.

16. In combination with an electric conductor, a normally inoperative power shunting circuit connected to said conductor, a cartridge containing explosive material, means whereby said cartridge is exploded upon the occurrence of predetermined conditions on said conductor, means for rendering said power shunting circuit operative in response to the explosion of said cartridge, and means for rendering said power shunting circuit again inoperative.

17. In combination with an electric con-

ductor, a normally opened circuit arranged when closed to shunt the power from said conductor, a cartridge containing explosive material, means for exploding said cartridge in response to predetermined conditions on said conductor, means operative in response to the explosion of said cartridge for completing said normally opened circuit, and circuit opening means in said normally opened circuit operative in response to a predetermined current flow therethrough.

18. The combination in a system of distribution, of a device for maintaining continuity of service on said system comprising an explosion cartridge, means for exploding said cartridge in response to conditions of short circuit on said system, a normally open power shunting circuit for said system closed by the explosion of said cartridge whereby said short circuit on said system is removed, and means for opening said power shunting circuit after short circuit is removed.

19. In combination with an electrical transmission system, a device for maintaining continuity of service on said system comprising an explosion cartridge, means for exploding said cartridge in response to the occurrence of a fault on said system, a normally inoperative power shunting circuit rendered operative to remove the fault from said system in response to the explosion of said cartridge, and means for opening said power shunting circuit when said short circuit is removed to return said system to normal.

20. In combination with an electric conductor, a normally inoperative power shunting circuit connected to said conductor, a cartridge in said circuit, explosive material within said cartridge adapted when ignited to produce highly conductive gases, means whereby said cartridge is exploded upon the occurrence of predetermined conditions on said conductor, means for utilizing the conductivity of the explosive gases for rendering said power shunting circuit operative, and a circuit opening device in said power shunting circuit rendered operative in response to a predetermined current flow therethrough.

21. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge included in said path, means for exploding said cartridge in response to conditions of short circuit on said conductor, a fuse in said current shunting path operative to open said path after a predetermined current flow therethrough.

22. A protective device for an electric conductor comprising an explosion cartridge, explosive material within said cartridge adapted when ignited to produce highly conductive gases, a normally open current

shunting path connected to said conductor including said explosion cartridge, a spark gap within said cartridge, a transformer connected to said conductor operative to supply a spark potential to said spark gap in response to conditions of short circuit on said conductor, means whereby said highly conductive gases produced by the explosion of said cartridge act to close said current shunting path to remove said short circuit, and a current responsive device in said current shunting path for opening said path to return said conductor to normal.

23. In combination with an electric conductor, a normally open circuit arranged when closed to shunt the power from said conductor, an explosion cartridge for closing said normally open circuit, means for exploding said cartridge upon the occurrence of conditions of short circuit on said conductor, current opening means rendered operative in response to a predetermined current flow through said shunt circuit, and a device having a condenser action in shunt to said current opening means.

24. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge operative when exploded to close said shunt path, means for exploding said cartridge in response to conditions of short circuit on said conductor, current responsive means operative in response to a predetermined current flow through said current shunting path for opening said path, and a device having a condenser action closing a path in shunt to said current responsive means.

25. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge included in said path, means for exploding said cartridge in response to conditions of short circuit on said conductor, a thermal cut-out for opening said current shunting path in response to a predetermined current therethrough, and an electrolytic condenser in shunt to said cut-out.

26. In combination with an electric conductor, a normally open circuit connected to said conductor and arranged when closed to shunt the power from said conductor, an explosion cartridge operative to close said normally open circuit, means for exploding said cartridge in response to short circuit conditions upon said conductor, and a reactance connected to said conductor to limit the current on said conductor during conditions of short circuit.

27. In a system of distribution, a protective device for said system comprising a normally open current shunting path between each pair of conductors, two explosive cartridges controlling each current shunting

path, means for exploding each cartridge in response to conditions of short circuit on its own conductor, means for closing each shunt path only in response to the simultaneous explosion of its two cartridges, and current responsive means for opening said path in response to a predetermined current flow therethrough.

28. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge included in said path and adapted when exploded to close said path, a spark gap within said cartridge for exploding said cartridge, a transformer in series with said conductor for selectively causing the discharge of said spark gap in response to predetermined conditions on said conductor, said spark gap being included in the secondary circuit of said transformer, and means for rendering the action of said transformer selective comprising a condenser in shunt to one winding of said transformer so proportioned with relation to the number of turns of said winding that a major portion of currents above a predetermined frequency will pass through said shunt while the major portion of currents below said predetermined frequency will pass through said winding.

29. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge included in said path and adapted when exploded to close said path, a spark gap within said cartridge for exploding said cartridge, a transformer in series with said conductor for selectively causing the discharge of said spark gap in response to predetermined conditions on said conductor, said spark gap being included in the secondary circuit of said transformer, and means for rendering the action of said transformer selective comprising a condenser in shunt to one winding of said transformer having a capacity so proportioned to the inductance of said winding that currents of a frequency higher than a predetermined frequency are by-passed through said condenser.

30. In combination with an electric conductor, a normally open current shunting path connected to said conductor, an explosion cartridge included in said path and adapted when exploded to close said path, a spark gap within said cartridge for exploding said cartridge, a transformer in series with said conductor for selectively causing the discharge of said spark gap in response to predetermined conditions on said conductor, said spark gap being included in the secondary circuit of said transformer, and means for rendering the action of said transformer selective comprising a con-

denser in shunt to the primary winding of said transformer so proportioned in relation to the inductance of said winding that a major portion of currents above a predetermined frequency will pass through said shunt while the major portion of currents below said predetermined frequency will pass through said winding, and a second condenser in shunt to the secondary winding of said transformer so proportioned in relation to the relative impedance of said primary winding and said first mentioned condenser that currents in said secondary winding above said predetermined frequency will be absorbed by said second condenser without producing a spark potential across said spark gap.

31. The combination with the conductors of a polyphase transmission line, of a normally open current shunting path connected to each conductor, means included in each

path and responsive to conditions of short circuit on its conductor for closing its respective path, said current shunting paths being so related that said means when operated gives an indication of the conductors short circuited.

32. The method of maintaining continuity of service on a polyphase transmission line comprising a plurality of conductors upon conditions of short circuit which consists in actuating means in response to a short circuit to close a path in shunt to the short circuit, removing the short circuit thereby and then opening said path automatically to return the line to normal position.

In witness whereof, I have hereunto set my hand this 15th day of February, 1915.

ELMER E. F. CREIGHTON.

Witnesses:

BENJAMIN B. HULL,
HELEN ORFORD.

Copies of this patent may be obtained for five cents each, by addressing the "Commissioner of Patents, Washington, D. C."