Jan. 1, 1924 1,479,465

T. T. GREENWOOD

CONTROL OF ELECTRIC CIRCUITS

Filed Jan. 19, 1918

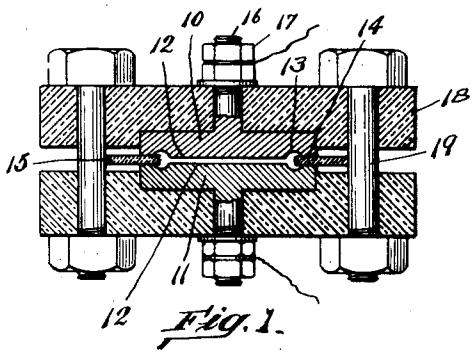


Fig. 1.

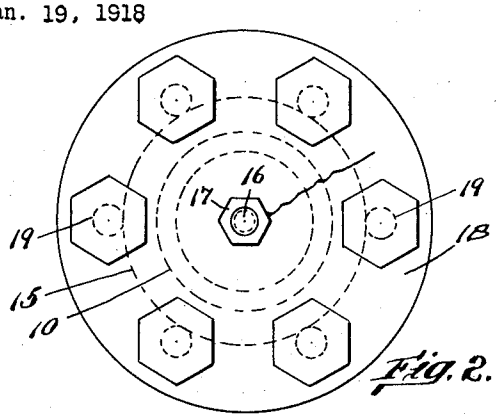


Fig. 2.

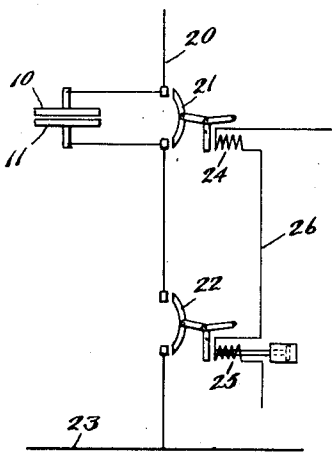


Fig. 3

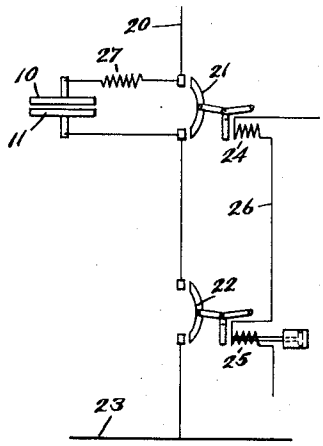


Fig. 4.

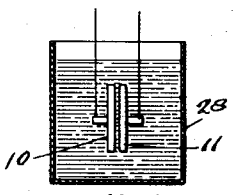


Fig. 5.

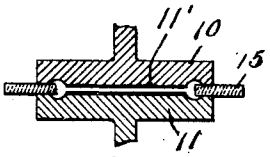


Fig. 6

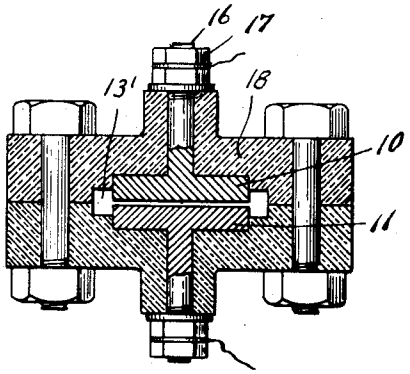


Fig. 8.

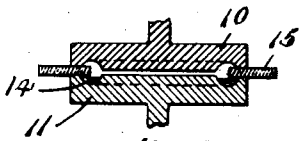


Fig. 7.

Inventor,
Talma T. Greenwood
by
B. J. Noyes, Atty.

Patented Jan. 1, 1924. 1,479,465

UNITED STATES PATENT OFFICE.

TALMA T. GREENWOOD, OF EAST TEMPLETON, MASSACHUSETTS, ASSIGNOR TO SEARS B. CONDIT, JR.

CONTROL OF ELECTRIC CIRCUITS.

Application filed January 19, 1918. Serial No. 212,551.

To all whom it may concern:

Be it known that I, TALMA T. GREENWOOD, a citizen of the United States, a resident of East Templeton, county of Worcester, and State of Massachusetts, have invented an Improvement in Control of Electric Circuits, of which the following is a specification.

My invention relates to the control of electric circuits, and has more particular reference to means for interrupting the current flow in said circuits.

With the high potentials now employed in transmission lines and other power circuits, and the high values of current also transmitted over these lines, the problem of safely interrupting the current flow in these lines becomes exceedingly difficult. Due to the high potentials employed, it has been found necessary and desirable to immerse the switches or circuit breakers in a bath of oil, and to make and break the switch contacts beneath the surface of the oil; the oil serving to quench and suppress the arc which tends to form between the switch contacts when the contacts are broken in the opening of the switch.

With the high current values also employed with the high potential circuits, the switches must be exceedingly massive in construction in order to provide the adequate heat dissipating surface necessary to prevent the temperature of the switch from rising to an abnormal degree and must be designed with extreme care in order that the circuit may be interrupted without disastrous results occurring to the mechanism.

It is of common occurrence that, upon the opening of an oil immersed switch universally employed to control such a high tension circuit, there occurs what is termed an "explosion", in that the enormous power developed in the arc formed between the switch contact members, which power is the entire energy of the circuit, is expended in vaporizing the body of oil surrounding the arc, and consequently in creating a comparatively high pressure in the vaporized oil. Due to the high pressure, the gases rapidly expand and force the oil in the container in all directions, sometimes wrecking the container.

When it is seen that there may be momentary energy extending into the thousands, and even hundred-thousands of kilowatts that must be controlled and dissipated, upon the interruption of the circuit, it may be realized that the problem of controlling this amount of energy is exceedingly difficult.

The object of my invention is in the provision of means whereby a high tension circuit may be interrupted without the occurrence of harmful results to the interrupting mechanism.

The means I employ to control and interrupt the current flow in a high tension circuit is in the provision of a novel circuit interrupter and control switches therefor.

In the normal operation of a circuit the interrupter is arranged to be shunted by a control switch, and the normal path of the line current is through the control switch or switches. Upon the desirability or necessity of interrupting the current flow in the circuit, the interrupter shunt switch is opened and the interrupter is thereby operatively inserted in the circuit. After the interrupter has functioned to interrupt the current flow in the circuit, another control switch is arranged to be opened to isolate the circuit from the source of energy.

The circuit interrupter is arranged to initially offer a minimum of impedance to the flow of current therethrough, in order that there be but a minimum amount of energy for the shunting switch to control, and afterwards offer an increasing impedance to the flow of current therethrough, thereby causing a decreasing flow of current therethrough until the current flow has practically ceased or until it is so reduced that it can be easily controlled by a control switch, which thereupon opens and the circuit is thereupon isolated from the source of energy.

A form of circuit interrupter well adapted for the purpose of interrupting the current flow in a circuit may comprise two relatively insulated plates, which may be termed discharge plates, maintained in closely spaced relation and between which a body

of air is confined. The potential of the circuit is adapted to be applied to the discharge plates upon the opening of the shunting switch, and the current of the circuit is initially adapted to pass between the plates. Since the entire energy of the circuit is expended in the arc between the discharge plates, the pressure of the confined volume of gas between the plates immediately rises to a value higher than that at which an arc can be maintained between the plates, and consequently the arc is extinguished. The second switch is now arranged to be opened, and the circuit is thereby disconnected from the source of energy.

Fig. 1 is a sectional view of a circuit interrupter.

Fig. 2 is a plan view of Fig. 1.

Fig. 3 illustrates diagrammatically the circuit connections with the interrupter.

Fig. 4 is a modification of Fig. 3.

Figs. 5, 6, 7 and 8 are modified forms of circuit interrupters.

As here shown, the circuit 20 to be controlled is connected to the source of energy or bus bar 23, and has a switch 21 therein. The interrupter shown has its terminals thereof connected to the contact members or poles of the switch. Said switch is arranged to be normally closed, and thereby serves to shunt the interrupter which is thereby operatively excluded from the circuit. A second switch 22 is arranged in the circuit and is in series with the first switch and with the interrupter, and said latter switch is also adapted to be normally closed.

Upon the desirability or necessity of opening the circuit, the controlling circuit 26 for the switches is closed to cause the opening of the shunting switch 21. The interrupter is thereby inserted in the circuit and operates to reduce or interrupt the current flow therein, and the second switch 22 is thereupon designed to open. Said second switch is given a time element somewhat greater than the shunting switch 21, in order that said shunting switch may open first. With both switches open the circuit is isolated from the source of energy or bus bar 23.

As previously stated, the circuit interrupter may comprise two plates, maintained in spaced relation, as shown in Figs. 1, and 5 to 8 inclusive. The space between the discharge plates, or the discharge portions of the plates between which the arc or line current is arranged to flow during the operation of the apparatus to interrupt the current flow, is comparatively small, and may be measured in thousandths of an inch. The gas enclosed between the two plates is confined, in order that there may be no undesirable escape of gas during the operation of the interrupter. The pressure of the confined air or other gas between the discharge plates may be substantially that of the atmosphere, or it may differ therefrom, as will be hereinafter more fully set forth.

It is well known that although an arc may be drawn to a comparatively great length in air, yet the potential drop between two electrodes must be comparatively great to enable an arc to be initially started between said electrodes; and the potential drop in air at atmospheric pressure is in the neighborhood of 50,000 volts per inch of distance between electrodes, or about 50 volts per one thousandth of an inch. It is also well known that the potential difference necessary to cause the arc to initially flow between two spaced apart electrodes increases with the pressure of the gas separating the electrodes, and the increase of the potential has been found to be approximately directly porportional to the absolute pressure.

The discharge plates may be so spaced apart that a potential of from 100 to 500 or more volts may be necessary to cause an initial discharge or arc between the electrodes, the particular discharge voltage being chosen with regard to the shunting switch. When the shunting switch is opened, an arc is drawn between the contact members thereof, as is usual, until the voltage drop across the arc is equal to the voltage at which current will flow between the discharge plates of the interrupter, at which point the line current flows between the discharge plates, and the arc between the switch contacts is extinguished. The entire current of the line now flows between the discharge plates.

Due to the comparatively small distance between the discharge plates and the comparatively small volume of air or other gas confined between the plates, the heat of the arc, which represents the entire energy of the line, causes the pressure of the confined air to practically instantaneously rise to a comparatively high value, and the pressure is such that the arc cannot persist between the discharge plates at the line voltage, and consequently the arc is immediately quenched or extinguished. The beginning of the discharge between the discharge plates or electrodes, and the quenching of the arc is practically simultaneous because of the comparatively small volume of gas confined between the plates, and the fact that comparatively the entire energy of the circuit is expended in heating the confined gas.

Although the conductivity of a gas increases with the temperature, yet with air and many other gases the pressure rise due to the heating of the gas by the arc is much greater in proportion than the increase in conductivity due to the heating, and therefore such arc will always be extinguished.

Due to the substantially instantaneous quenching of the arc immediately it is formed, the discharge faces of the plates

may remain at substantially their normal temperature, and there is consequently no tendency for a metallic bridge to form across the small gap between the plates, to thereby short circuit the interrupter. After the pressure in the confined volume of air between the discharge plates has risen to a point sufficient to quench the discharge, the plates will operate as cooling surfaces and cool the heated confined gas; and the pressure will drop eventually to its normal value, at which time the apparatus will again be in condition to interrupt the line circuit.

Due to the small volume of confined gas, and the comparatively large cooling surface for the heated gas, the cooling effect will be extremely rapid, and but a short interval will occur between one discharge and the diminution of pressure in the gas between the plates sufficient to condition the apparatus for a second operation.

As here shown, the discharge plates 10 and 11 are formed with central and circular discharge faces 12, maintained in parallel closely spaced relation. Circular grooves 13 are formed in the discharge plates within the outer periphery of the plates, and sharply and definitely define the discharge faces of the plates. Between said grooves 13 and the outer periphery of the plates, there are formed flat parallel portions 14, between which a circular ring 15 of insulating material, such for instance, as mica, is clamped. The thickness of the insulating ring 15 is preferably made greater than that of the space between the discharge faces 12, in order that its thickness may be sufficient to safely withstand the total circuit voltage without rupture, and said insulating ring is arranged to extend beyond the plates a sufficient amount to effectively prevent an external discharge between the plates.

The inner periphery of the ring 15 is arranged to be extended within the grooves 13 to some extent, in order that there may be no portion between the two discharge plates of less resistance than between the discharging faces thereof, as it is well known that if the inner periphery of the ring 15 is placed substantially flush with the edge portion 14 at its junction thereof with the grooves 13, the discharge tends to take place between said edges in preference to taking place between the parallel faces 12 of said discharge plates.

The plates are provided with lugs 16, which may be integrally formed therewith, and which may be provided with nuts 17 between which conductors may be clamped to make connection between the line and the discharge plates. The discharge plates may be partially imbedded in massive blocks 18 of insulating material, which extend beyond the periphery of the discharge plates and are secured together by bolts 19.

By means of the insulating blocks 18 and and the bolts 19, the discharge plates are securely clamped together and maintained in spaced relation by the insulating ring 15 against the separating force which comes into existence with the passage of an arc between the plates.

Fig. 8 shows a somewhat modified form of circuit interrupter in that the groove 13′ is formed in the insulating blocks 18 and said blocks are adapted to be bolted securely together to confine a body of gas between the discharge plates.

The volume of air confined between the two discharge plates is adapted to be comparatively small, and the major part of the air is adapted to be confined between the discharge faces 12 of the plates, in order that as little energy as possible may be necessary to heat the air to a temperature sufficient to cause a sufficiently high pressure to quench the arc, in order that the pressure may practically instantaneously rise to the requisite value to accomplish the purpose.

The interrupter is arranged to be connected in an electric circuit represented by 20 in Fig. 3, and the discharge plates 10 and 11 are arranged to be normally shunted by the switch 21. A second switch 22 is arranged in series with the switch 21 and the interrupter and the electric circuit or line may be connected below the switch 22 with a source of energy or bus bar 23. The trip coils 24 and 25 for said switches 21 and 22 may be included in the same controlling circuit 26, and the trip coil 25 may have a time element somewhat greater than that of coil 24 in order that switch 21 may be opened shortly before switch 22. The control circuit 26 may be controlled or operated by any convenient or suitable means.

In the normal operation of the electric circuit of line 20, both switches 21 and 22 are closed and the interrupter is shunted by the switch 21. The pressure of the confined gas between the discharge plates may be substantially atmospheric, or at least, normal pressure, and the resistance of the gas to an electric discharge is at its minimum.

Upon the occurrence of an overload in the line, or when it is desired to interrupt the current flow in the line, the switch 21 is caused to be opened. When said switch begins to open, an arc forms between the switch contact members, and as the space between the contact members increases with the continued opening movement of the switch, the potential of the arc increases. At some point during the opening movement of the switch 21 the potential of the arc is equal to or greater than the potential necessary to cause an arc to occur between the discharge plates 11 and 12; and consequently the resistance of the gas confined between the discharge

plates breaks down and the entire line potential is impressed across the plates. The line current consequently flows between the discharge plates and the arc occurring between the contact members of the switch 21 in its opening movement is extinguished because of the initially much less resistance of the interrupter.

Upon the opening of the shunting switch 21, the switch 22 is in series with the circuit interrupter.

Due to the arc between the plates and the comparatively small volume of air between said plates, the pressure, as heretofore explained, practically instantly rises to a value above that at which an arc may be maintained at said pressure, and consequently the arc is extinguished. At this point the time element of the trip coil 25 of the switch 22 is designed to permit the switch 22 to be opened. Inasmuch as the pressure between the discharge plates has risen to a point sufficient to quench the current flow in the line, there is now no current flowing; and consequently there will be no arc between the contacts of the switch 22 during its movement to open position. At some period subsequent to the opening of the switch 22 the pressure in the gas between the discharge plates drops, due to radiation of heat from said plates, and the discharge apparatus again regains its normal state of minimum resistance, at which point it is again in readiness to interrupt the current flow in the line 20 when the switches are again operated after being reset to their initial circuit controlling condition.

It is not necessary that the controlling means for said switches 21 and 22 be tripping coils; as any means whereby the switch 22 is opened at some period subsequent to the opening of the switch 21 but before the discharge apparatus has regained its initial maximum conductivity, will suffice to adequately control the line.

In Fig. 4 a reactance 27 is inserted in the connections between the discharge apparatus and the shunting switch 21. The other connections between the discharge apparatus and the switches is the same as in Fig. 3.

Inasmuch as the pressure rise upon the occurrence of an arc between the discharge plates is practically instantaneous, it may not be necessary to enclose the discharge plates or the discharge faces thereof in a confined space provided the inertia of the air or other fluid is sufficiently great to permit the pressure rise between said faces and to prevent the escape of compressed air therefrom until after the arc is quenched.

Fig. 5 illustrates a form of discharge apparatus in which the discharge plates 10 and 11 are immersed in a container 28 filled with an insulating liquid, which may be with comparative facility volatilized. A suitable liquid for the purpose may be carbon tetrachloride, which is fluid, non-inflammable, easily gasified and has high insulating properties. An insulating oil for the purpose is not especially desirable, because after a few discharges the oil will char and bridge the small gap between the discharge plates. The plates are maintained, as before, in closely spaced parallel relation, but the space between the plates is free for access thereto of the surrounding fluid, and the insulating ring 15 of Fig. 3 is omitted. Upon the passage of an arc between the discharge faces, the insulating fluid is ruptured and that portion of the fluid between the discharge faces is vaporized, resulting in a high pressure between the discharge plates, which serves to quench the arc, practically instantly it is formed.

Due to the substantially instantaneous rise of pressure, the volatilized insulating liquid is held between the discharge faces of the plates for a sufficient length of time to quench the arc because of the great inertia of the surrounding liquid. After the arc is formed and the pressure has risen to a value sufficient to quench the arc, and the pressure has existed for an appreciable length of time, the inertia of the surrounding liquid is overcome, and the gas is expelled from between the discharge plates. As it passes from between the discharge plates it encounters the mass of comparatively cold body of fluid by which it is condensed, and a partial vacuum is thereby formed between the plates which causes liquid to flow therebetween, thus conditioning the apparatus for another operation.

Due to the comparatively small volume of gas produced and to the condensing of the volatile vapors by the main body of liquid, there is no resultant explosion, as sometimes occurs in the operation of an oil immersed switch upon the opening thereof.

It is not essential, for the proper functioning of the interrupter, that the enclosure in which the discharge or arc takes place be filled with air or another gas. It may be desirable in certain instances to fill the space between the discharge plates with the vapor of a volatile fluid, such for instance as anhydrous ammonia, sulphur dioxide, or any one of a large number of similar vapors. It may be preferable, in certain instances, to fill the space with water vapor.

With an interrupter arranged with a volatile vapor, such for instance, as sulphur dioxide, between the discharge faces, a small amount of liquid sulphur dioxide may be placed between the plates and may occupy the space formed by the grooves 13 if the plates are in a horizontal position; or may occupy a portion of the space between the discharge faces themselves if the plates are in a vertical position, and the remainder of

the confined space may be filled with the vapor of the fluid. The pressure of the vapor is dependent upon the temperature of the liquid. Upon the occurrence of a discharge between the discharge plates, the intervening space of which is filled with such a volatile vapor and its liquid, the heat of the discharge serves to heat the volatile vapor and to volatilize the liquid. In this case the pressure between the plates for a given temperature rise will be greater than is the case if the total energy of the arc were expended in heating the vapor alone.

Due to the absorption of heat in vaporizing the volatile liquid, and the consequent lower final temperature of the interrupter, it is possible in certain conditions that such an arrangement of interrupter with a volatile fluid in the space between the plates, may function more satisfactorily than if the intervening space were filled with a gas alone.

A further modification of the interrupter is shown in Fig. 6. In this case the discharge plates, or at least the discharge face portions thereof, are formed of a metal which forms an amalgam with mercury, and the discharge faces are coated with mercury to form a thin film 11′ thereon. The confined space between the discharge plates in this case may be filled with a gas or vapor which does not readily combine with mercury.

In the operation of such an arrangement of the apparatus, upon the occurrence of a discharge between the plates, the heat of the discharge serves to vaporize the mercury, which acts as a conducting medium; and due to its uni-directional properties, may serve to interrupt the flow of current between the plates upon the expiration of a half wave.

A further modification is shown in Fig. 7. In this case the space between the discharge plates is filled with mercuric vapor at atmospheric temperature, and consequently low pressure, and the groove in the lower plate 11 is partially filled with liquid mercury as at 14′. Inasmuch as there is a low pressure existing between the spaced plates, said plates may be spaced a greater distance apart than is the case if a comparatively high pressure exists in the gas or vapor between the plates, because of the lower resistance of the low pressure gas or vapor.

In the operation of such an apparatus the heat of the discharge serves to vaporize the mercuric vapor, which operates in the well known manner to stop the current flow at the expiration of a half wave.

A number of forms of the discharge apparatus have been shown and described. In some the gaseous pressure between the plates is atmospheric; in others it is greater than, and in still others less than atmospheric. The use of gases which have no uni-directional conductivity properties have been described, and those which have uni-directional conductivity properties have also been described. The use of a volatile liquid between the plates has also been suggested.

All the modified forms of circuit interrupter herein described embody the principle above set forth; namely, that of initially presenting a minimum of impedance to current flow and at some later period presenting a greater impedance to current flow, at which period the second control switch is designed to operate to isolate the circuit from the source of energy.

All the interrupters shown operate to set up their higher subsequent impedance in the same manner, in that the heat of the arc is utilized to cause the function of the confined gas, liquid or vapor to quench the arc to thereby interrupt the current flow in the line to which the discharge apparatus is connected. The heat of the arc may be utilized to cause a direct pressure rise sufficient to quench the arc, or it may be utilized to furnish a supply of a gas having uni-directional conductivity properties, which may alone serve to suppress the arc or prevent its reformation after the expiration of a half wave; or which, combined with the increase of pressure, serves the same purpose.

I claim:—

1. A circuit interrupter comprising a pressure-tight casing adapted to confine a relatively small volume of an insulating fluid normally at a relatively low pressure, said casing having two relatively massive, highly heat-absorbent electrodes separated by the fluid in the casing and between which an electric arc is adapted to form and heat the fluid and increase the fluid pressure within the casing and quench the arc.

2. A circuit interrupter comprising a pressure tight casing adapted to confine a relatively small volume of an insulating fluid normally at a relatively low pressure, said casing having two heat-absorbent electrodes which have relatively-extensive, closely spaced, opposed faces separated by the fluid and between which an electric arc is adapted to form and heat the fluid and increase the fluid pressure within the casing and quench the arc.

3. A circuit interrupter comprising two relatively massive, heat-conducting plates having opposed arcing faces of relatively great extent, an insulating separator interposed between said plates beyond said arcing faces, and clamping means securing said plates and separator in pressure-tight engagement, the space between the arcing faces of said plates adapted to contain an insulating fluid adapted to be heated by an electric arc formed between said faces to increase its pressure and quench the arc.

4. A circuit interrupter having two heat-

absorbent electrodes formed with relatively large, closely-spaced, arcing faces between which an electric arc is adapted to form, and a relatively small volume of insulating fluid confined between said arcing faces adapted to be heated by the arc and increase its pressure and quench the arc, and said electrodes arranged immediately to cool the heated fluid and restore the interrupter to its normal condition.

In testimony whereof, I have signed my name to this specification, in the presence of the subscribing witness.

TALMA T. GREENWOOD.

Witness:
H. B. DAVIS.