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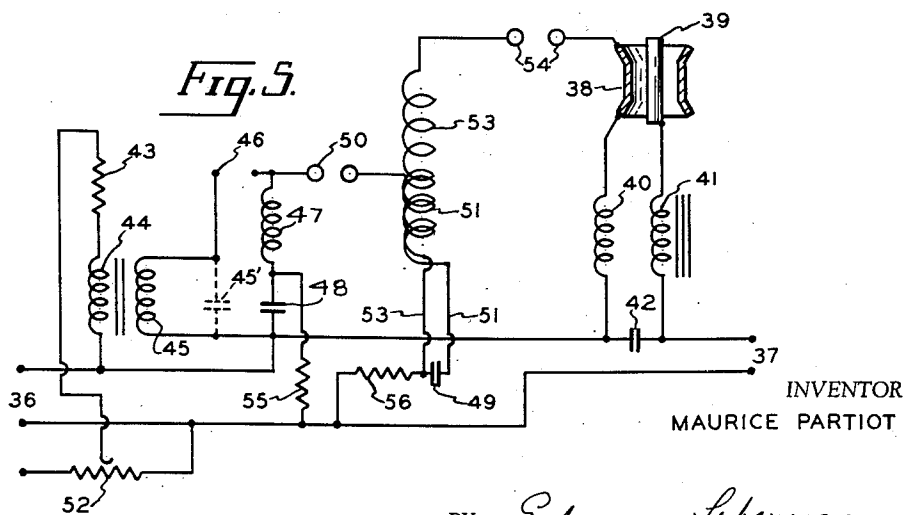
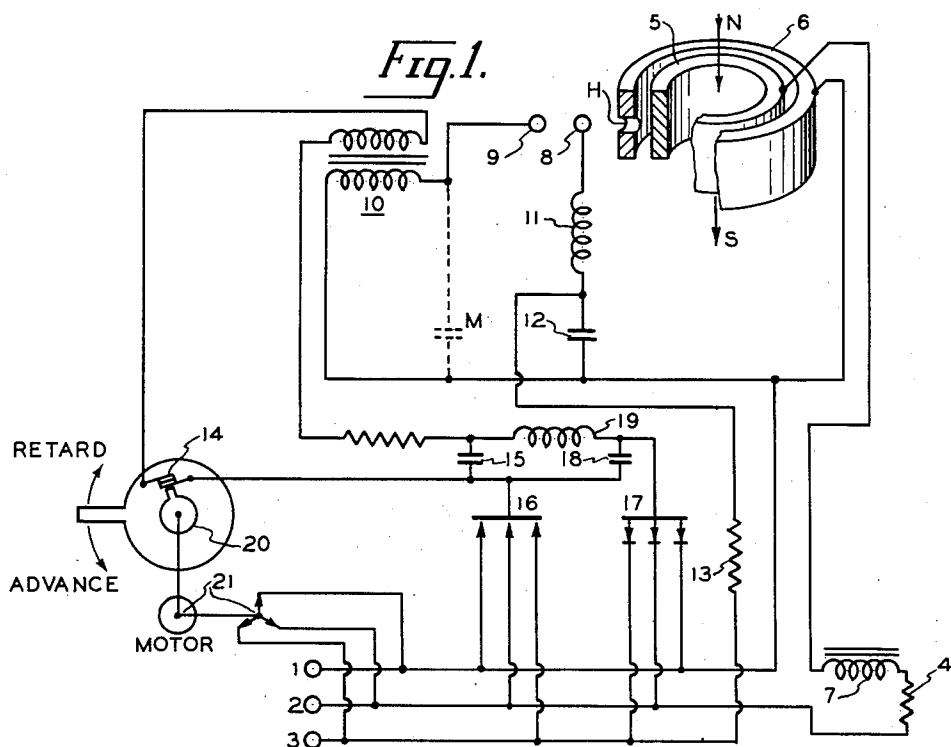
M. PARTIOT

2,581,970

SYSTEM FOR CONTROLLING FLOW OF ELECTRIC CURRENTS

Filed June 20, 1949

3 Sheets-Sheet 1



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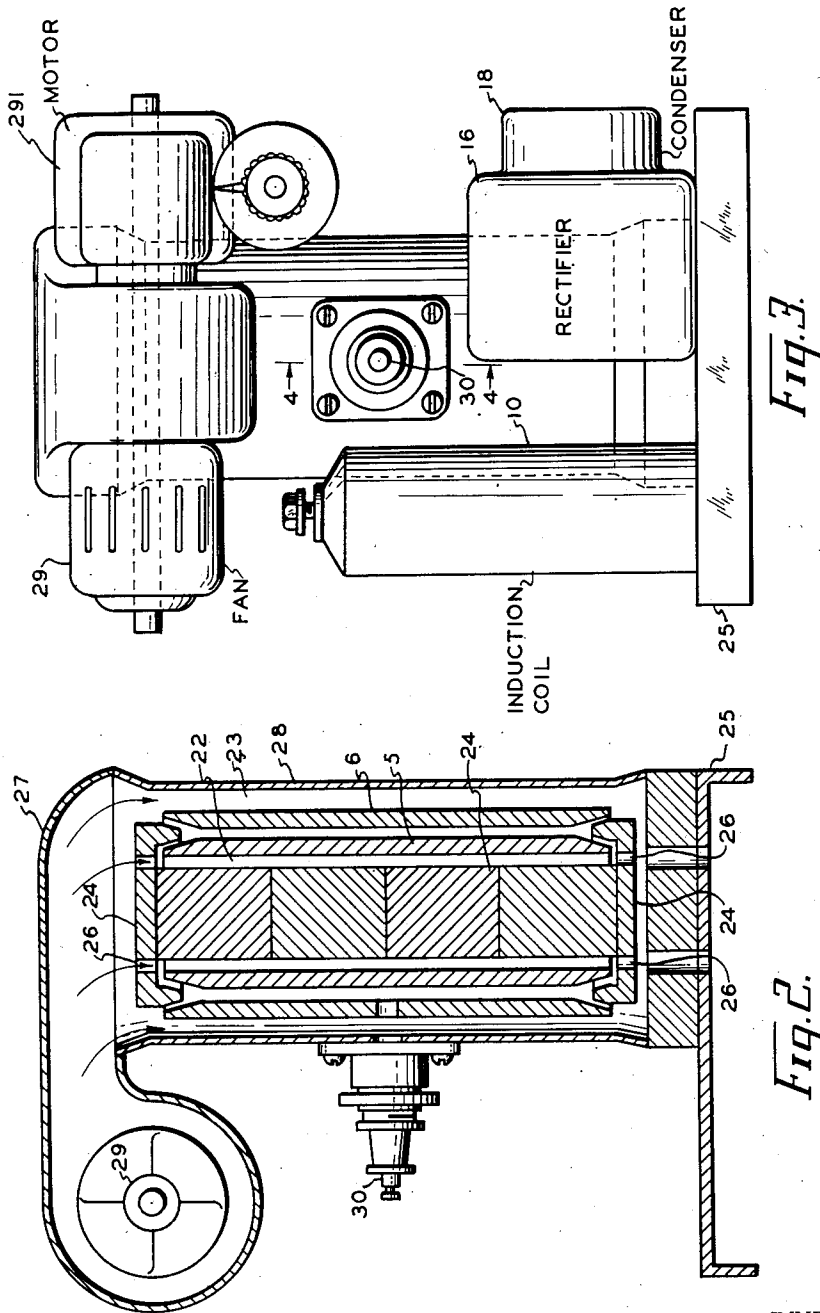
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SYSTEM FOR CONTROLLING FLOW OF ELECTRIC CURRENTS

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3 Sheets-Sheet 2



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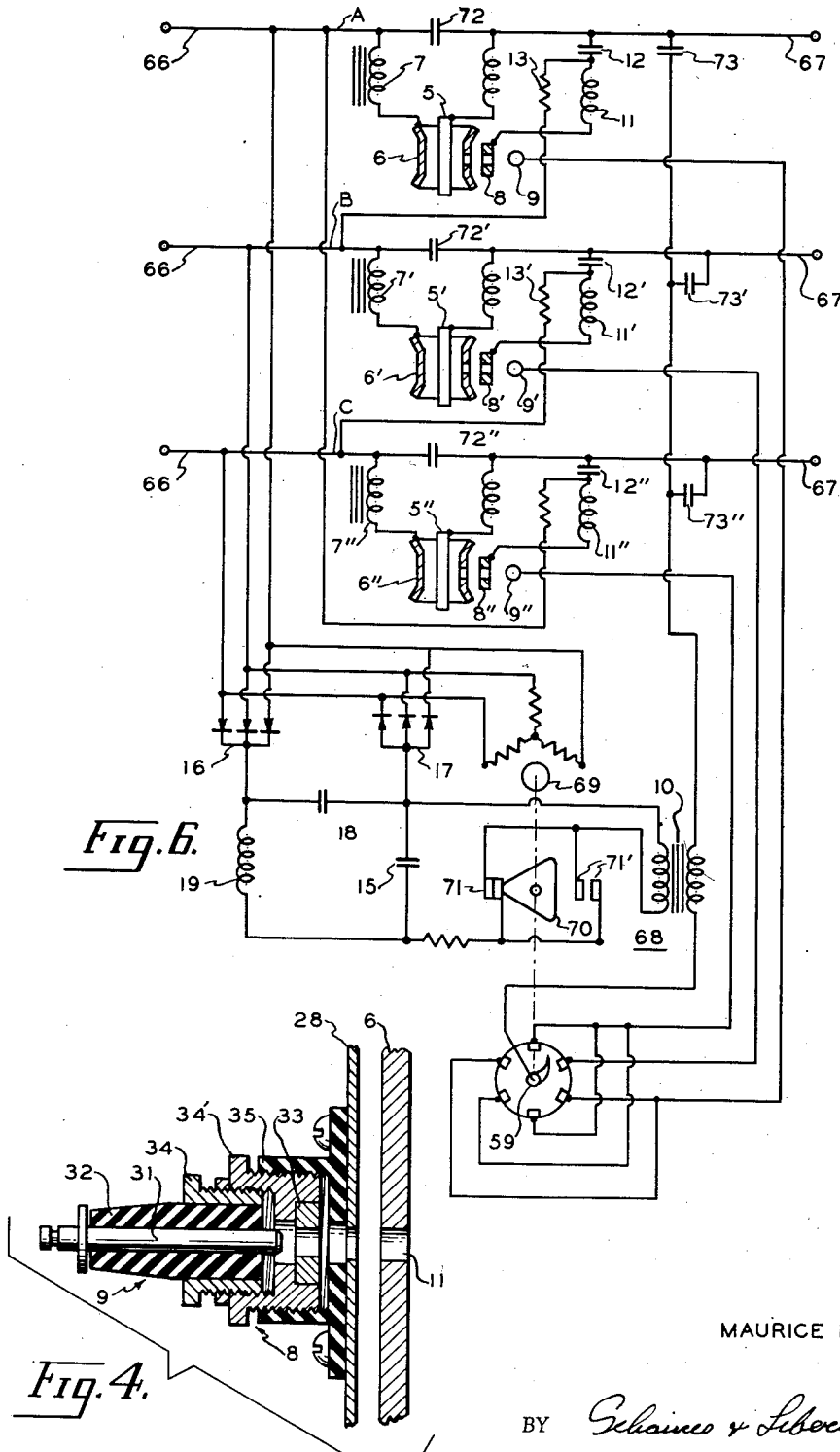
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SYSTEM FOR CONTROLLING FLOW OF ELECTRIC CURRENTS

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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SYSTEM FOR CONTROLLING FLOW OF
ELECTRIC CURRENTS

Maurice Partiot, New York, N. Y.

Application June 20, 1949, Serial No. 100,275
In France October 7, 1948

11 Claims. (Cl. 315—268)

1

The present invention relates generally to systems for controlling electric circuits, and particularly to systems of this character which operate by means of arc discharges in series with the circuit. The invention finds particular application in systems for rectifying alternating currents and for controlling the magnitudes of currents.

It is a broad object of the present invention to provide a novel system for initiating current flow in electrical circuits at predetermined controllable times.

It is a further broad object of the invention to provide novel methods and apparatus for initiating arc discharges.

It is another object of the invention to provide novel static rectifiers in which the average value of the rectified current may be readily controlled.

It is known that when an arc is established between two cooled electrodes which are relatively closely spaced one from another, for example, by one-sixteenth of an inch, and when the arc is continually moved in such a way as to avoid undue heating at any point on the electrodes, the arc persists so long as current intensity in the arc does not fall below a predetermined value (about 2.5 amperes). When the current in the arc falls below this value, however, even for an extremely short interval of time, the arc discharge terminates, and does not initiate again spontaneously. The present invention utilizes this property of arc discharges for effecting transformation and control of electric currents, and especially of alternating currents.

In accordance with the present invention, I utilize two co-axial cylindrical electrodes, which may preferably be fabricated of nickel, and which are placed within a constant magnetic field directed parallel to the axis of the cylinders. The electrodes are cooled in any convenient manner, as by means of an air blast. The electrodes are connected in series with a current supply network, so that current may flow in the network only when an arc exists between the electrodes.

In order to initiate an arc between the electrodes, in accordance with one embodiment of the invention, there is first generated locally a very intense ionization of the gaseous medium existing between the electrodes, which may be air. This ionization has the effect of creating a point where an arc may be readily initiated, and the arc is then utilized to conduct current in the circuit for the interval of time desired.

It is an important feature of the present invention to provide mechanisms and circuits for initiating ionization between the electrodes at con-

2

trolled times, by means of simple inexpensive circuit elements, and without utilizing high voltages, which are expensive to generate, as well as dangerous.

In accordance with a preferred embodiment of the invention, initiation of the primary arc is effected in three steps, or by means of three sequentially operated circuits. Initially, an induction coil is used, which furnishes a small spark at the precise instant it is desired to initiate the primary arc. This small spark enables discharge of a condenser between a pair of electrodes, which creates a strong auxiliary arc for a very short period of time, and consequently a strong ionization. The auxiliary arc is established adjacent to or within the confines of the primary electrodes of the system, and the ionization introduced by the auxiliary arc initiates the arc between the main electrodes. A magnetic field is established co-axially with the main electrodes, which are mutually cylindrical and co-axial to cause the arc continually to change its location by rotation about the cylindrical electrodes. This prevents localization of the arc, and thereby undue heating at any point on the electrodes, and spreads the arc over a great surface of the electrode.

The above and still other features, objects and advantages of the present invention will become apparent upon consideration of the following detailed description of various embodiments thereof especially when taken in conjunction with the accompanying drawings wherein:

Figure 1 illustrates in schematic circuit diagram the basic circuits of the present invention.

Figure 2 is a vertical section taken through the electrodes of the invention, and illustrating the manner in which they may be cooled.

Figure 3 is a view in elevation corresponding with the structure of Figure 2 as seen from the left side of that figure.

Figure 4 is a section taken on the line 44 of Figure 3, illustrating the structure of a spark electrode shown in elevation in Figure 2.

Figure 5 is a modification of the system of Figure 1, in schematic diagram.

Figure 6 is a modification of the system of Figure 1 as applied to three phase controlled rectification of electrical currents.

Referring now more specifically to Figure 1 of the accompanying drawings, which illustrates an application of the present invention to the rectification of currents in one of the phases of a three phase source, the reference numerals 1, 2 and 3 identify respectively the terminals of the supply source, it being desired to rectify

3

current flowing between the terminals 1 and 2 to a load generically represented as a resistance 4. For the purpose of controlling the moment of initiation of current flow between the terminals 1 and 2 and into the load 4 there is connected in series between the terminals 1 and 2 and the load 4, a pair of co-axial cylindrical electrodes 5 and 6, preferably constructed of nickel, and having therebetween a small spacing. Accordingly, in the absence of current flow between the terminals 1 and 2 the entire potential existing between the two terminals is applied between the electrodes 5 and 6, tending to cause an arc to jump perpendicularly to the axis of the cylinders. The spacing of the electrodes is such as normally to prevent creation of the arc.

A magnetic field is applied parallel to the axis of the cylinders, as indicated by the arrows labeled N and S. The axial magnetic field causes the arc, when established, to rotate tangentially to the cylindrical electrodes, and by utilizing a sufficiently intense magnetic field, the rotative speed of the arc may be made very great, about 60 feet per second. Thereby it is assured that the arc does not remain stationary at any point on the surface of the electrodes, preventing localization of heat generation. Furthermore, the electrodes wear out very slowly and regularly, and it has been found in practice that a pair of electrodes may be employed for maximum current flow, for several thousands of hours without being replaced.

To initiate arc discharge between the electrodes 5 and 6, there is provided an auxiliary electrode 8 and a primary electrode 9, disposed adjacent an aperture H formed in the wall of the outer electrode 6 and extending there-through. Establishment of an arc between the electrodes 8 and 9 is accomplished in the following steps, in accordance with the invention. The electrodes 8 and 9 are initially subjected to a high voltage pulse derived from the secondary winding of an induction coil 10. Electrodes 8 and 9 are further connected via a choke coil 11 across a condenser 12, which is capable of storing considerable power, and which may be recharged after each discharge thereof across the electrodes 8 and 9. Specifically, the condenser 12 may be charged by connecting it in series with a resistance 13 across terminals 1 and 3 of the three phase source of voltage.

The primary winding of the induction coil 10 may be supplied with pulses of current by means of cam operated breaker points 14 connected in series with the primary winding, and with a source of D.-C. voltage represented in Figure 1 as a condenser 15. The condenser 15 may be maintained charged from the three phase terminals 1, 2 and 3 via conventionally connected groups of rectifiers 16 and 17, the outputs of which may be filtered in conventional fashion by the filter condenser 18 and the choke coil 19. It will be realized that any other convenient mode of charging and maintaining the condenser 15 continuously charged may be adopted, without departing from the principles of the present invention, or any alternative source of voltage supply for induction coil 10 may be utilized.

The breaker points 14 are actuated by a cam 20 which is driven by synchronous motor 21, conventionally represented, and which is powered from the three phase terminals 1, 2 and 3. In accordance with the usual construction the breaker points 14 may be mounted on a frame

4

which can be turned relative to the axis of the cam 20, permitting regulation of the timing of the breaker point operation.

When the alternating voltage between the terminals 1 and 2 has attained some predetermined value, of the order of perhaps 15 volts, the breaker points 14 are caused to open by the cam 20. The current flowing in the primary winding of the induction coil 10 is thus abruptly interrupted. Thereby, a considerable voltage is induced across the secondary winding of the induction coil 10, causing a small spark to be induced across the terminals 8 and 9, and discharging the capacity M represented as connected across the secondary winding of the induction coil 10, and which may constitute the inherent capacitance of that winding. The value of the capacity of the condenser M, when taken in conjunction with the value of inductance of the coil 11, is such that an oscillatory discharge between the electrodes 8 and 9 takes place, involving considerable voltage but relatively small current. Nevertheless, the flow of high frequency current in the circuit including the inductance 11 results in a high voltage across inductance 11 and hence between the electrode 8 and the electrode 6, which is superposed on the voltage across the condenser 12, the latter, nevertheless, remaining relatively small. This voltage creates a spark between the electrode 8 and the electrode 6, as a consequence of which a discharge path is created for the condenser 12, and the latter then proceeds to discharge creating a very intense arc or spark.

The ionization created by the arc or spark discharge between electrodes 6 and 8 is guided through the hole H, and reaches the electrode 5. The line existing voltage between the electrodes 5 and 6 is thus applied across an ionized path, which breaks down in response to the applied voltage, and an arc is established between the last named electrodes. The inductance 7 connected in series between the electrodes 5 and 6, in series with the load 4, serves to stabilize the arc so established, and the arc is maintained accordingly until the end of an alternation of current permitting current flow accordingly in the load 4 from the terminals 1 and 2. Once the arc has been established between the electrodes 5 and 6 it rotates rapidly, as has been explained above, preventing local heating, and local wear on the electrodes 5 and 6.

In summary then, the make and break contacts 14 initiate a spark between the electrodes 8 and 9, which in turn releases a spark between the electrodes 6 and 8. The latter spark initiates discharge of an arc in response to discharge of the condenser 12, and the latter arc in turn initiates the principal arc between the electrodes 5 and 6.

Turning now to Figures 2, 3 and 4 of the drawings, the principal electrodes 5 and 6 are illustrated in Figure 2 in cross section, the spacing between the electrodes diverging at the extremities of the cylinders, to prevent the arc ever establishing itself at these extremities, and further to enable ready evacuation of non-conducting nickel oxide dust, which is formed during the operation of the mechanism.

A magnetic field is produced by a core or a plurality of cores 24, which may be fabricated of special high permeability magnetic alloy. Secured to the bottom and top of the core are yokes 24' which serve to channel or guide the lines of magnetic flux from the cores 24 into the space between the electrodes.

5

Each of the yokes 24' is provided with apertures 26 to enable flow of air for cooling the electrodes, the air passing through the apertures 26 into the space existing between the core 24 and the inner electrode 25. The yokes 24' are so formed as to enable flow of air between the electrodes 5 and 6 and a space is provided between the outer electrode 6 and the casing 28 of the structure through which air may flow for cooling the outer surface of the outer electrode 6. The casing 28 is provided at its upper end with a passage 27 which leads to a fan 29 driven by a motor 29', the cooling air flowing over the electrodes on both sides thereof, and then externally of the casing 28.

The auxiliary electrode system is represented in Figures 2, 3 and 4 generally by the reference numeral 30, and is shown in Figure 2 attached to the casing 28. Reference is made to Figure 4 of the drawings in particular for illustration of the internal structure of the electrodes 30.

Referring now more specifically to Figure 4 of the drawings there is shown an elongated central electrode 31 (electrode 9 in Figure 1) mounted within an insulating cylinder 32, and having a portion extending therefrom to constitute a connection terminal. The electrode corresponding with 8 in Figure 1 is constituted specifically of an angular member 33, which is arranged coaxially with the elongated electrode 31. The electrodes 31 and 33, between which pass sparks during the operation of the system, may be fabricated of extremely spark resistant material, such as tungsten or the like. The insulating cylinder 32 may be mounted in a holder 34 which is threaded externally and which threadedly engages a further holder 34', to which is secured the electrode 33. Rotation of the holder 34 with respect to the holder 34' accordingly serves to set the spacing between the elongated electrode 31 and the angular electrode 33. The holder 34' is threadedly engaged within an insulating frame 35, which may in turn be bolted to the container 28, which at this point is provided with an opening aligned with the elongated electrode 31, to enable ionization produced by sparking between the electrodes 31 and 33 to reach through the aperture H in the electrode 6.

Reference is now made particularly to Figure 5 of the accompanying drawings wherein is illustrated schematically a variant or modification of the system of Figure 1 of the drawings. The objective of the system illustrated in Figure 5 of the accompanying drawings is to control flow of current between the terminals 36 and 37, the necessary circuit being normally broken by the electrodes 38 and 39, except when an arc is produced therebetween. Accordingly control of current flow is established by controlling the initiation and termination of arcing between the electrodes 38 and 39. To this end, voltage is derived from across the terminals 36 and applied to the primary winding 44 of a transformer via a variable resistance 52 and a fixed resistance 43, the variable resistance 52 serving to control the phase of the current in the primary winding 44, and thereby the time of initiation of sparks and arcs in the system.

A secondary winding 45 is inductively related to the primary winding 44 and includes, either inherently or by direct connection thereacross, a capacitance 45', which establishes a resonance condition for the winding 45, when the spark gap 46 breaks down in response to the voltage applied thereto.

6

Connected in series with the spark gap terminals 46 is not only the secondary winding 45 but also a condenser 48 and an inductance 47. The condenser 48 is connected between the terminals 36 in series with a current limiting resistance 55. At the moment when a spark passes between the electrodes 46, the voltage established across by secondary winding 45 will be found to exist largely across the inductance 47 for a short period of time. Since the inductance 47 is in series with the spark gap 50 this voltage causes initiation of a spark between the terminals 50. When the spark has been initiated the voltage existing across the condenser 48, which is capable of storing considerable power, discharges through the gap 50 almost instantaneously as an intense high current discharge. Since the spark gap 50 is in series with the winding 51 the abrupt discharge of the condenser 48 through the spark gap 50 effects an intense high frequency current in the winding 51. Coupled to the winding 51 is a further winding 53 having a large number of turns. There is, accordingly, developed across the winding 53 an extremely high voltage, which generates in the spark gap 54 a further spark which is more intense than that generated in the spark gap 50.

A condenser 49 is provided, which is connected between the terminals 36 in series with a resistance 56, which serves to limit current flow in the condenser 49 during charge. The condenser 49, moreover, is connected in series with the winding 53, the spark gap 54, and the choke coil 40 across the line 36. The condenser 49 accordingly discharges through the spark gap 54, strengthening the arc or spark there existing. The passage of the arc in the gap 54 has the effect of creating across the inductance 40 an extremely high voltage. This high voltage is impressed between the main electrodes 38 and 39, generating an arc thereacross, initiation of which enables current flow between the terminals 36, 37, this current flow serving to continue the arc until the magnitude of the A.-C. voltage on the line 36 is reduced to a very low value, late in a half cycle of alternating current. The choke coil 41, which is connected in series with the arc 38, 39, has the effect of stabilizing the output of the latter. The condenser 42 on the other hand prevents high frequency currents from circulating in various parts of the equipment, where it might create serious and undesired effects.

The system illustrated in Figure 6 of the accompanying drawings is a modification of the system of Figure 1, specifically as applied to the control of current flow in three phase systems.

The reference numeral 66, in Figure 6, identifies a three phase input and the reference numeral 67 a three phase output. For the purpose of controlling current flow in the three phase system, spark gaps are connected in series with each one of the three phase lines, a spark gap 5, 6 being inserted in line A, a spark gap 5', 6' in line B, and a spark gap 5'', 6'' in line C.

The general mode of operation of the main spark gaps in each of the lines A, B and C follows that described in connection with the system of Figure 1 of the drawings. More specifically, and considering the line A, the principal spark gap 5, 6 is primed by an auxiliary spark gap 8, which is in turn primed by a pilot spark gap 9. The flow of current in the auxiliary spark gap 8 is re-enforced by the discharge current of condenser 12 which receives energy across the lines A and B via the resistance 13.

Since the system of Figure 1 has been described in respect both to its connection of circuit elements, and its mode of operation, in considerable detail hereinbefore, this description is not repeated in relation to Figure 6.

The pilot spark gaps 9, 9' and 9'' are connected in the system of Figure 6 by means of a distributor system, generally identified by the reference numeral 68, and which corresponds with the distributor system usually utilized for ignition purposes in six cylinder gasoline motor vehicles. The distributor may be driven by a small three phase synchronous motor 69, which may be driven from the three phase line 66, so that a definite correspondence is established between the rotations of the motor 69 and the phases of the voltages existing on the line 66. The motor 69 may be utilized to drive a cam 70 which actuates two breaker points 71 and 71' in alternation. If it is desired to rectify alternating current in the line 66, 67, the breaker point 71' should not be utilized, since it is then desired that the gaps 5, 5', 6', and 5'', 6'', be broken down only in response to voltage of one polarity, or only during alternate half cycles of voltage on the lines A, B and C. If it desired, on the other hand, to control the flow of alternating current between the terminals 68 and the terminals 67, it is essential to establish arcs in the various spark gaps 5, 5', 6', 5'', 6'', during each half cycle of voltage applied to each of the lines A, B and C. This may be accomplished by using both breaker points 71 and 71'.

The breaker points 71 and 71' are disposed oppositely to the axis of rotation of the cam 70, and the cam 70 is provided with three equally spaced rises, so that the breaker points 71 and 71' operate in alternation, at 60 degree intervals with respect to the rotation of the motor 69.

The breaker points 71 and 71' are connected in parallel with each other, and in series with the primary winding of induction coil 10. The secondary winding of the induction coil 10, on the other hand, is connected to the rotary member of a distributor 55 at one of the terminals of the winding and in parallel to the lines A, B and C via coupling condensers 73, 73' and 73'' respectively at the other terminal. The distributor unit 59 is provided with six equally spaced stationary contacts, opposite ones of which are tied together, providing three output leads which are connected respectively to the spark terminals 9, 9' and 9''.

Accordingly, for each half cycle of alternating voltage on each of the lines A, B and C one arc initiating pulse of voltage is applied to the appropriate one of the pilot spark terminals 9, 9' and 9''. If the breaker points 71 are removed from the system, obviously each of the pilot terminals 9, 9' and 9'' are supplied with only one arc initiating pulse of voltage for each full cycle of line voltage.

In the system of Figure 6 the condensers 72, 72' and 72'' are utilized as high frequency bypass condensers to localize high frequency currents generated by the arcs. The inductances 7, 7' and 7'', which are connected in series between the arcs 5 and 5, 5' and 6', and 5'' and 6'', respectively, on the other hand, are utilized for stabilizing the arcs when they have been established.

While I have described and illustrated various specific embodiments of the present invention, it will be clear that variations and modifications of the specific circuits illustrated and described may be resorted to without departing from the true spirit of the invention.

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

1. In a system for controlling flow of alternating current between a pair of terminals in response to alternating voltage impressed thereacross, a pair of principal electrodes connected in series with said terminals, an auxiliary terminal, a priming terminal, means for impressing a spark producing voltage between said priming terminal and said auxiliary terminal, means responsive to said spark for producing a further spark between said auxiliary terminal and one of said principal electrodes, means responsive to said further spark for initiating arcing between said principal electrodes, and a load circuit connected in series with said pair of terminals and said pair of principal electrodes.

2. In a system for controlling flow of alternating current to a load circuit between a pair of terminals in response to alternating voltage impressed thereacross, a pair of principal electrodes in free air connected in series with said load circuit between said terminals, an auxiliary electrode located adjacent said pair of electrodes, a condenser and a voltage pulse source connected in series between said auxiliary electrode and one of said pair of electrodes, means for charging said condenser, means responsive to a pulse of voltage by said voltage pulse source for initiating a discharge of said condenser between said auxiliary electrode and one of said pair of principal electrodes, and means responsive to said discharge for initiating discharge between said pair of principal electrodes in response to said alternating voltage by introducing ionized gas between said principal electrodes.

3. A system in accordance with claim 2 wherein said voltage pulse source comprises an inductance, and a pair of primary electrodes connected in series, and means for inducing sparks in said primary electrodes in synchronism with said alternating voltage.

4. The combination in accordance with claim 2 wherein said principal electrodes are co-axial metallic cylinders, and wherein is provided means for establishing a magnetic field directed co-axially with said cylinders and extending therebetween.

5. In a system for controlling current flow to a load in an alternating current power circuit, a pair of co-axial spaced cylindrical principal electrodes in series with said circuit, said pair of co-axial spaced cylindrical principal electrodes in series with said circuit and existing in a gaseous atmosphere, an aperture in the outer one of said pair of co-axial spaced cylindrical electrodes, auxiliary spaced arcing electrodes located adjacent said aperture, and means for initiating an arc between said auxiliary electrodes to ionize the gaseous atmosphere intermediate said principal electrodes via said aperture, sufficiently to enable arc creation between said principal electrodes in response to voltage in said alternating current circuit.

6. In a system for controlling current flow to a load in an alternating current power circuit, a pair of co-axial spaced cylindrical principal electrodes in series with said circuit, said pair of co-axial spaced cylindrical principal electrodes in series with said circuit and existing in gaseous atmosphere, an aperture in the outer one of said pair of co-axial spaced cylindrical electrodes, auxiliary spaced arcing electrodes located adjacent said aperture, means for initiating an arc between said auxiliary electrodes to ionize the

gaseous atmosphere intermediate said principal electrodes via said aperture, sufficiently to enable arc creation between said principal electrodes in response to voltage in said alternating current circuit, and means for establishing a magnetic field between said principal electrodes and in a direction co-axial therewith and having an intensity sufficient to rotate said arc about the axis of said principal electrodes.

7. In a system for controlling current flow to a load in an alternating current power circuit, a pair of principal electrodes in air connected in series with said circuit, a pair of auxiliary electrodes in a gaseous atmosphere, a condenser connected across said auxiliary electrodes, means for charging said condenser to a predetermined voltage and with relatively great energy, an induction coil for generating a transient high voltage, means for applying said transient high voltage across said auxiliary electrodes to initiate relatively slight ionization in the gas therebetween, whereby said condenser discharges across said auxiliary electrodes to initiate intense ionization in the gaseous atmosphere between said auxiliary electrodes, said auxiliary electrodes located sufficiently adjacent said principal electrodes to induce intense ionization in the gaseous atmosphere between said principal electrodes, for priming said principal electrodes to transmit arcing current in response to the voltage of said alternating current circuit.

8. In a system for controlling current flow to a load in an alternating current power circuit, a pair of principal electrodes having adjacent surfaces in the form of parallel surfaces of revolution and connected in series with said circuit, said pair of principal electrodes existing in a gaseous atmosphere, an aperture in the outer one of said pair of principal electrodes, auxiliary spaced arcing electrodes located adjacent said aperture, and means for initiating an arc between said auxiliary electrodes to ionize the gaseous atmosphere intermediate said principal electrodes via said aperture, sufficiently to enable

arc creation between said principal electrodes in response to voltage in said alternating current circuit.

9. In a system for controlling current flow to a load in an alternating current power circuit, a pair of spaced principal electrodes in series with said circuit, said principal electrodes having adjacent extended arcing surfaces substantially parallel to each other and existing in a gaseous atmosphere, an aperture in one of said pair of principal electrodes, auxiliary spaced arcing electrodes located adjacent said aperture, means for initiating an arc between said auxiliary electrodes to ionize the gaseous atmosphere intermediate said principal electrodes via said aperture, sufficiently to enable arc creation between said principal electrodes in response to voltage in said alternating current circuit, and means for establishing a magnetic field between said principal electrodes in a direction substantially parallel to said surfaces over the extent thereof and having sufficient intensity to move said arc in a direction parallel to said surfaces and perpendicular to the direction of said magnetic field.

10. The combination in accordance with claim 9 wherein said surfaces are parallel surfaces of revolution.

11. The combination in accordance with claim 10 wherein said parallel surfaces of revolution have the same axis of symmetry, and wherein said axis of symmetry is rectilinear.

MAURICE PARTIOT.

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