Feb. 9, 1943. H. W. LORD 2,310,741

ELECTRIC TRANSLATING APPARATUS

Filed March 30, 1940

Fig. 1.

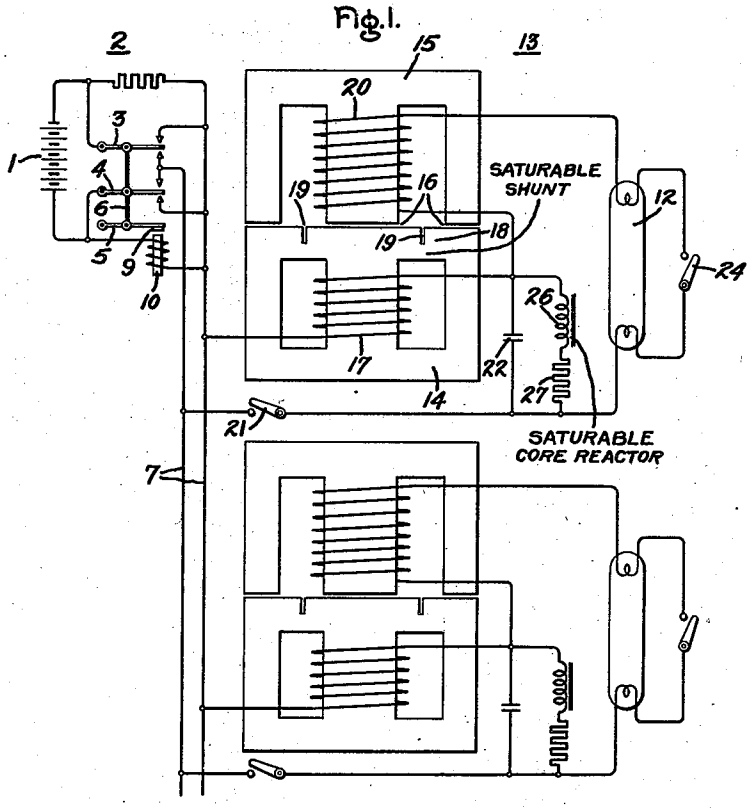


Fig. 2.

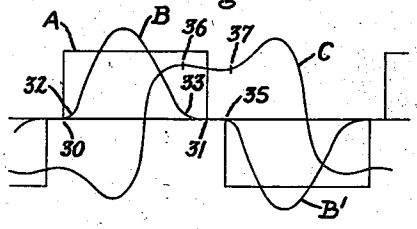


Fig. 4.

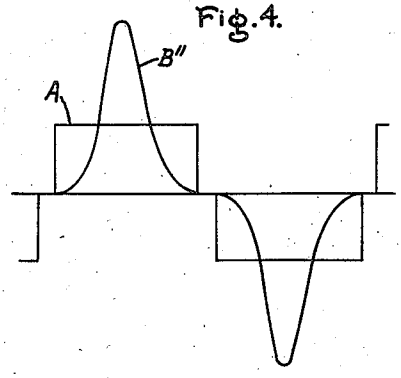
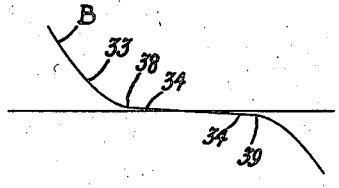


Fig. 3.



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2,310,741

ELECTRIC TRANSLATING APPARATUS

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Application March 30, 1940, Serial No. 327,072

25 Claims. (Cl. 176—124)

My invention relates to electric translating apparatus and more particularly to improved electric translating apparatus for energizing gaseous discharge devices, such as fluorescent lamps. Certain forms of apparatus have been devised in the past for converting a low voltage direct current into an alternating current having the desired higher voltage by employing an inverter including some form of circuit controlling means, such as a mechanical commutator, and a transformer. Installations including such apparatus are subject to various disadvantages. With an inverter comprising a part of the apparatus designed to control a group of lamps simultaneously the apparatus lacks flexibility of control since the use of less than the full number of lamps constituting the group results in an improper operation of the apparatus. Moreover the weight and cost of such equipment has been excessive, particularly where the number of lamps comprising a group has been considerably reduced or individual lamp control provided in order to improve the flexibility. In certain cases the flicker and stroboscopic effects produced with such apparatus have been objectionable.

It is the object of my invention to provide improved apparatus of the above-mentioned character with which the disadvantages noted may be greatly if not entirely avoided.

It is another object of my invention to provide a new and improved electric translating apparatus including switching means for converting direct current to alternating current characterized by a current wave form in the input circuit having extended periods of low current to facilitate operation of the switching means and of a substantially rectangular current wave shape in the output circuit.

It is a still further object of my invention to provide a new and improved electric translating apparatus particularly adapted for supplying electric discharge devices, such as fluorescent lamps, which operates satisfactorily with a variable load and at the same time overcomes the disadvantages of expense and weight that result from supplying a complete converting system for each individual load device.

A still further object of my invention is to provide an improved ballast circuit for electric discharge lamps which improves the power factor and maintains good current wave form through the lamp circuit.

Briefly, in accordance with the illustrated embodiment of my invention I have provided an improved combined apparatus for energization from a direct current source through the contacts of a vibratory switch and which includes an inductive device and series resonant circuit which function both to ballast the lamp and to draw a current wave through the switch contacts such that sparking is substantially eliminated, this elimination of sparking being obtained irrespective of whether the lamp is operating normally, is short circuited or is entirely removed. The apparatus which I have provided also causes the wave of current supplies to the lamp to have a steep slope at the points of reversal which in addition to eliminating flicker has a meritorious value in lengthening the life of the lamp.

My invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

Referring to the drawing, Fig. 1 is a circuit diagram illustrating an embodiment of my invention and Figs. 2, 3 and 4 show curves of wave forms obtained with the apparatus comprising my invention. In Fig. 1, the source of electrical energy is represented as the battery 1 which for example may be a 32 volt storage battery such as commonly comprises a part of the lighting equipment of a railway car. The voltage of the battery is converted into an alternating voltage by means of any suitable circuit controlling means, which as illustrated, comprises a vibratory switch of the reversing type. As I prefer to use a commutator of the latter type I have shown such a one at 2 having the resilient switch blades 3 and 4 which are tied together and to the driving reed 5 by the insulating strip 6. The ends of the blades 3 and 4 engage the front and back contacts which connect with the feeder circuit 7 in the manner of an ordinary reversing switch, the front and back contacts for each blade being spaced as short a distance as possible and still obtain satisfactory operation. The outer or free end of the reed 5 is provided with the armature 9 which also provides a certain amount of inertia and cooperating with the armature 9 is the driving magnet 10 which receives energy from the battery and is controlled by the blades and contacts in a well understood manner to cause the switch arms to operate. Although the switch arms may vibrate with any desired frequency I prefer to so construct it that it shall operate with a frequency of approximately 60 periods per second. The open circuit voltage impressed on the feeder circuit 7 is represented, for example by the voltage curve A in Fig.

2 in which it will be seen that the short time intervals between the positive and the negative half cycles are those due to the spacing of the front and back contacts of the switch 2.

The feeder circuit 7 is arranged to supply energy to a plurality of individually controlled like load circuits, shown as lamp circuits, of which two are represented in Fig. 1. Each lamp circuit supplies an electric discharge lamp represented at 12 through the apparatus 13 which serves the double function of ballasting the lamp and causing the current wave drawn from the source through the switch always to be of such a character that sparking at the switch contacts is avoided regardless of the functioning of the lamp. The apparatus 13 includes a transformer, which is disclosed and claimed in my copending application for Transformer, Serial No. 346,343, filed July 19, 1940, having a two-part core structure comprising the parts 14 and 15 which are separated from each other by the air or non-magnetic gaps 16. The part 14 is shown of rectangular form having the primary winding 17 on the central leg thereof and having the magnetic shunts 18 between the central and outer legs. Each of these shunts comprises two parts, the one part including the air gaps formed by the slots 19 and the other part including the material below the slot which is adapted to saturate during the greater part of the current wave traversing the primary winding. The other part 15 of the transformer core is shown as having an E-shape with the secondary winding 20 on the center leg thereof.

Connected in series with the primary winding 17 to be supplied from the feeder circuit 7 through the control switch 21 is the capacitor 22, the winding and the capacitor forming a resonant circuit tuned to a frequency which is slightly higher than that of the commutator. At the beginning and at the end of each half cycle of current in the resonant circuit, that is, when the primary current is small those portions of the magnetic shunts below the air gap slots are able to carry the magnetic flux without saturation, hence the inductive property of the resonant circuit is relatively high and the resulting resonant frequency of the circuit is low. During the greater portion of each half cycle of the current, however, the shunts are saturated and as a result the inductive property of the circuit is low and the resulting resonant frequency is high.

In as much as the natural frequency of the resonant circuit thus changes during each half cycle, it may be termed a non-linear resonant circuit.

The discharge device 12 is connected in series with the secondary winding 20 across the capacitor 22 so that the energy received by the lamp is supplied at various intervals during each cycle of operation by the secondary winding, and by the capacitor 22 and directly from the feeder through the primary winding. The discharge lamp may be of any suitable type and is represented by way of example as having heated electrodes at the ends thereof. For the purpose of initially heating the electrodes before starting the lamp, I have shown by way of example the short-circuiting switch 24 which is initially closed and after the electrodes have become heated to an electron emitting temperature is opened thereby causing the lamp to start by reason of the inductive kick of the secondary winding. It will be understood that various automatic means may be provided for closing the switch 24 for a predetermined time when the circuit is energized and subsequently opening it to cause the lamp to start.

To insure a greater uniformity of operation of the above described apparatus under conditions of excess voltage and to insure the maintenance of a uniform frequency of the resonant circuit under conditions of large variations of load I have provided the resonant circuit with a non-linear shunt around the capacitor 22 comprising the saturable core reactor 26 and the resistor 27. Under conditions of normal voltage of the source of supply the reactor 26 will operate with a flux density therein which is a little below the point of saturation. However, any material increase in the voltage of the source will cause a saturation of this reactor thereby decreasing impedance of the shunt circuit of which it forms a part to compensate for the effect on the resonant circuit of such voltage increase. The shunt moreover prevents any material change in the frequency of the resonant circuit should the load suddenly change, as for example, by the removal of the lamp. Thus the shunt circuit including reactor 26 and resistor 27 provides means for compensating for changes in the primary circuit impedance due to voltage changes of the source as well as compensating for variations in load and may be considered a stabilizing circuit.

Referring now to the wave forms comprising Figs. 2 and 3, at the instant that the switch contacts close in one position thereof, which point is indicated on Fig. 2 at 30, an oscillatory current begins to flow from the battery, through the commutator, the feeder and the resonant circuit which includes the winding 17 and the capacitor. In as much as the resonant circuit is tuned to a frequency slightly higher than that of the commutator only the first half cycle of the oscillatory current passes before the switch contacts open. The shape of this half cycle is represented by B, the times of the closing and opening of the circuit by the switch being represented respectively by the points 30 and 31. During the greater part of this half cycle the shunts 18 are saturated, hence, the inductance of the winding 17 at that time is relatively low. Near the beginning and end of the half cycle, however, when the value of the current is small the magnetic shunts are able to carry the flux without saturation. At these times, therefore, the inductance of the winding 17 has a higher value, namely, that corresponding to a desaturated condition of the magnetic circuit. The effect of the change from one inductance value to another is to vary the rate of change of the current, the effect being shown by the curved portions 32 and 33 of the current wave. The rate of change of the current finally reaches a very low value represented by the flat portion 34 of the curve, see Fig. 3, into which the curved portion 33 merges. In this figure I have represented on a larger scale the form that the curve B would take in the zero part thereof were the circuit not opened by the switch. The current passes through zero in this flat portion which portion makes such a small angle with the zero axis that for an appreciable interval before and after the time of actual zero value the current is practically zero, in fact is so small that only a minute spark if any is produced if the circuit is opened at any instant during that interval.

With the apparatus which I have devised the opening of the circuit by the switch may there-

fore occur at any point along the flat portion 34 of the current curve, for example anywhere between the points 38 and 39 of Fig. 3 without causing detrimental sparking at the switch contacts. By reason of the length of the flat portion it becomes unnecessary to use special care to insure that the time of interruption of the circuit shall occur exactly at the time of zero current; moreover because of it a safe margin is provided to insure against switch sparking by reason of small variations that may occur in the frequency of the switch and the resonant circuit and in the structural features of the apparatus. When the switch contacts close in the other position, as at the point 35, in Fig. 2, a similar half cycle of current but of the opposite polarity, indicated at B', is drawn from the battery through the commutator, the interruption of the current at the end of each half cycle occurring at a corresponding point in the flat portion 34 of the current wave.

Curve C drawn to a different scale than that of the curve B, represents the wave form of the current flowing through the lamp which current is supplied principally by the secondary winding of the transformer but during the intermediate portion thereof, approximately between the points 36 and 37, is supplied by the capacitor 22. The gaps 16 between the core structures associated with windings 17 and 20 maintain the exciting reactance of winding 20 at a relatively low value. This renders it possible for the capacitor 22 to maintain a substantial current through the load circuit during open circuit condition of the primary winding occurring during movement of the movable switch contacts from one closed circuit position to another. It is apparent that some of the features of the transformer capacitor combination of the illustrated embodiment of my invention may be utilized to advantage as a ballast circuit for discharge devices such as fluorescent lamps when energized from a sinusoidal alternating voltage source as well as from a commutated direct current supply as illustrated in the drawing. It will be noted also that this lamp current curve C is very steep where it crosses the zero axis, the shape of the curve being due to the effectiveness of the capacitor 22 in both the primary and secondary circuits which results in part from the transformer structure just described. An important advantage resulting from an output current curve having such a steep slope is the substantial elimination of lamp flicker and an increase in lamp life.

The curves B and B' represent the current waves drawn from the feeder with the lamp in normal operation. Should the lamp be removed or rendered inoperative the current curve would then become somewhat more peaked such as is represented, for example, by the curve B'' of Fig. 4. Although the current under such conditions is more peaked than under the normal lamp operating condition that portion of the current curve adjacent the zero axis, namely the flat portion, is substantially the same. Moreover, that portion of the current curve also remains substantially the same when the lamp is short circuited by the starting switch. Thus the production of a flat portion in the current wave where it passes through zero and the positioning of that portion to include the point of interruption of the switch is substantially independent of the functioning of the load.

I have chosen the particular embodiment described above as illustrative of my invention and it will be apparent that various modifications may be made without departing from the spirit and scope of my invention which modifications I aim to cover by the appended claims.

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

1. In combination, a source of direct current supply, a commutator connected therewith for producing a substantially square shaped alternating voltage wave having zero voltage portions between the half-cycles thereof, a discharge lamp connected to be supplied from said commutator and apparatus in said connection including means for ballasting said lamp and means including a resonant circuit and a core having a saturable part associated therewith for causing the alternating current drawn from said commutator to pass through zero at a decreased rate of change, the interval of said decreased rate of change including the time of interruption of the circuit by the commutator and means for maintaining the operation of said resonant circuit substantially independent of the functioning of the lamp.

2. In combination, a source of direct current supply, a commutator connected therewith for producing a substantially square shaped alternating voltage wave having zero voltage portions between the half-cycles thereof, a resonant circuit directly connected with said commutator and having a frequency higher than that of said voltage wave connected to be energized thereby, an electrical load connected to be energized from an element of said circuit, and means including a core having a saturable part cooperating with said circuit for causing each current wave therein to have a flat portion where the wave passes through zero, the time interval represented by said flat portion including the time at which the commutator opens the circuit, said resonant circuit including means operative to maintain the frequency of the circuit substantially uniform over wide ranges of variation of said load.

3. In combination, a source of direct current supply, a commutator connected therewith for producing a substantially square shaped alternating voltage wave having zero voltage portions between the half cycles thereof, means for connecting a discharge lamp to be supplied from said commutator and apparatus in said connection comprising a transformer having a part operative to ballast the lamp and a saturable part and comprising a resonant circuit including a winding associated with said saturable part whereby the current of said circuit has a flattened portion where it passes through zero independent of the opening of the contacts, the time of interruption of the current by the commutator occurring during said flattened portion.

4. In combination, a source of direct current supply, a commutator connected therewith for producing a substantially square shaped alternating voltage wave having zero voltage portions between the half cycles thereof, a transformer having a core structure providing a nonmagnetic gap in the flux path interlinking the primary and secondary windings thereof and providing a magnetic shunt between said windings, said shunt having a saturable portion and a nonmagnetic gap arranged in parallel, a capacitor connected in series with said primary winding to be supplied from said commutator and forming a resonant circuit, a discharge lamp, and means connecting said lamp and said secondary winding in series across said capacitor.

5. In combination, a source of direct current supply, a commutator connected therewith for producing a substantially square shaped alternating voltage wave having zero voltage portions between the half cycles thereof, a transformer having a core structure providing an air gap in the flux path interlinking the primary and secondary windings thereof and providing a magnetic shunt between said windings, said shunt having a saturable portion and an air gap arranged in parallel, a capacitor connected in series with said primary winding to be supplied from said commutator and forming a resonant circuit, a discharge lamp, means connecting said lamp and said secondary winding in series across said capacitor and means for compensating for the effect on said resonant circuit of an increase in voltage of the source comprising a circuit including a saturable core reactor connected across said capacitor.

6. In combination, a source of direct current supply, a commutator connected therewith for producing a substantially square shaped alternating voltage wave having zero voltage portions between the half-cycles thereof, a feeder circuit connected to be supplied from said commutator, and a plurality of lamp circuits connected to be supplied from said feeder circuit and each including a discharge lamp, control apparatus and a control switch in the connection between the lamp and the feeder circuit, each of said control apparatus including means for ballasting the lamp associated therewith and means including a resonant circuit and a core having a saturable part associated therewith operative independently of the functioning of the lamp to cause the current drawn from said commutator to pass through zero at a decreased rate of change, the time of interruption of the circuit by the commutator occurring during the interval of said decreased rate of change whereby sparking at the commutator contacts is avoided regardless of the occurrence of small variations in the separate lamp circuits.

7. In combination, a source of direct current supply, a commutator connected therewith for producing a substantially square shaped alternating voltage wave having zero voltage portions between the half-cycles thereof, a transformer including a primary winding, a secondary winding and a core structure, a resonant circuit directly connected with said commutator and including a capacitor and a winding of said transformer, a load having the electrical characteristics of an arc discharge device connected for energization from the other of said transformer windings and said capacitor, said core having a part constructed to saturate at current values above a predetermined value for causing each half cycle of current in the circuit to have a flat portion where the wave passes through zero.

8. In combination, a source of direct current, a plurality of resonant circuits, a separate load circuit connected to be energized from each of said resonant circuits, a feeder circuit for connecting said resonant circuits to be supplied in parallel from said source, a reversing switch for reversing the polarity of the direct current potential supplied from said source to said feeder circuit, and means for operating said reversing switch at substantially the same frequency as that of said resonant circuits.

9. A direct current supply circuit, a plurality of series resonant circuits each comprising a plurality of reactive elements, a load circuit connected for energization from a reactive element of each resonant circuit, connecting means for supplying said resonant circuits in parallel from said direct current circuit, common switching means in said connecting means for periodically reversing the polarity of the direct current potential supplied from said supply circuit to said resonant circuits, and means for operating said switching means at a frequency slightly lower than the frequency of said resonant circuits.

10. In combination, a source of direct current, an electric discharge device, electric translating apparatus interconnecting said source and said discharge device comprising transformer means including a primary winding and a secondary winding, circuit controlling means interconnecting said source and said primary winding for periodically energizing said primary winding, a condenser electrically connected with one of said windings for tuning the circuit of the primary winding to substantially the frequency of operation of said circuit controlling means, and a stabilizing circuit responsive to the voltage of said condenser for maintaining the tuning of said primary circuit substantially independent of the operation of said discharge device.

11. In combination, a source of direct current, an electric discharge device, transformer means comprising a secondary winding connected to supply energy to said discharge device and a primary winding, circuit controlling means interconnecting said primary winding and said direct current source, means for operating said circuit controlling means periodically to energize said primary winding, a condenser conductively associated with said secondary winding and effective to tune the circuit of the primary winding to substantially the frequency of operation of said circuit controlling means, and regulating means connected across said capacitor comprising a series connected saturable inductive device and a resistance element.

12. In combination, a source of direct current, an electric discharge device, a transformer comprising a secondary winding connected to supply energy to said discharge device and a primary winding, circuit controlling means interconnecting said source and said primary winding, means for operating said circuit controlling means periodically to energize said primary winding, capacitance means associated with one of said windings for tuning the circuit of said primary winding to substantially the frequency of operation of said circuit controlling means, and a stabilizing circuit connected with said secondary winding for rendering the tuning of said circuit substantially independent of the functioning of said discharge device or variations of said source voltage comprising a saturable inductance device and resistance element connected in series.

13. In combination, a source of direct current, a plurality of series resonant circuits, a plurality of separate electric energy consuming loads each energized from one of said resonant circuits, common switching means interconnecting said circuits and said source of direct current, means for operating said switching means to energize said resonant circuits in parallel at substantially the frequency of oscillation of said resonant circuits.

14. A direct current supply circuit, an alternating current load circuit, electric translating apparatus interconnecting said circuits comprising transformer means including a primary and a secondary winding, circuit controlling means

interconnecting said direct current supply circuit and the primary winding of said transformer device for periodically energizing said transformer primary winding, and capacitance means conductively associated with both said primary and said secondary windings for receiving and storing energy when said primary winding is energized from said supply circuit and for supplying energy to the circuit of said secondary winding during the period that said circuit controlling means is effective to open the circuit between said supply circuit and said primary winding to maintain substantial current flow in said secondary winding during open circuit of said primary circuit.

15. A direct current supply circuit, an alternating current load circuit, electromagnetic means and circuit controlling means interconnecting said circuits, means for controlling the operation of said circuit controlling means to energize periodically said electromagnetic means from said supply circuit to effect an electromagnetic transfer of energy between said supply circuit and said load circuit, and capacitance means conductively associated with said electromagnetic means and cooperating therewith to reduce periodically the current through said circuit controlling means to zero and to supply energy to said load circuit for a period in each cycle of current in said load circuit including the period of zero current through said circuit controlling means.

16. A direct current supply circuit, an alternating current load circuit, electric translating apparatus interconnecting said circuits comprising transformer means having a primary winding and a secondary winding, circuit controlling means connected in circuit with said primary winding and operative periodically to connect said primary winding with said direct current supply circuit, a capacitance conductively connected with at least one of said windings for maintaining a current through said secondary winding during periods of zero current in said primary winding occurring during circuit interrupting operation of said circuit controlling means, and means for maintaining the impedance of said secondary winding at a low value when the circuit of said primary winding is interrupted.

17. A direct current supply circuit, an alternating current load circuit, electric translating apparatus interconnecting said circuits comprising transformer means having a primary winding and a secondary winding, mechanical switching means interconnecting said primary winding and said direct current supply circuit, means for operating said switching means to open and close said primary circuit periodically, a capacitance connected with said secondary winding for maintaining a current therethrough during the periods that said switching means is in the open circuit position, and means including a nonmagnetic gap in the magnetic circuit linking said primary and secondary windings for maintaining the impedance of said secondary winding at a low value during the period that said switching means is in open circuit position.

18. A direct current supply circuit, an alternating current load circuit, electric translating apparatus interconnecting said circuits comprising a transformer device including primary and secondary windings having a common terminal, capacitance means having one terminal thereof connected with said common terminal and the other terminal thereof connected with one terminal of said load circuit, and circuit controlling means operable to connect periodically the other terminal of said condenser and the terminal of said primary winding remote from said common terminal with said direct current supply circuit.

19. Electric translating apparatus for supplying an alternating current voltage to a load having the characteristics of an arc discharge device from a direct current source comprising a transformer including a primary winding, a secondary winding and a core structure for said windings, switching means for periodically energizing said primary winding from said direct current source to produce an alternating current flux in said core structure, means for maintaining the primary current at a relatively low value over a prolonged period near the beginning and end of each half cycle comprising a magnetic shunt arranged between said windings and having parallel saturable and nonsaturable portions, and means for maintaining a substantially even flow of secondary current during the period of reduced primary current including a nonmagnetic gap in the local magnetic circuit of said secondary winding.

20. A direct current supply circuit, an alternating current load circuit, electric translating apparatus interconnecting said circuits comprising inductive means having a plurality of winding sections and including a core structure having a saturable portion for introducing a nonlinear current impedance characteristic in said translating apparatus, circuit controlling means for periodically connecting said translating apparatus with said direct current supply circuit, and a condenser associated with said winding sections and cooperating therewith to provide a series resonant circuit having a frequency slightly higher than the period of operation of said circuit controlling means when the saturable portion of said core structure is saturated to produce an oscillating current through said controlling means having extended periods of low current at the times of operation of said current controlling means, said capacitance means also cooperating with said inductive device to maintain a substantial current through said load circuit during the extended periods of low current through said circuit controlling means.

21. A direct current supply circuit, an alternating current load circuit, electric translating apparatus interconnecting said circuits comprising inductive means having a plurality of winding sections and including a core structure having a saturable portion for introducing a nonlinear current impedance characteristic in said translating apparatus, mechanical switching means interconnecting said translating apparatus and said supply circuit, means for operating said switching means periodically to reverse the connection between said translating apparatus and said supply circuit, a condenser associated with one of said winding sections and cooperating therewith to provide a series resonant circuit having a frequency slightly higher than the period of operation of said switching means when the saturable portion of said core structure is saturated to produce an oscillating current through said switching means having extended periods of low current at the times of operation of said circuit controlling means, a nonmagnetic gap in said core structure in the magnetic circuit linking said winding sections operable to maintain the impedance of one of said winding sections at a low value when the

other of said winding sections is open circuited by operation of said circuit controlling means to reverse the connection between said translating apparatus and said supply circuit, said capacitance means cooperating with said one of said winding sections to maintain a substantial current through said load circuit during the period that said switching means is in open circuit position.

22. In combination, a source of alternating current voltage, electric translating apparatus energized from said source for ballasting an electric discharge device comprising a transformer including a primary winding, a secondary winding and a core structure constructed to provide high flux leakage between said windings, a capacitor connected in series with one of said windings, and a nonmagnetic gap in the series magnetic circuit of said primary and secondary windings.

23. In combination, a source of alternating current voltage, an electrical energy consuming load, electric translating apparatus interconnecting said source and said load comprising a transformer including a primary winding, a secondary winding and a core structure having a magnetic shunt between said windings, a capacitor connected in series with said secondary winding and a nonmagnetic gap in the series magnetic circuit of said primary and secondary windings.

24. In combination, a source of periodic voltage, an electric discharge device, electric translating apparatus interconnecting said source and said device comprising transformer means including a primary winding and a secondary winding, a condenser electrically connected with one of said windings for tuning the circuit of the primary winding to substantially the frequency of said periodic voltage, and a stabilizing circuit connected across said condenser for maintaining the tuning of said primary circuit substantially independent of the operation of said discharge device.

25. In combination, a direct current supply circuit, a transformer including a primary winding, a secondary winding and a core structure, a discharge lamp connected with said secondary winding, mechanical switching means interconnecting said supply circuit and said primary winding, means for operating said mechanical switching means to energize said primary winding with a periodic voltage, and means for regulating the primary current to minimize sparking at the contacts of said mechanical switching means comprising a magnetic shunt extending between said windings and having parallel saturable and nonsaturable portions with said saturable portion designed to be unsaturated during a period of time including the operating time of said mechanical switching means and saturated during the remainder of each cycle of said periodic voltage.

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