

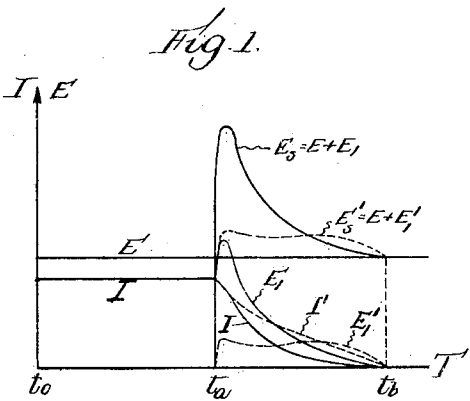
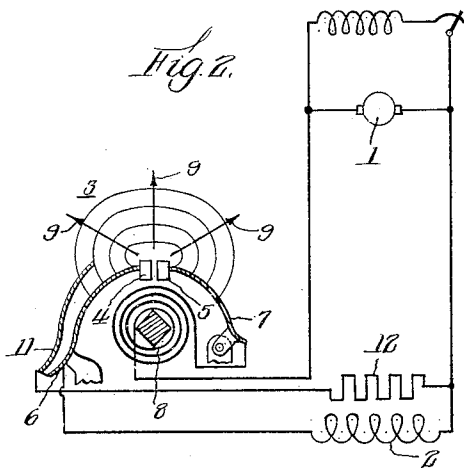
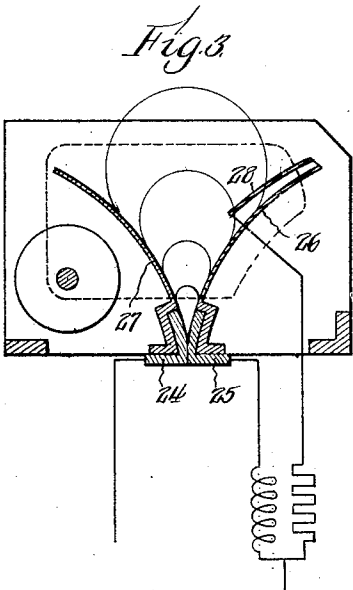
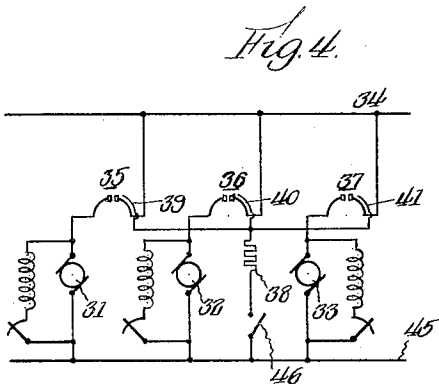
March 4, 1930.

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1,749,539

SWITCH APPARATUS

Filed June 28, 1927



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UNITED STATES PATENT OFFICE

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SWITCH APPARATUS

Application filed June 28, 1927, Serial No. 202,103, and in Germany July 3, 1926.

My invention relates to switch apparatus and it has particular relation to such apparatus utilizing the blow-out arc for performing auxiliary operations in conjunction with the associated circuits and apparatus.

Among the objects of the invention is a switch apparatus of the foregoing type in which the blow-out arc is arranged to establish auxiliary circuit paths for reducing the voltage across the switch terminals on the interruption of inductive circuits.

In its broad aspects my invention aims at the prevention of arc-re-ignition by reason of excess voltages induced at the switch terminals incident to the interruption of a current.

The invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings wherein

Fig. 1 is a curve diagram illustrating the current and voltage relations at the terminals of a switch;

Fig. 2 is a circuit diagram illustrating one form of the invention;

Fig. 3 is a sectional view of a switch embodying one form of the invention; and

Fig. 4 is a circuit diagram illustrating another embodiment of the invention.

When a direct current circuit containing inductance is opened, the magnetic energy released at the interruption of the current produces a voltage rise which appears as an added voltage at the points of the break. The amount of power that is to be interrupted and handled in the switch is thus increased and the resulting arc is lengthened. The additional voltage is caused by the magnetic field which is induced by the direct current flowing through the circuit when the switch is closed. On opening the switch the rapid decrease in the field strength induces a voltage which tends to maintain the current. This induced voltage is co-directional with the line voltage. The arc which forms at the switch is therefore started and maintained by the sum of the line voltage and of the induced additional voltage.

The current and voltage conditions at the interruption of such circuit are illustrated in

the curves of Fig. 1 in which the voltage E and current I at the terminals of the switch are plotted against the time T . At the instant when the circuit is broken, indicated by t_a , the current through the switch and the line voltage have values indicated by the horizontal lines I and E . The voltage at the terminals of the closed switch and of the inductance included in the circuit is zero at this moment. On opening the circuit the current falls as shown by the portion of the full line curve I following the ordinate drawn at t_a . The decrease of the current induces in the inductance an electromotive force E_1 , which is superposed on the line voltage E and gives a resultant switch voltage $E_s = E + E_1$ at the terminals of the switch. This voltage rise may be very great and constitutes a serious difficulty in connection with design and operation of large direct-current circuit breakers, particularly when applied to highly reactive circuits. According to the invention, these difficulties are avoided through the suppression of the voltage rise in the inductance by causing the magnetic energy to be discharged through suitable energy-absorbing apparatus in a circuit which is automatically closed and opened in response to the switching process. To this end the swinging arc is caused to establish a shunt circuit while traveling along the arcing horns of the switch by means of an auxiliary horn that is provided in the path of the travel of the main arc. This auxiliary horn is included in a circuit containing energy-absorbing means and the inductance, the magnetic energy of which is to be discharged and is so arranged that the main switching arc completes this circuit permitting the magnetic energy to be gradually discharged without inducing excessive voltages at the main switch terminals, in conjunction with an inductive direct-current circuit. In other words, the voltage rise is prevented by providing a switch in which power-consuming means are connected in parallel with the inductance in such manner that while one end of the power-absorbing means is directly connected to one end of the inductance, the other ends of the inductance and the power

absorbing means are connected by the arc incident to the interruption of the circuit. This arc is formed in the gap between one of the main switch terminals and a special horn placed close to the same, the special horn being connected to the power absorbing means. An arrangement of such character is shown diagrammatically in Fig. 2 wherein a direct-current circuit comprising a source of energy 1 and an inductive load 2 is arranged to be closed by a switch 3 having a pair of current interrupting or arcing terminals 4 and 5 associated with arcing horns 6 and 7 respectively. A magnetic blow-out coil 8 is included in the circuit through the switch. The switch 3 is so arranged that on opening the circuit at the arcing terminals 4 and 5 the blow-out coil 8 will produce a field tending to blow the arc outwardly along the surface of the arcing horns 6 and 7 as indicated by the arrows 9 until the arc is so far lengthened as to become unstable and clear the circuit. In order to reduce the voltage rise across the arcing terminals and across the horns of the switch by reason of the voltage induced in the inductance 2 of the circuit incident to the current interruption, the switch is provided with a special arrangement for causing the magnetic energy of the inductance 2 to be discharged without affecting the voltage at the interrupting terminals. To this end I provide, in addition to the main arcing horns 6 and 7, an auxiliary arcing horn 11 which is connected in series with a resistor 12 or other energy-absorbing means in parallel to the inductance 2, a terminal of the resistor being connected to one terminal of the inductance and the auxiliary horn 11 being disposed adjacent the horns 6 which leads to the other terminal of the inductance 2. The auxiliary horn 11 is so arranged that the blow-out arc, in its travel under the action of the blow-out field, short-circuits the gap between the auxiliary horn 11 and the adjacent main horn 6 thereby completing a discharge circuit for the inductance 2. This discharge circuit permits gradual decrease of the current in the inductance 2 and a dissipation of the magnetic energy stored in the inductance in the resistor 12 without detrimentally affecting the voltage conditions between the main arcing horns 6 and 7. As a result the interrupting arc between the main arcing terminals 6 and 7 will be readily extinguished since there will be no excessive voltage rise across said terminals, thus removing any tendency to re-ignition.

In many cases it will not be necessary to provide a special resistor 12 for dissipating the energy stored in the inductance of the circuit, the shunting arc between the auxiliary electrode 11 and the associated electrode 6 being sufficient for this purpose. By properly designing the cooperating horn portions

and the gap width therebetween the arc may be given the characteristics required for this purpose. In such case the auxiliary horn is directly connected to the corresponding terminal of the inductance, the resistor 12 being omitted.

The gradual decrease of the current through the inductance and dissipation of the magnetic energy thereof may be assisted by making the distance between the main and auxiliary horns gradually decreasing in the direction of the travel of the shunting arc.

The current and voltage conditions in a switch of such construction appear from Fig. 1. The current drop will not be as steep as in the case of a switch of the prior art, as indicated by full line curve I, but will be gradual as indicated by the practically straight dotted line I'. As a result the electromotive force induced in the inductance 2 will at first remain approximately constant and then gradually fall to zero, as shown by the dotted curve E'. The total voltage across the switch terminals which is the sum of the line voltage E and the inductance voltage will then be $E'_{\text{total}} = E + E'$, and is indicated by the dotted line E'. By a comparison of this dotted line curve with the full line curve $E_{\text{total}} = E + E_1$, it is seen that a very substantial reduction of the voltage across the switch terminals has been obtained by my improved arrangement.

If no requirement is made in respect to the elimination of the over voltages and only a reduction thereof is required, the auxiliary horn is so arranged as to be outside of the arcing path in case of the interruption of small current and is reached by the arc in the course of its travel only in case the interrupting current is very large. With such arrangements the parallel discharge resistor is included in the circuit only shortly before the completion of the current interruption between the main switch contacts. When breaking small powers with such arrangement, the auxiliary horn will not come into operation at all. It will, however, function when the currents are heavy, as in the case of a short-circuit.

As shown in Fig. 2 the arcing horns 6 and 7 of the switch depart from the conventional form and extend downwardly on both sides of the interrupting contacts 4 and 5, constituting two arcuate downwardly bent segments. On interrupting the current the blow-out coil 8 will force the arc upwardly and the resulting arc will assume the shape of a loop extending between the upper convex sides of the horn segments. The movement of the arc will be of a double nature. The arc loop will gradually increase in size. At the same time the arc terminals on the upper horn surfaces will move away from the point of the break. The auxiliary horn 11 is arranged adjacent the end portion of one of the

main horn segments 6 so as to be reached by the main arc as it travels away from the point of the break. By spacing the upper end of the auxiliary horn 11 sufficiently from the point of the break of the switch the arrangement may be readily adjusted so that when handling small currents the arc will be destabilized and interrupted without ever reaching the point at which it shunts the gap between the auxiliary horn 11 and the main horn 6.

In Fig. 3 is shown another modification of the invention in which a conventional switch having interrupting contacts 24, 25 with upwardly extending horns 26, 27 is provided with the auxiliary horn 28.

My invention is particularly useful in large direct-current systems, for instance, railways and the like, utilizing a plurality of parallel-connected power circuits. When a number of circuit breakers are provided in sub-stations of such character for the various parallel-operating machines it is not necessary to provide a shunting resistance for each circuit breaker. It is sufficient to combine a single shunting resistor, common to all the breakers of such type. An arrangement of this character is shown in Fig. 4 wherein a plurality of parallel-operating dynamo-electric machines 31, 32, 33 are arranged to be connected to a bus bar 34 by means of switches 35, 36, 37 of the type shown in Fig. 2. Instead of providing a separate discharge resistance for each of the circuit breakers a single resistor 38 is provided and connections are made as shown between the auxiliary horns 39, 40, 41 and one terminal of said resistor. The other terminal of said resistor is connected to the other bus bar 45 of the circuit, a switch 46 being provided for disconnecting said resistor in case the shunting arc persists on the auxiliary horn of any one of the switches. The latter may be the case, for example, when a number of machines are operating in parallel and are not all cut off at the same time.

What I claim is:

1. In a circuit comprising a source of energy and impedance means, a switch having a pair of main arcing electrodes for interrupting the current in said circuit, one of said electrodes being connected to one terminal of said impedance means, an auxiliary arcing electrode associated with said switch and connected to the other terminal of said impedance means, said auxiliary electrode being disposed in the path of the travel of the interrupting arc on said one of said electrodes and forming therewith a gap converging in the direction of arc travel.

2. In a circuit comprising a direct-current source and inductance means, a switch having a pair of main arcing electrodes for interrupting the current in said circuit, one of said electrodes being connected to one terminal of said inductance means, an auxiliary arcing electrode associated with said switch and connected to the other terminal of said inductance means, said auxiliary electrode being disposed in the path of the travel of the interrupting arc on said one of said electrodes and forming therewith a gap converging in the direction of arc travel.

3. In switch apparatus of the character described, a contact member, an arcing horn associated with said member, and a member complementary with respect to said arcing horn and disposed in spaced relation with respect thereto on the arcing-surface side thereof to provide a gap between such surface and the adjacent surface of said complementary member, said gap being disposed to receive a portion of the arc occurring incident to switching operation of said apparatus and converging in the direction of travel of the arc.

In testimony whereof I have hereunto subscribed my name this 15th day of June, A. D. 1927, at Zurich, Switzerland.

ROBERT KELLER.