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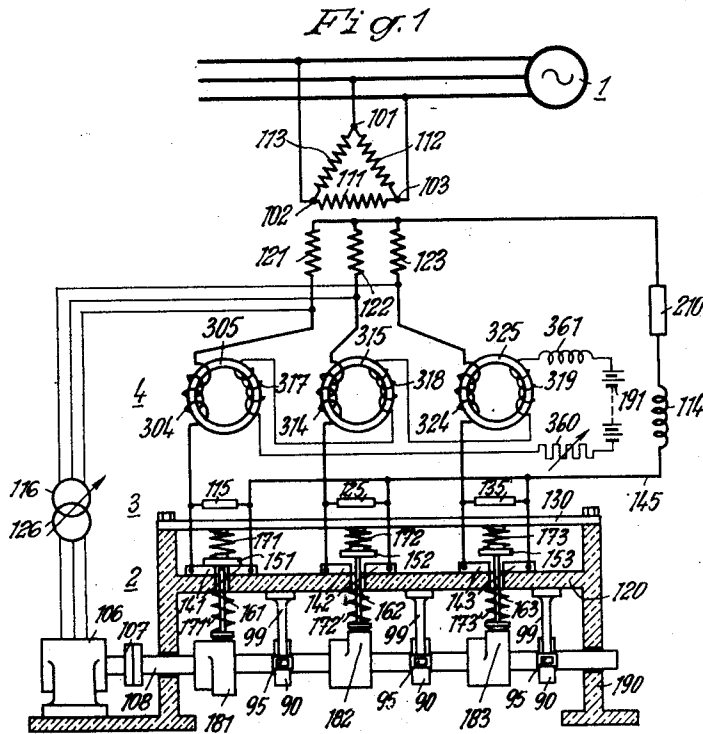
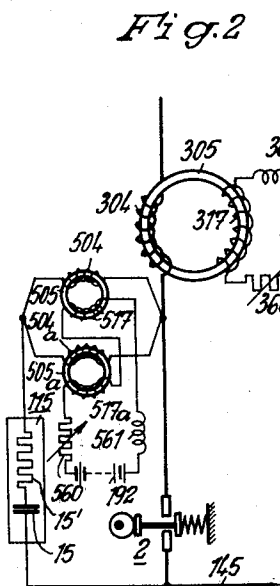
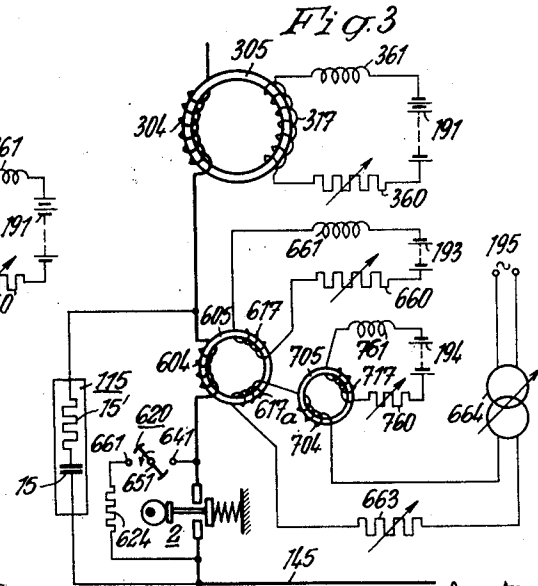
F. KOPPELMANN

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APPARATUS FOR CONVERTING CURRENTS

Original Filed Oct. 5, 1937

2 Sheets-Sheet 1



Inventor  
 Floris Koppelman  
 by Knight Bros.  
 Attorneys

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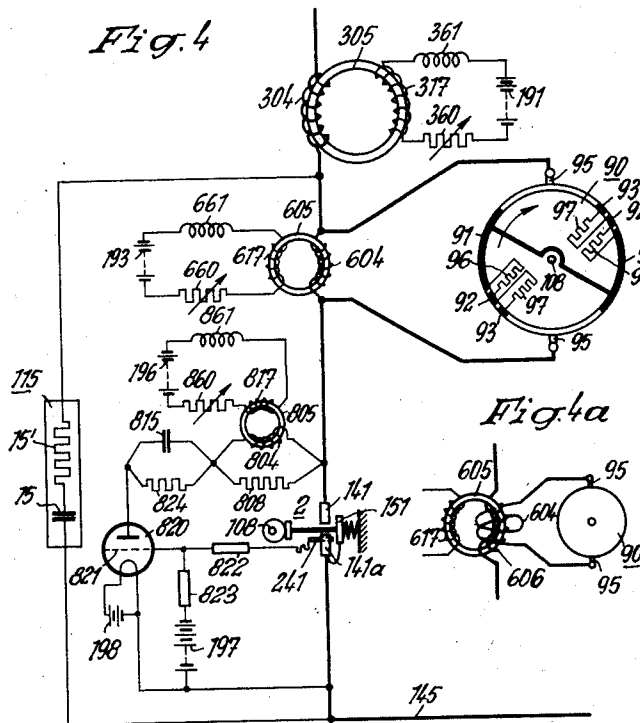
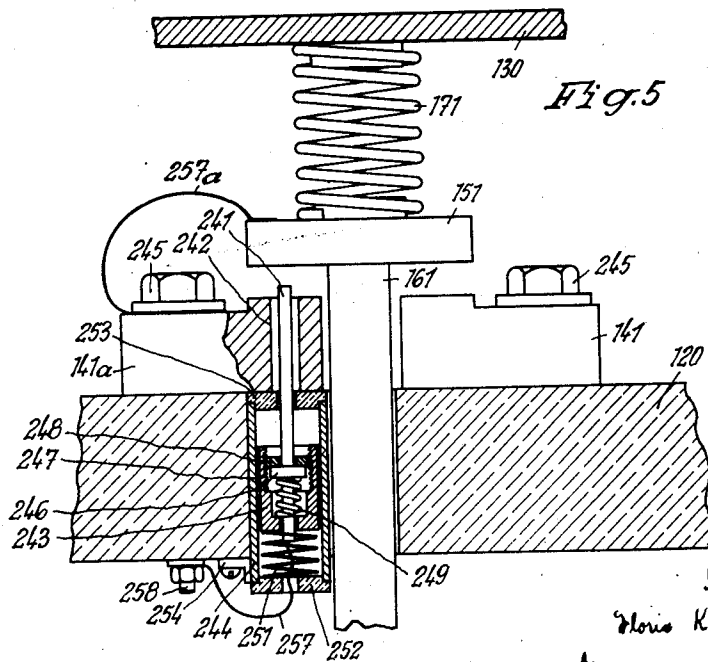
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Inventor  
F. Koppelman  
by Knight Bros  
attorneys

## UNITED STATES PATENT OFFICE

2,188,361

## APPARATUS FOR CONVERTING CURRENTS

Floris Koppelman, Berlin-Siemensstadt, Germany, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt, Germany, a corporation of Germany

Application October 5, 1937, Serial No. 167,422.  
Renewed May 2, 1939. In Germany October 5, 1936

24 Claims. (Cl. 175-364)

The present invention relates to an apparatus for converting single phase or polyphase alternating current into direct current or vice versa, or single phase or polyphase alternating current into alternating current of another frequency by means of periodically operated mechanical contacts. Such an apparatus is described in the copending application Serial No. 114,965, filed on December 9, 1936. An apparatus of the above-mentioned character differs from the known apparatus of similar type by the use of means for simultaneously influencing the current and the voltage across the switching gap of each phase. These means consist of a current distorting impedance connected in series with the switching gap, and of a current path connected in parallel relation to the make and break contacts. Some particularly advantageous types of said means will be hereinafter described, and others which may also be used in connection with the present invention form the subject matter of the following copending applications: Serial No. 122,232, filed on January 25, 1937; Serial No. 129,987, filed on March 10, 1937; Serial No. 128,185, filed on February 27, 1937; Serial No. 125,363, filed on February 12, 1937; Serial No. 133,758, filed on March 30, 1937.

The purpose of the simultaneous influencing of the current and voltage is to suppress the arcing when opening the make and break contacts by automatically causing the current to assume substantially the zero value shortly before the beginning of the opening of the contacts and to maintain the zero value for a certain interval while the contacts are opened, whereas the current interrupted at the make and break contacts is at least partly maintained through the parallel path in such a manner that the voltage drop of the circuit to be interrupted is applied at first substantially to the impedances connected in series to the make and break contacts and that the voltage across the make and break contacts increases only gradually. The ratio of the resistance of the parallel path to the resistance of said impedances is chosen in this case so small, and the increase of the restriking voltage is thereby so retarded, compared to the speed with which the contacts are broken by the mechanical drive of the converting apparatus, that the restriking voltage across the switching gap is at every moment smaller than the voltage necessary for the rupture of the switching gap produced. In this manner, the contacts, even in the case of a great average operating current and a high average operating voltage, are not any more

stressed at the moment at which the contacts are broken than in the case of a weak current system in which currents of the order of magnitude of 1 ampere or less flow or in which an operating voltage of the order of 10 volts or less is present.

A particularly advantageous means for attaining the above-mentioned automatic distortion of the current is a so-called switching reactor which is series-connected to the make and break contacts. Such a switching reactor is also described in the above-mentioned copending application Serial No. 114,965. It consists of an inductance coil whose iron core consists of a particularly high-graded ferromagnetic iron alloy of extreme permeability and of extremely great saturation induction, which iron is suddenly saturated with increasing current upon exceeding a predetermined current value, as is manifested by a relatively sharp saturation bend of its magnetization curve. The number of turns of the coil is so chosen that the coil is unsaturated only at very small instantaneous values of the current in the neighborhood of the zero value and is saturated already upon exceeding an instantaneous value of the current of the order of one thousandth or of one ten-thousandth of the normal average operating current. The resistance of such a reactor is very small in the saturated state. It permits, therefore, in the state of saturation the passage of the normal operating current during the greatest portion of each period during which the current flows without appreciably impeding this current. However, as soon as the reactor, owing to the decrease of the current below a predetermined value, is suddenly desaturated while the current according to the descending portion of its curve approaches the zero value, the resistance of the reactor assumes almost instantaneously a very high value which is several thousand times greater than the resistance in the saturated state. Consequently, the current flowing through the reactor during the period of the desaturation is greatly impeded and there occurs a weak current interval during which the current intensity has a negligible value, i. e., is practically zero. The reactor must be so dimensioned that this interval is of the order of a millisecond. During this time the contacts may be broken without there occurring any arcing, if as a result of a suitable dimensioning of the current path parallel to the contacts care is taken to increase the restriking voltage only slowly. The resistance of the parallel path must be so rated that it amounts only to a fraction of the resistance of the reactor in the unsaturated state;

then the total voltage of the circuit distributes itself in proportion to the said resistances over the switching gap and the reactor, provided that all other resistances may be neglected. The total voltage of the circuit is therefore almost exclusively applied to the reactor in the unsaturated state.

By an auxiliary winding on the magnet core of the reactor, the latter may be biased additionally opposite to the direction of the operating current to be transmitted in such a manner that the desaturation of the reactor occurs already while the operating current varies according to the descending portion of its current curve and still has a positive instantaneous value, i. e., before the operating current passes through its zero value. The additional magnetic bias may be effected with the aid of direct current or by an alternating current which has the same frequency as the alternating current to be converted and whose position of phase is adjustable with the aid of an induction regulator or the like in such a manner that the magnetic bias has at the desired moment before the breaking of the contacts the desired direction opposite to the direction of the operating current.

The present invention relates to improvements of converting apparatus of the above-outlined type, and especially refers to the switching-in operation of the contacts. The nature of these improvements will be apparent from the following considerations.

The above-mentioned means for simultaneously influencing the current and the voltage may under certain circumstances cause relatively large currents to occur when switching in the make and break contacts. These large currents may be due to the fact that the switching reactor—which when being switched out is unsaturated and has a very high resistance—may under certain conditions be just in the state of saturation when being switched in and therefore have a very small resistance. A further reason for the occurrence of large currents at the switching in moment is that the condensers connected in parallel relation to the make and break contacts are discharged when switching in. Furthermore, relatively high voltages may occur across the switching gap shortly before the engagement of the contacts. Consequently, an arc may be produced when switching in, which carries immediately a current of relatively high intensity, whereby the contacts may be damaged and become useless after a relatively short operating period. Such damages are the more likely, if the contacts are made of good conducting metals, such as silver, copper or the alloys thereof for the purpose of reducing the voltage losses during the period of the current flow. In series with the parallel-connected condensers, high-ohmic resistors could be connected by which the discharge current of the condensers is maintained small. The resistance of such resistors would, however, be so great in this case that the striking voltage when switching out may not be sufficiently reduced and consequently the danger of an arcing now would be increased when switching out.

The main object of the present invention consists in preventing the creation of large currents or current surges at the closing moment of the contacts when switching in the circuit breakers.

A further object of the invention consists in reducing the voltage existing across the switching gap immediately before the closing moment

of the contacts in such a manner that a sparking cannot take place before the closure of the contacts.

According to the invention an additional reactor is employed in connection with every circuit breaker to which a switching reactor is connected in series. This additional reactor herein-after referred to as switching-in reactor is so arranged that it lies shortly before and when switching in the circuit breaker in a circuit which includes in series the make and break contacts, the condenser of the parallel path and the switching-in reactor. The switching-in reactor has also an auxiliary exciting winding by means of which it is so biased with direct current or alternating current that it is magnetically saturated when switching out; i. e., the switching-in reactor has a low resistance for the current flowing therethrough when switching out, whereas it is unsaturated when switching in so that it has a high resistance for the current flowing therethrough at the switching-in moment.

For a better understanding of the present invention reference may be made to the accompanying drawings in which

Fig. 1 shows a three-phase converting apparatus, the fundamental total connection according to the above-mentioned copending application Serial No. 114,965 being shown schematically while the switching apparatus is illustrated more in detail.

Figs. 2 to 4 show three different forms of the invention in which for the sake of simplicity only that portion of one phase is indicated which manifests the inventive improvements, whereas the mechanical portion of the converting apparatus is shown schematically. The part circuits shown may be employed in a single phase system or may be according to Fig. 1 combined to arrangements of any number of phases.

Fig. 4a shows a modified detail of Fig. 4.

Fig. 5 shows in detail the contact device of the arrangement according to Fig. 4 on an enlarged scale.

The arrangement according to Fig. 1 consists of four main groups of parts, namely the power source 1 which supplies the converting apparatus with three-phase alternating current through an intermediate transformer; the switching device 2 which is equipped with an adjustable synchronous drive; the device 3 for influencing the voltage and the devices 4 for influencing the current.

To the supply circuit fed by the power source 1 are connected the input terminals 101, 102, 103 of the primary windings 111, 112, 113 of a transformer whose secondary windings are designated by the numerals 121, 122, 123. The secondary winding is star-connected. The neutral point is connected to the current consuming device 210 through a conductor. From the free terminals of the windings 121, 122, 123 extend the main conductors to the switching reactors 304, 314, 324 which are wound on the magnet cores 305, 315, 325. The cores are provided with auxiliary exciting windings 317, 318, 319 which are biased by a direct-current source (battery) 191. In the biasing circuit is inserted a rheostat 360 which permits adjusting the magnitude of the biasing current to the desired value depending upon the operating conditions. Furthermore, in the direct-current circuit is inserted a reactance coil 361 which prevents the pulsations of current which might be caused by the inductive coupling of the biasing coil with the main coils of the

switching coils from reaching the direct-current source.

From the switching coils extend main conductors to each of the make and break contacts 141, 142, 143 which are arranged in pairs. The latter are placed on the intermediate plate 120 of an insulating frame 190. Each stationary contact pair cooperates with a movable contact 151, 152, 153 which in the closed position bridges the make and break contacts and is under the influence of a spring 171, 172, 173 respectively which in turn presses against a cross bar 130 of insulating material. The main current circuit extends from the second contact of each contact pair to a common conductor 145 which forms the other pole of the current consuming device 210 and in which is inserted a smoothening inductance coil 114.

To the make and break contacts are parallel-connected the current paths 115, 125, 135 respectively which may consist of ohmic or inductive or of capacitive resistor units or of any combination of such resistor units and which under certain conditions may be provided with the additional devices hereinafter described in connection with Figs. 2 to 4.

The movable bridge contacts 151, 152, 153 perform in operation an upward movement which is brought about by tappets 161, 162, 163 consisting of insulating material. The latter are under the influence of a spring 171', 172', 173' respectively and are operated by cams 181, 182, 183 which are firmly mounted on a shaft 108 and angularly displaced by 120° with respect to one another. The shaft 108 is mounted in the frame 190 and is driven by the synchronous motor 106 through an intermediate coupling 107. The synchronous motor is connected to the secondary winding 226 of an induction regulator whose primary side is connected to the output terminals of the secondary windings 121, 122, 123. The induction regulator serves to vary the phase position of the rotating field of the driving motor 106; in this manner the moments at which the contacts are closed and opened are so adjusted that the opening of the contacts always occurs during the above explained weak current intervals in the neighborhood of the zero value of the current to be interrupted. On the shaft 108 are further arranged auxiliary circuit breakers 90 cooperating with current collectors (brushes) 95 which are held by supports 99 secured to the intermediate plate 120. The purpose and the operation of the last-mentioned auxiliary circuit breakers are hereinafter described in connection with Fig. 4. By the simultaneous adjustment of the biasing current with the aid of the rheostat 360 and of the moments at which the contacts are opened and closed with the aid of the induction regulator 116, 126 a control of the current and the voltage may also be attained within wide limits (cf. the above-mentioned copending application Serial No. 122,232).

In Fig. 2, 304 denotes the switching reactor with the magnet core 305 and the auxiliary biasing winding 317 which is connected to the direct-current source 191 through the rheostat 360 and the reactor 361. The main conductor extends from the switching reactor 304 through circuit breaker 2 to the conductor 145 leading to the current consuming device 210 (not shown in Fig. 2).

In parallel relation to the make and break contacts lies as above mentioned an impedance arrangement 115. This arrangement consists of a condenser 15 and a low-ohmic resistor 15'. In

the parallel path is further inserted an auxiliary switching reactor 504 which need only be rated for a small current, since the currents flowing through the parallel path amount to a fraction of the main current or only flow for a very short time. The magnet core 505 of the reactor 504 is also provided with a biasing winding denoted by the numeral 517 and connected to a battery 192 through a rheostat 560 and a reactor 561. The direction of current of the magnetic bias is so adjusted as to exert a magnetic action in the same direction as the current flowing into the condenser 15 when opening the contacts. The magnitude of the exciting current is so adjusted that the core 505 of the switching-in coil is just saturated if no current flows in the main winding 504. The discharge current created when closing the contacts flows in the opposite direction through reactor 504 and counteracts the direct-current magnetic bias. Consequently, the reactor becomes unsaturated shortly before the moment at which the contacts of breaker 2 are opened and assumes therefore a high resistance. The high inductive resistance prevents the capacitive discharge current from increasing until the contacts are firmly closed. In order to maintain the inductance of the reactor in the saturated state; i. e., the air inductance of its winding as small as possible very high-graded iron of very high permeability is preferably employed for the core 505 of this auxiliary switching-in reactor as well as for the core 305 of the main switching reactor in order to reduce the number of turns to a minimum. As stated above with relation to the main switching reactor, such ferromagnetic material of extremely high permeability is employed, the characteristic of which has a sharp saturation bend.

Since for purely geometrical reasons it is difficult to attain a value below a predetermined limit value for the air inductance of the auxiliary switching-in reactor it is advisable to connect two or, if desired, also various of such switching-in reactors in parallel relation with one another in such cases where a very small air inductance, i. e., a very small resistance is required for the current flowing in the charging direction. To this end, a second auxiliary switching reactor 504a with the core 505a and the biasing winding 517a is provided in Fig. 2. The biasing windings 50517 and 517a are connected in series.

This arrangement may be advantageously employed not only in the manner as shown in the embodiment of Fig. 2 but also represents a valuable improvement in all switching devices of any arrangement, such as is, for instance, the case with rectifiers and inverters of different types, highly sensitive regulators and relays to which a condenser is connected in parallel relation for facilitating the switching out operations.

In the embodiment shown in Fig. 3 an auxiliary switching reactor 604 is not arranged in the parallel path but directly in series with the circuit breaker 2. The iron core 605 of this auxiliary switching reactor is provided with two auxiliary exciting windings 617 and 617a. The exciting winding 617 is fed by the battery 193 through a rheostat 660 and a reactor 661. The exciting winding 617a is connected to an alternating-current source 195. The latter must have the same frequency as the alternating current taken from the main transformer. The exciting winding 617a may, for instance, be directly connected—if desired, through an auxiliary induction regulator 664 serving to accurately adjust

the proper position of phase—to one of the secondary windings of the feeding main transformer itself which has the suitable position of phase for this purpose. Furthermore, in the auxiliary exciting circuit lies a rheostat 663 and another auxiliary switching reactor 704 with an iron core 705. This auxiliary switching reactor 704 need only be rated for a very small current. Its iron core 705 has an additional exciting winding 717 which is fed from a battery 194 through a resistor 760 and a reactance coil 761.

The current flowing in the exciting winding 617 is so adjusted that the core 605 is biased in the opposite direction as by the main current. The magnitude of this exciting current is so adjusted with the aid of the rheostat 660 that the state of saturation is nearly attained by the bias effected by winding 617 alone. If the main current begins to flow shortly after the contacts have been closed the switching reactor 604 has a very high resistance and consequently maintains the current at a low value until the state of saturation is attained when the current flows in the opposite direction. The exciting winding 617a is not effective during this interval, for the magnitude and direction of the biasing current in the winding 717 and the magnitude and phase position of the alternating current taken from the power source 195 are so chosen that the core 705 is unsaturated shortly before the closure of the contacts 2 so that the auxiliary switching reactor 704 has a very high resistance and the current flowing therein and therefore in the winding 617a is practically zero. However, as soon as the contacts are closed the core 705 attains the state of saturation. In this manner the resistance of the switching coil 704 drops to a very low value. The switching reactor 704 permits therefore substantially without any hindrance the passage of the alternating current taken from the power source 195. The magnitude and the position of phase of this alternating current is so chosen that it exerts a magnetic effect on the core 605 in the same direction as the main current in the switching reactor 604. The switching reactor 604 is therefore rendered ineffective by the alternating current during the period of the flow of current proper and during the time the main contacts 2 are being separated.

In order to reduce also the voltage across the make and break contacts when switching in, a special parallel path is provided as shown in the embodiment according to Fig. 3 in which is inserted a low-ohmic resistor 624 and which is controlled by an auxiliary contact device 620. This auxiliary contact device consists of two stationary contacts 641 and a revolving part 651 which is driven in synchronism with the driving shaft for the main contact device and is so adjusted that it closes a parallel circuit shortly before the main contacts close. Since the auxiliary contact device 620 has only to carry a very small current momentarily and since a good contact is not essential insofar as also in the case of a relatively bad contact the resistance of the parallel path is always so small as to be neglected with respect to the resistance of the auxiliary switching reactor 4 which is at the same time in an unsaturated state, a slight consumption of the auxiliary contact device 620 may be put up without impairing the normal operation of the converter. Furthermore, the auxiliary contact may be made of a material which is particularly resistant to arcing; for instance of tungsten. For the above-mentioned reasons it

is immaterial if the contact material has a greater resistance and a greater contact resistance than the main contacts.

As soon as the parallel path is closed by the auxiliary contact device 620, the total voltage distributes itself over the contact device 2 and the auxiliary switching reactor 604 according to the ratio of the resistance of the parallel path in which the resistor 624 and the auxiliary switching device 620 are inserted, to the resistance of the auxiliary switching reactor 604 which is in an unsaturated state. Since the resistance of the parallel path amounts only to a fraction of the resistance of the unsaturated auxiliary reactor the voltage across the main contacts shortly before their closure is so small as to be neglected. An arcing will therefore not occur at the main contacts.

Also in the embodiment shown in Fig. 4 the auxiliary switching reactor 604 is connected in series with the interrupting device 2 and both are bridged by the parallel path through the resistance combination 115 consisting of an ohmic resistor 15' and a condenser 15. The iron core 605 of the auxiliary switching reactor 604 carries an auxiliary winding 617 for effecting a magnetic bias. Winding 617 is energized by the power source 193 through a reactor 661 and a rheostat 660. The magnetic bias is so adjusted that shortly before the engagement of the contacts 141, 141a and 151 the core 605 of the auxiliary switching reactor is in a nearly saturated state opposite to the direction of the main current which begins to flow through the auxiliary switching reactor 604 after the closure of the contacts. This main current therefore maintains practically the zero value until it has reversed the magnetization of the iron core and until the state of saturation is attained in the other direction. Only in this case the main current may flow through reactor 604 without hindrance. In order to maintain also the voltage between the contacts at a low value shortly before the engagement of the contacts, a further parallel path is directly parallel connected to the contacts 141 and 141a, the resistance of this parallel path being small compared to the resistance of the auxiliary switching coil 604 which is at this moment in an unsaturated state. The parallel path consists of a discharge tube 820 whose grid 821 is connected through a high-ohmic resistor 822 to an auxiliary contact 241, the closure of which leads. The grid 821 is biased by a battery 197 through a high-ohmic resistance 823. The cathode is heated by a heating battery 198. A protective resistor 824 is connected in series with the discharge tube 820. Instead of the resistance 824 also a condenser 815 with a parallel-connected resistor 824 may be series-connected to the discharge tube. Another switching reactor 804 may be arranged in the lead to the discharge tube in order to protect the tube against a dangerous over-current. The iron core 805 of the reactor 804 is provided with an additional biasing winding 817 which is energized by the direct-current source 196 through a reactor 861 and a rheostat 860. The magnetic bias is effected in a direction opposite to the direction of the current flowing normally through the discharge tube. The magnitude of the biasing current is so adjusted that the auxiliary switching reactor 804, 805 is highly saturated and permits the current to flow in normal operation through the discharge tube 820 without exceeding the saturation point. In cases where considerably greater cur-

rents may occur which would stress and destroy the discharge tube the auxiliary switching reactor 804, 805 comes within the working range below the saturation so that such dangerous currents are prevented by the high inductive resistance of the unsaturated auxiliary switching reactor 804. If as above mentioned a condenser 815 with a parallel-connected ohmic resistance 824 is arranged in series with the auxiliary switching reactor 804 the condenser protects also the discharge tube even if the magnetization of the auxiliary switching coil 804, 805 has attained the saturation point in the opposite direction after reversal by the interfering current. The auxiliary reactor 804, 805, therefore, may be dimensioned smaller, as if the condenser 815 and the parallel resistor 824 were not available. A resistor 808 having a high resistance may be parallel-connected to the auxiliary switching reactor 804 in order to facilitate the equalization of the magnetic energy when reversing the magnetism thereof.

The grid bias of the discharge tube 820 is adjusted to such a high value that the flow of current therethrough is prevented so long as the auxiliary contact 241 is not in engagement with the movable contact 151. The latter is connected to the stationary contact 141a by a flexible auxiliary conductor. As soon as it engages the preliminary contact 241 the grid inverse voltage will be reduced. The discharge tube 820 allows therefore a current to flow therethrough. Consequently, the voltage at the main contacts 141 and 141a drops substantially to a value equal to the sum of the ignition voltage of the discharge tube 820 and of the voltage drop in the protective devices 815, 824, 804 and 808. This residual voltage across the contacts amounts only to a fraction of the total voltage which is substantially applied to the auxiliary switching reactor 604 being just unsaturated at this moment. Owing to the small residual voltage across the switching gap an arcing cannot occur across the contacts 141 and 151.

An advantageous arrangement of the leading auxiliary contact 241 is illustrated in Fig. 5 in which the contact device shown in Fig. 4 is illustrated on an enlarged scale. The contact device consists as shown in Fig. 1 of the stationary contacts 141, 141a secured to the insulating plate 120. The movable contact 151 is under the influence of the spring 171 which presses against a second insulating plate 130. The drive is brought about by the tappet 161. The terminals for the leads are denoted by the numeral 245. The stationary contact 141a is provided with a bore 242 in which moves the pin contact 241. The contact pin has a collar 246 and may be moved within a piston-shaped sleeve 243. The movement within this sleeve is limited by a stop 259 and an inner nut 248 which is adjustable by means of a fine thread 247. The collar 246 is pressed against the adjusting nut 248 by a spring 249. Upon the downward movement of the tappet 161 and the movable contact 151 the pin contact 241 is pressed down against the force of the spring 249. The piston-shaped sleeve 243 is movably arranged within a second sleeve 244 which is secured to the insulating plate 120 by means of an angle iron 254. The outer sleeve 244 is closed at both ends by covers 252 and 253 consisting of insulating material and being each provided with a bore. The bore of the cover 253 serves as a guide for the contact pin 241. Between the lower cover 252 and the piston-shaped

sleeve 242 is arranged a weak spring 251 which tends to press the sleeve 242 in the upward direction. The movement is, however, damped by the air above the sleeve 243 and is limited by the engagement of the collar 246 of the contact pin 241 with the stop 259 upon the closure of the contacts. The piston-shaped sleeve 243 may therefore move in the upward direction during the operating period only gradually by the same amount as the upper end of the auxiliary contact 241 wears off with time. In this manner the contact pin 241 is automatically readjusted during the operating period by such an amount that its upper end projects beyond the contact surface of the stationary contact 141a always the same length when opening the contacts. The length of this portion of the pin may be so adjusted with the aid of the adjusting nut 248 that the time interval which elapses between the engagement of the auxiliary contact 241 and the movable contact 151 and that of the movable contact 151 and the stationary main contact 141, has the desired value. This value is maintained constant during the operation owing to the automatic adjustment by the spring 251.

A conductor 257 extends through the bore of the lower cover 252 from the contact pin 241 to the terminal 258. Another auxiliary conductor 257a extends from the movable contact 151 to the stationary contact 141a. Both auxiliary conductors carry only the current flowing in the grid circuit of the discharge tube 820 and are therefore very thin.

Furthermore, in Fig. 4 is provided a device by which the auxiliary switching reactor 604 is short-circuited during the period of flow of current proper. This device consists of a contact device 90 driven in synchronism with the shaft and of the brushes 95 which are connected to the ends of the reactor 604 through conductors. The contact device 90 consists of two segments 91 which are directly connected to each other. Adjacent to each of these segments are arranged two short segments in the direction of rotation which are connected to the bridging segments 91 through the resistors 96 and 97. The short-circuit of the switching reactor is therefore not suddenly eliminated but a resistance is at first gradually inserted in the bridging short-circuit connection. In this manner the interruption of the short-circuit connection is rendered as sparkless as possible. Instead of connecting the short-circuit conductor of the brushes 95 directly to the ends of the auxiliary switching reactor 604 the latter may be provided according to Fig. 4a with an additional short-circuit winding 606 having a slight leakage to which the bridging contact device 90, 95 is connected.

As shown in Fig. 1 the revolving contact device 90 is mounted on the same shaft 108 as the driving cams for the contact device. The supports 99 for the brushes 95 are secured to the plate 120 of the insulating frame 190.

The invention may be embodied in other forms than those shown and described without departing from the scope of the invention.

What is claimed is:

1. An arrangement for converting alternating current into direct current or vice versa, or alternating current of one frequency into alternating current of another frequency, comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising a

switching reactor series-connected with said make and break contacts and designed to abruptly increase its impedance at small instantaneous values of the current in the neighborhood of its zero value, and a voltage-biasing impedance path parallel-connected to said make and break contacts for reducing the operating voltage recurring between said contacts, in combination with a variable auxiliary inductance designed to have a high resistance when switching in said make and break contacts, said inductance being series-connected in a circuit including said make and break contacts and said parallel path.

2. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising an inductance coil series-connected with said contacts and having a magnetic core designed to become abruptly unsaturated at current intensities near the zero value and of a current path including capacitors arranged in parallel to said make and break contacts for reducing the operating voltage recurring between said contacts, in combination with an auxiliary switching-in reactor connected in series with the make and break contacts in the circuit including said contacts and said parallel path, said switching-in reactor having a magnet core designed to be unsaturated only at small instantaneous current values in the neighborhood of the zero value and to become saturated upon the instantaneous current exceeding a given value which amounts to a fraction of the mean current carried by said switching-in reactor in the state of saturation.

3. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising a current-biasing reactor series-connected to said make and break contacts and a voltage-biasing current path parallel-connected to said make and break contacts for reducing the operating voltage recurring between said contacts, in combination with an auxiliary switching-in reactor connected in series with said make and break contacts in the circuit including said make and break contacts and said parallel path, said switching-in reactor having a magnet core designed to become abruptly unsaturated upon the lowering of the instantaneous current intensity to values in the neighborhood of the zero value, a biasing winding arranged on the core of said switching-in reactor, and a biasing circuit connected to said winding, said circuit including an auxiliary current source and variable means for controlling the magnetic bias effected by said winding.

4. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising a current-biasing reactor series-connected to said make and break contacts and designed to periodically increase its reactance at low current intensities, and a voltage-biasing current path parallel-connected to said make and break contacts for reducing the operating voltage recurring between said contacts, in combination with an auxiliary switching-in reactor connected in series with said make and break contacts in the circuit including said make and break contacts and said

parallel path, said switching-in reactor having a magnet core designed to become abruptly unsaturated upon the lowering of the instantaneous current intensity to values in the neighborhood of the zero value, a biasing winding disposed on the core of said switching-in reactor, a biasing circuit connected to said winding, an alternating current source having the frequency of the current to be interrupted by said contacts, said source being connected in said biasing circuit, and means in said circuit for controlling the phase position of the biasing current with respect to the phase position of said current to be interrupted.

5. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising a current-biasing reactor series-connected to said make and break contacts and designed to periodically increase its reactance at low current intensities, and a voltage-biasing current path parallel-connected to said make and break contacts for reducing the operating voltage recurring between said contacts, in combination with an auxiliary switching-in reactor connected in series with said make and break contacts in the circuit including said make and break contacts and said parallel path, said switching-in reactor having a magnet core designed to become abruptly unsaturated upon the lowering of the instantaneous current intensity to values in the neighborhood of the zero value, a biasing winding arranged on the core of said switching-in reactor, and an energizing circuit connected to said winding, said circuit being so adjusted that said switching-in reactor is in the state of saturation upon the opening of said break and make contacts.

6. In combination with a device for closing and opening an alternating current circuit, a switching reactor having an inductance winding series-connected with said device so as to be traversed by the alternating current to be controlled by said device and a magnet core designed to be unsaturated at small current intensities in the neighborhood of the current zero value, an auxiliary biasing winding disposed on said magnet core, a second switching reactor having a main winding connected with said auxiliary biasing winding of said first reactor and a magnet core also designed to be unsaturated at said small instantaneous current intensities and saturated upon exceeding a predetermined intensity amounting to a fraction of the normal mean operating current flowing through said main winding of said second reactor, a biasing winding disposed on the core of said second reactor, and an energizing circuit connected with said latter biasing winding, said energizing circuit being adjusted to cause said second reactor to have in a given interval within each cycle of said alternating current an increased inductive resistance so that in said interval the auxiliary biasing current controlling said first reactor has a minimum value.

7. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising a self-saturating switching reactor series-connected to said make and break contacts for decreasing the current intensities in the neighborhood of the passage of the current through its zero value and voltage-biasing means con-

5 nected in parallel to said make and break contacts and being provided with a variable auxiliary impedance designed to have an increased impedance value when switching in said make and break contacts, and an auxiliary contact device for bridging said auxiliary impedance during a given interval within each current cycle, said interval including at least the period of the opening of said contacts.

10 8. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising  
15 a self-saturating switching reactor series-connected to said make and break contacts for decreasing the current intensities in the neighborhood of the passage of the current through its zero value and voltage-biasing means connected in parallel to said make and break contacts and being provided with a variable auxiliary impedance designed to have an increased impedance value when switching in said make and break contacts, an auxiliary contact device for bridging  
20 said auxiliary impedance, and means for operating said auxiliary contact device.

9. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising a self-saturating switching reactor series-connected to said make and break contacts for decreasing the current intensities in the neighborhood of the passage of the current  
30 through its zero value and voltage-biasing means connected in parallel to said make and break contacts and being provided with an auxiliary switching reactor designed to have an increased resistance when switching in said make and break contacts, said auxiliary reactor having a magnet core and an additional biasing winding arranged on said core so as to have a slight leakage, and an auxiliary contact device for  
40 bridging said additional winding during the opening of said make and break contacts.

10. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising a self-saturating switching reactor series-connected to said make and break contacts for decreasing the current intensities in the neighborhood of the passage of the current  
50 through its zero value and voltage-biasing means connected in parallel to said make and break contacts and being provided with a variable auxiliary impedance designed to have an increased impedance value when switching in said make and break contacts, a parallel path containing current-limiting impedances, said path being arranged in parallel to said make and break contacts in order to reduce the voltage prevailing  
60 across the switching gap between said contacts, and means for connecting said parallel path with said make and break contacts shortly before their closure.

11. A current converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means comprising a self-saturating switching reactor series-connected to said make and break contacts  
70 for decreasing the current intensities in the neighborhood of the passage of the current through its zero value and voltage-biasing means connected in parallel to said make and break contacts and being provided with a variable auxiliary impedance designed to have an increased impedance value when switching in said make and break contacts, a parallel path containing current-limiting impedances, said path being arranged in parallel to said make and break contacts in order to reduce the voltage prevailing across the switching gap between said contacts, an auxiliary contact device for closing said parallel path shortly before the closure of said make and break contacts, and means for operating said auxiliary contact device in synchronism with said switching device.

12. A converting arrangement comprising a switching device having mechanically operated contacts, means for simultaneously influencing the current and voltage across the switching gap, said means consisting of a current-biasing self-saturating switching reactor series-connected to said contacts and of a voltage-biasing path parallel-connected to said contacts, said means being further provided with a variable auxiliary impedance having a high impedance value when closing said contacts, a second parallel path including current-limiting devices and being directly parallel-connected to the make and break contacts in order to reduce the voltage prevailing across the switching gap between said contacts, said second parallel path containing a grid controlled discharge tube, an auxiliary current source connected in the grid circuit of said tube for supplying a blocking voltage to said grid, an auxiliary contact device connected with said grid circuit so as to diminish when operated said grid voltage in order to allow a current flow through said tube, and means for operating said auxiliary contact device in synchronism with said switching device so as to be actuated shortly before the closure of the contacts of said switching device.

13. A converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means consisting of a self-saturating switching reactor series-connected to the make and break contacts and of a voltage-biasing path parallel-connected to said make and break contacts, and being provided with a variable auxiliary impedance having a high impedance value when closing the make and break contacts, an automatic device for bridging said make and break contacts shortly before their closure through a second parallel path including current-limiting impedances and being directly parallel-connected to said make and break contacts in order to reduce the voltage prevailing across the switching gap, said bridging device comprising a grid controlled discharge tube, an ohmic resistance series-connected with said tube for protecting said tube against overload in case of disturbances, and means for controlling the grid voltage of said tube in dependency upon the operation of said make and break contacts.

14. A converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means consisting of a self-saturating switching reactor series-connected to said make and break contacts and of a current-biasing path parallel-connected to said make and break contacts, and being provided with a variable auxiliary impedance having a high impedance value when closing the make and break contacts, an automatic device for bridging said make and break contacts shortly before their closure through a second parallel path including current-limiting impedances and being directly parallel-connected to said make and break contacts in order to reduce the voltage prevailing across the switching gap, said bridging device comprising a grid controlled discharge tube, an ohmic resistance series-connected with said tube for protecting said tube against overload in case of disturbances, and means for controlling the grid voltage of said tube in dependency upon the operation of said make and break contacts.

15. A converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means consisting of a self-saturating switching reactor series-connected to said make and break contacts and of a current-biasing path parallel-connected to said make and break contacts, and being provided with a variable auxiliary impedance having a high impedance value when closing the make and break contacts, an automatic device for bridging said make and break contacts shortly before their closure through a second parallel path including current-limiting impedances and being directly parallel-connected to said make and break contacts in order to reduce the voltage prevailing across the switching gap, said bridging device comprising a grid controlled discharge tube, an ohmic resistance series-connected with said tube for protecting said tube against overload in case of disturbances, and means for controlling the grid voltage of said tube in dependency upon the operation of said make and break contacts.

rent path parallel-connected to the make and break contacts, and being provided with a variable auxiliary impedance having a high impedance value when closing said make and break contacts, a device for bridging said make and break contacts shortly before their closure through a second parallel path including current-limiting devices and being directly parallel-connected to said make and break contacts in order to reduce the voltage prevailing across the switching gap, said bridging device comprising a grid controlled discharge tube, a parallel-connection disposed in series with said tube and including a condenser and an ohmic resistor for protecting said tube against overload in case of disturbances, and means for controlling said tube in dependency upon the operation of said make and break contacts.

15. A converting arrangement comprising a switching device having mechanically operated make and break contacts, means for simultaneously influencing the current and voltage across the switching gap, said means consisting of a self-saturating switching reactor series-connected to said make and break contacts and of a current path parallel-connected to said make and break contacts, and being provided with an auxiliary switching-in reactor having a high resistance when closing said make and break contacts, a device for bridging said make and break contacts shortly before their closure through a second parallel path including current-limiting devices and being directly parallel-connected to said make and break contacts in order to reduce the voltage prevailing across the switching gap, a grid controlled discharge tube arranged in said second parallel path, an auxiliary switching reactor having a main winding series-connected with said tube and a magnet core designed to become unsaturated at low current intensities near the zero value, a biasing winding on said core, and an energizing circuit connected with said biasing winding, said energizing current being adapted to supply said biasing winding with a current acting in opposition to the current flowing through said tube and magnetizing said core to such an extent beyond its saturation point that said current flowing through said tube during normal operation does not cause said magnetization to drop below said saturation point.

16. A converting arrangement comprising a switching device having mechanically operated main contacts, means for simultaneously influencing the current and voltage across the switching gap, said means consisting of a self-saturating switching reactor series-connected to said contacts and of a current path parallel-connected to said contacts, and being provided with a variable auxiliary impedance having a high impedance value when closing said contacts, an impedance arrangement disposed in parallel to said contacts and designed to bridge the switching gap shortly before each closure of said contacts, an auxiliary contact device for controlling said bridging arrangement, said contact device consisting of a contact pin movably disposed in a bore of a stationary contact of said main contacts so as to protrude from the contact surface of said stationary main contact in order to cooperate with the movable countercontact of said stationary main contact, spring means for holding said pin in said protruding position, and an adjustable stop for securing said position.

17. A converting arrangement comprising a switching device having mechanically operated

main contacts, means for simultaneously influencing the current and voltage across the switching gap, said means consisting of a self-saturating switching reactor series-connected to said contacts and of a current path parallel-connected to said contacts, and being provided with a variable auxiliary impedance having a high impedance value when closing said contacts, an impedance arrangement disposed in parallel to said contacts and designed to bridge the switching gap shortly before each closure of said contacts, an auxiliary contact device for controlling said bridging arrangement, said auxiliary contact device having a pin movably arranged in a bore of a stationary main contact so as to protrude from said contact in order to cooperate with the movable countercontact of said stationary main contact, a piston-shaped sleeve movably disposed on said pin and connected with said pin by a spring and an adjustable stop arrangement for limiting the relative movements between said sleeve and said pin, a stationary air cylinder surrounding said sleeve and designed for dampening the movements of said sleeve, and a spring disposed between said cylinder and said sleeve for holding said sleeve and said pin in operative position.

18. With a device for opening and closing an alternating current circuit at a moment of predetermined phase position with respect to the cycle of said current, in combination, voltage-biasing means connected in parallel to said device for reducing the increase of the operating voltage recurring at the opening moment across said device, an inductance coil connected in a circuit including in series said device and said means, said coil being provided with a core of ferromagnetic material having a high permeability and a magnetization curve with a sharp saturation bend, a biasing winding disposed on said core, and an energizing circuit connected with said winding and adapted to cause a desaturating bias of said core shortly before the closing moment of said device, thereby abruptly increasing the inductance of said coil.

19. With a contact device for opening and closing an alternating current circuit in a given time relation to the cycle of said current, said device being adjusted to effect said opening at a moment in the neighborhood of the zero value of said current, in combination, means connected with said circuit for distorting the curve of said current so as to produce a weak current interval including said opening moment, voltage-biasing means connected in parallel to said device for reducing the increase of the operating voltage recurring at the opening moment across said device, an inductance coil connected in a circuit including in series said device and said means, said coil being provided with a core of ferromagnetic material having a high permeability and a magnetization curve with a sharp saturation bend, a biasing winding disposed on said core, and an energizing circuit connected with said winding and adapted to cause a desaturating bias of said core shortly before the closing moment of said device, thereby abruptly increasing the inductance of said coil.

20. With a contact device for periodically opening and closing an alternating current circuit in synchronism with the cycle of said current, said device being adjusted to effect said opening at a moment in the neighborhood of the zero value of said current, in combination, a periodically variable impedance connected in said circuit and designed to increase its impedance value during

an interval including said opening moment, a reactive impedance path connected in parallel to the gap of said contact device for decreasing the voltage across said gap during the opening operation, an inductance coil series-connected in the circuit including said gap and said parallel path, said coil being provided with a core of ferromagnetic material having a high permeability and a magnetization curve with a sharp saturation bend, a biasing winding disposed on said core, and a biasing circuit connected with said winding and adapted to control the state of magnetization of said core and thereby the inductance of said coil shortly before the contact closing moment of said device in order to counteract the sparking tendency caused by said parallel path during the closing operation of said device.

21. With a device for opening and closing an alternating current circuit in a given time relation to the cycle of said current, said device being adjusted to effect said opening at a moment in the neighborhood of the zero value of said current, in combination, means connected with said circuit for distorting the curve of said current so as to produce a weak current interval including said opening moment, a capacitive path connected in parallel to said device for decreasing the voltage across said device during the opening operation, an inductance coil series-connected in the circuit including in series said device and said parallel path, said coil being provided with a core of ferromagnetic material having a high permeability and a magnetization curve with a sharp saturation bend, a biasing winding disposed on said core, and a biasing circuit connected with said winding and adapted to control the state of magnetization of said core and thereby the inductance of said coil shortly before the closing moment of said device in order to impede the capacitive discharge current of said path during the closing operation of said device.

22. With a device for opening and closing an alternating current circuit in a given time relation to the cycle of said current, in combination, a capacitive path connected in parallel to the gap of said device for decreasing the voltage across said gap during the opening operation of said device, an inductance coil series-connected in the circuit including in series said gap and said parallel path, said coil being provided with a core of ferromagnetic material having a high permeability and a magnetization curve with a sharp saturation bend, a biasing winding disposed on said core, and a biasing circuit connected with said winding and adapted to control the state of magnetization of said core and thereby the inductance of said coil shortly before the closing moment of said device in order to impede the capacitive discharge current of said path during the closing operation of said device.

allel path, said coil being provided with a core of ferromagnetic material having a high permeability and a magnetization curve with a sharp saturation bend, a biasing winding disposed on said core, and a biasing circuit connected with said winding and adapted to control the state of magnetization of said core and thereby the inductance of said coil shortly before the closing moment of said device in order to impede the capacitive discharge current of said path during the closing operation of said device.

23. With a contact device for opening and closing an alternating current circuit in a given time relation to the cycle of said current, said device being adjusted to effect said opening at a moment in the neighborhood of the zero value of said current, in combination, means connected with said circuit for distorting the curve of said current so as to produce a weak current interval including said opening moment, a reactive path connected in parallel to the gap of said contact device for decreasing the voltage across said gap during the opening operation of said device, a variable impedance series-connected in the circuit including said gap and said parallel path, controlling means for causing said variable impedance to vary its impedance value shortly before the contact closure of said device so as to counteract the sparking tendency caused by said parallel path at the closing moment of said device.

24. A current converting arrangement comprising a switching device having periodically operating make and break contacts, a saturable reactor series connected to said contacts for periodically producing a weak current interval at low current intensities, means for controlling said reactor to effect said weak current interval in a desired time relation to the operation of said switching device, a second saturable reactor having one pole connected with one of said contacts and the other pole connected with the other contact of said switching device so as to form part of a parallel circuit with respect to the switching gap between said contacts, and means for controlling said second reactor to cause said reactor to increase its reactance shortly before the closing moment of said contacts.

FLORIS KOPPELMANN.