Nov. 23, 1937. H. E. YOUNG 2,099,715

CONSTANT CURRENT SYSTEM

Filed May 12, 1936 2 Sheets-Sheet 1

Fig. 1.

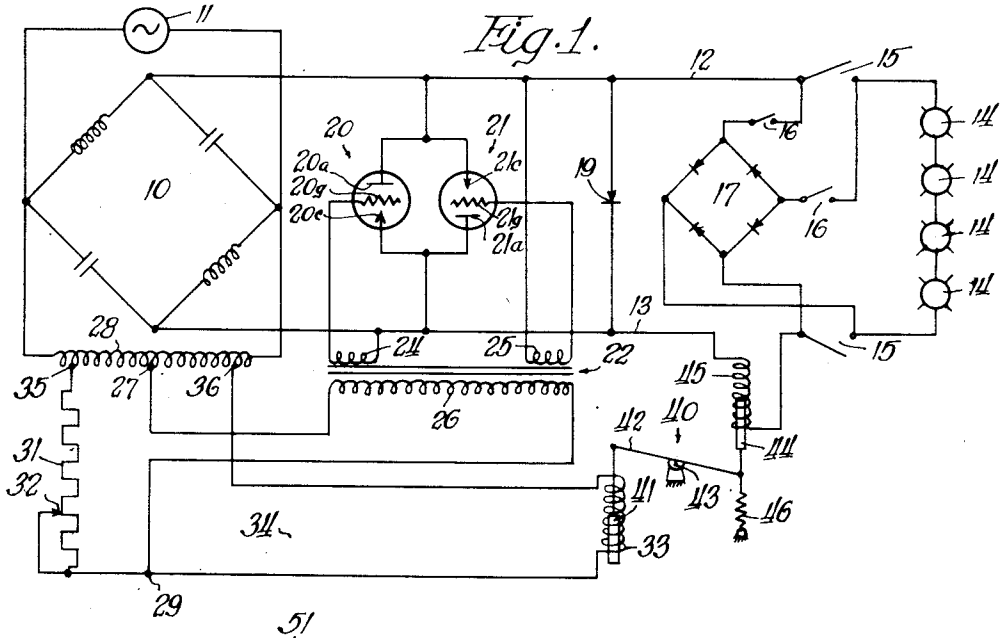
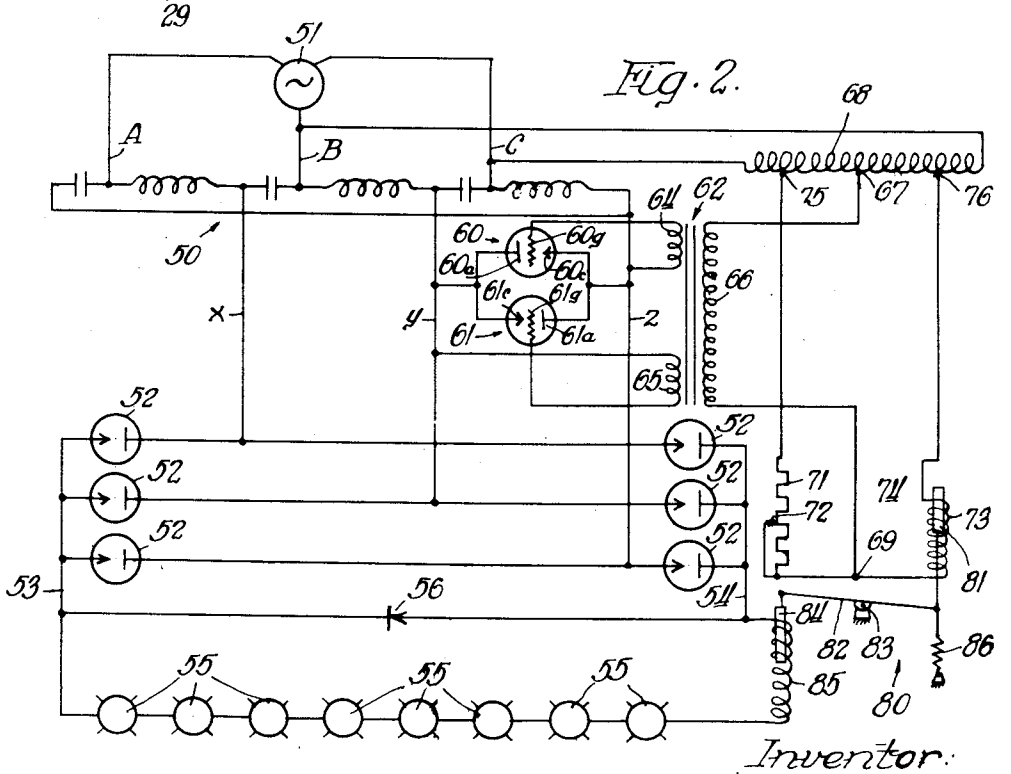


Fig. 2.



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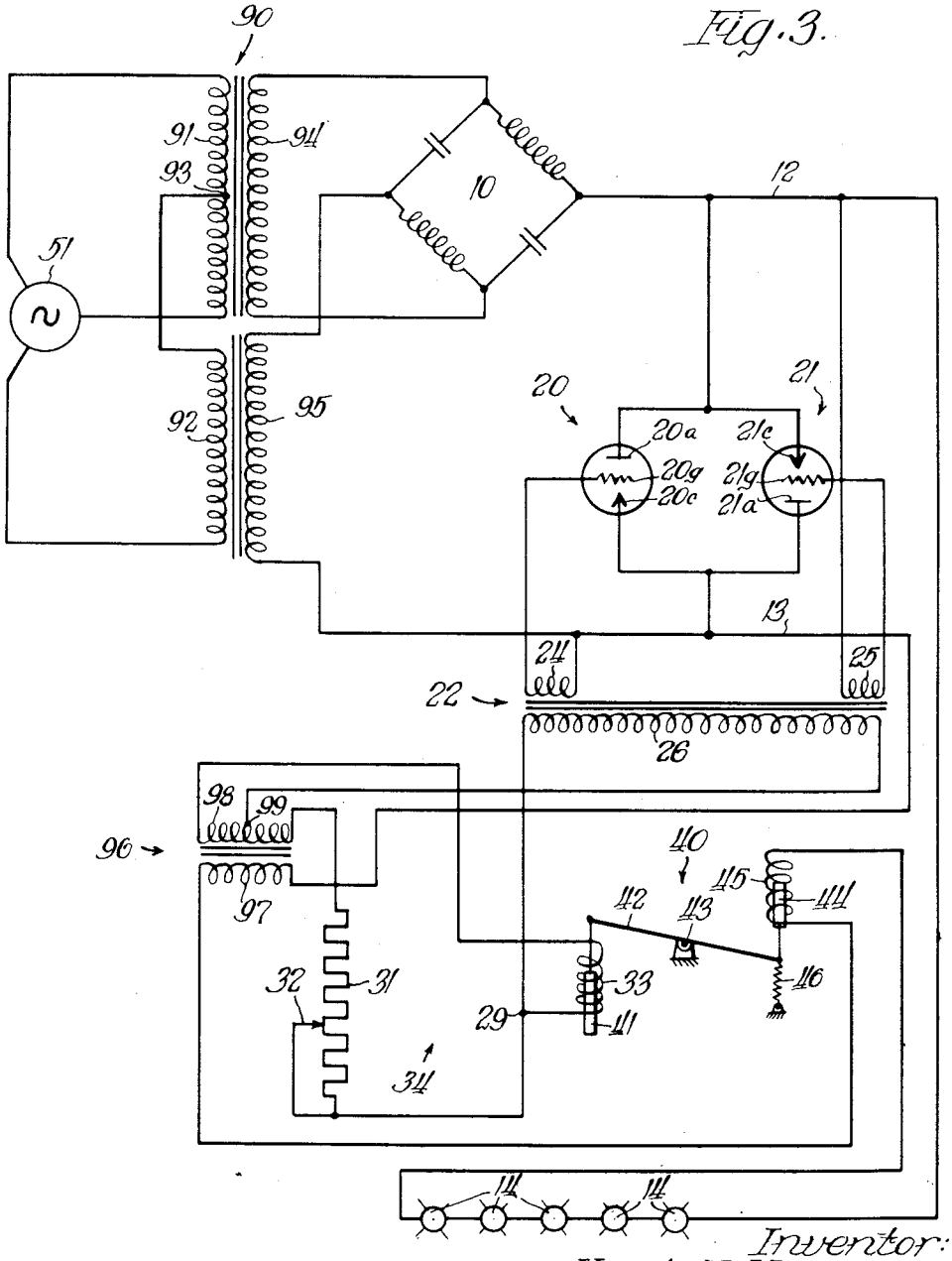
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Fig. 3.



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2,099,715

CONSTANT CURRENT SYSTEM

Hugh E. Young, Chicago, Ill.

Application May 12, 1936, Serial No. 79,329

20 Claims. (Cl. 175—363)

My invention relates generally to electrical control systems, and it has particular relation to systems of the constant current type.

In the operation of electric lamps, such as incandescent lamps for street lighting and the like, it is desirable that the current be held constant, or substantially so, in order to provide the desired illumination and to prolong the life of the lamps as much as possible. The lamp life is materially decreased by even slight increase in current above the rated value and it is, therefore, desirable to operate the lamps under such conditions that the rated current value will not be exceeded, even to the slightest degree.

For street lighting applications where a large number of lamps is operated at the same time, it is customary, in many cases, to connect the lamps in series circuit relation for the purpose of reducing installation and operating costs to a minimum. Some regulating device is provided for maintaining the current in the series circuit constant regardless of the number of lamps connected or the voltage of the supply circuit. Various types of regulating devices may be used. In my copending application, Serial No. 33,706, filed July 29, 1935, I have disclosed a monocyclic type of regulator in combination with grid controlled arc rectifying tubes which are arranged to control the voltage applied to the regulator or the current flowing in the load circuit as a function of the supply voltage or of the load current. While the various systems there disclosed are satisfactory for certain operating conditions, I have discovered that they require dependence to a considerable degree on the reliability of the grid controlled arc rectifying tubes for their continued operation and that, if the tubes fail, the entire system may be put out of service until they are replaced.

It is therefore an object of my invention to provide a constant current system which shall be simple, efficient, and reliable in operation, and which may be readily and economically manufactured and installed.

The principal object of my invention is to provide for preventing the current flow in a circuit requiring constant current from exceeding the constant value of the current at which the circuit is designed to operate most efficiently.

An important object of my invention is to provide for variably shunting a load circuit connected to a constant current device to maintain the current in the load circuit constant regardless of variations in line voltage applied to the device.

A further object of my invention is to provide for shunting the excess current from a circuit requiring constant current in such manner that the system can still function even though the apparatus used should be disabled.

A still further object of my invention is to provide regulating means for shunting the excess current from a circuit requiring constant current which will be operative only when the load current exceeds the constant value of the current and which will permit functioning of the system even though the regulating means may be disabled.

Still another object of my invention is to provide for controlling the conductivity of an electric valve connected across the load terminals of a constant current device in accordance with the load current to prevent the load current from exceeding its constant value.

A more specific object of my invention is to provide for controlling the conductivity of a pair of inversely connected electric valves connected across the load circuit of a monocyclic square to shunt therethrough all current from the load circuit in excess of the normal constant current that would otherwise flow through the load circuit.

Other objects of my invention will, in part, be obvious and, in part, appear hereinafter.

My invention, accordingly, is disclosed in the embodiments hereof shown in the accompanying drawings, and it comprises the features of construction, combination of elements, and arrangement of parts which will be exemplified in the constructions hereinafter set forth and the scope of the application of which will be indicated in the appended claims.

For a more complete understanding of the nature and scope of my invention, reference may be had to the following detailed description taken in connection with the accompanying drawings, in which:

Figure 1 illustrates diagrammatically one embodiment of my invention; and

Figures 2 and 3 illustrate diagrammatically two additional embodiments of my invention.

The commercial power systems of the present day are so arranged and constructed that the line voltage and frequency are maintained at fairly constant values. In order to provide constant current for operating a group of series connected incandescent street lamps, a static regulator of the monocyclic type may be provided. As long as the supply voltage and frequency remain constant, the current which is supplied by

the monocyclic square will remain constant regardless of the number of lamps which are connected across it within the limits of its range of operation. Since the monocyclic square transforms the constant voltage energy of the supply circuit into constant current energy for the load circuit, the current flowing in the load circuit is directly proportional to the voltage of the supply circuit. Any changes in voltage or frequency, however slight, will cause corresponding changes in the current flowing in the load circuit. If the supply voltage is increased over its normal rated value, there will be a corresponding increase in the current flowing in the load circuit, and, as a result, the life of the lamps connected therein will be materially shortened. These slight changes in the supply voltage may be caused by faulty operation of regulating devices or by system disturbances which are ordinarily encountered in the operation of such systems.

In practicing my invention, I take advantage of the normally constant voltage characteristics of a power transmission system of the present day, and provide a static regulator of the monocyclic type for supplying the required constant current for operating a group of series connected incandescent lamps. In addition to this apparatus, I provide a variable shunt across the load terminals of the monocyclic square which is called into operation only when the current in the load circuit exceeds the normal constant value thereof. At all other times the shunt circuit is ineffective and therefore, if, for some reason it should fail, such failure would not affect the energization of the lamps, although they would be subject to the flow of excess current on increase in the supply voltage applied to the monocyclic square.

According to one embodiment of my invention, I have provided a monocyclic square which may be energized from a single phase source of alternating current. The load terminals are connected to a circuit including the series connected incandescent lamps which may be used for street lighting purposes. A pair of inversely connected grid controlled arc rectifying devices is connected across the load circuit, and the conductivity thereof is controlled by means of a phase shifting circuit, the operation of which is under the control of the current flowing in the load circuit. The phase shifting circuit is so adjusted that, under normal operating conditions, the arc rectifying devices remain in the non-conducting state. However, as soon as the current in the load circuit exceeds a predetermined value, the arc rectifying devices are rendered conducting to shunt therethrough the excess current. By changing the time in each half cycle at which each of the arc rectifying devices is rendered conducting in accordance with the excess current which tends to flow in the load circuit, greater or less amounts of the current may be shunted with the result that the excess current is prevented from flowing through the lamp.

In another embodiment of my invention, a static regulating device is provided for transforming polyphase alternating current at a constant voltage to polyphase alternating constant current energy which may be rectified by suitable arc rectifiers to supply a load circuit with direct current in which a group of incandescent lamps are connected in series circuit relation. A pair of inversely connected grid controlled arc rectifying devices is provided across one of the constant current phases and the conductivity thereof is controlled by means of a phase shifting circuit in accordance with the current flowing in the load circuit to maintain this current constant and to shunt through the arc rectifying devices the excess current.

Referring now particularly to Figure 1 of the drawings, the reference character **10** designates, generally, a static regulator of the monocyclic type which is connected for energization to a supply circuit which may comprise a single phase alternating current generator **11**. The regulator **10** is adapted to transform the constant voltage energy of the supply circuit into constant current energy in a circuit comprising conductors **12** and **13** which may be connected to a group of series connected incandescent lamps **14** by means of switches **15** as illustrated. In the event that it is desired to energize the lamps **14** with direct current, the switches **15** may be opened and switches **16** may be closed to connect a rectifier **17** which may be of any suitable type, such as one of the copper oxide type, to convert the alternating current from the load conductors **12** and **13** into direct current. For operation of the lamps **14** on alternating current, the switches **16** are opened and the switches **15** are closed.

In the event that the load circuit should become open-circuited for any reason, it is desirable that the high voltage which would then appear between the conductors **12** and **13** be provided for. A cut-out **19**, which may be of the film type, is provided across the conductors **12** and **13** and is adapted to break down or be punctured on the occurrence of the high voltage, thereby causing the conductors **12** and **13** to be short-circuited, with the result that there is no likelihood of any damage occurring due to an extremely high voltage appearing in the load circuit.

As long as the voltage applied by the generator **11** to the regulator **10** remains constant, the current which flows through the load circuit to the lamps **14** will likewise remain constant. However, if the voltage of the generator **11**, for some reason, tends to rise, there will be a corresponding increase in the current flowing through the load circuit. This excess current is shunted by means of a pair of inversely connected arc rectifying devices **20** and **21** which are connected, as illustrated between the conductors **12** and **13** and across the load terminals of the regulator **10**. The arc rectifying devices or valves **20** and **21** are provided, respectively, with anodes **20***a* and **21***a*, with cathodes **20***c* and **21***c*, which may be of the hot type, and control electrodes **20***g* and **21***g*. A grid transformer, shown generally at **22**, is provided, having secondary windings **24** and **25** connected to the grid or control electrodes **20***g* and **21***g*, respectively. The transformer **22** is provided with a primary winding **26** which is connected between the mid-tap **27** of an autotransformer **28** and the common connection **29** between a potentiometer **31**, having a movable connection **32**, and a variable inductor **33**. The autotransformer **28** may be connected for energization to the generator **11**, as illustrated, while the phase shifting circuit **34**, comprising the potentiometer **31** and the inductor **33**, may be connected to taps **35** and **36** on the autotransformer **28**.

In order to control the inductance of the inductor **33**, a regulator **40** is provided having an armature **41** forming a movable core within the turns of the inductor **33**. The armature **41** is mounted at one end of a lever arm **42** which is pivoted at **43** and has provided at its other end

an armature 44, the position of which is controlled by means of a winding 45 connected in series circuit relation with the conductor 13 as shown. A biasing spring 46 is provided to cooperate with the armature 44 for controlling the position of the armature 41.

In operation, as long as the current flowing through the lamps 14 and the winding 45 does not exceed a predetermined value which is the value at which the lamps 14 operate most efficiently, the valves 20 and 21 remain in the non-conducting state. This is accomplished by adjusting the phase shifting circuit 34 so that the control potentials applied to the control electrodes 20*g* and 21*g* under these conditions will have such phase relationship with respect to the corresponding cathodes 20*c* and 21*c* that there is no tendency for current to flow therethrough. However, as soon as the current flowing through the lamps 14 and the winding 45 exceeds a predetermined value, the armature 44 is moved upwardly against the biasing force of the spring 46 to effect a corresponding downward movement of the armature 41. The inductance of the inductor 33 is then decreased to shift the phase of the voltage which is applied for energizing the primary winding 26 of the grid transformer 22. This shift in phase is reflected in the control potential which is applied to the control electrodes 20*g* and 21*g*, so that the valves 20 and 21 are rendered conducting during the half cycles of the alternating current which they are adapted to conduct at times corresponding to the degree of phase shift. The degree of phase shift will be controlled by the amount of excess current which tends to flow through the lamps 14. Thus more or less current will be shunted by the valves 20 and 21, depending upon the time in each half cycle at which they are rendered conducting.

It will be observed that the valves 20 and 21 are employed only for conducting the excess current which would otherwise flow to the lamps 14. Since this excess current will usually be comparatively slight, the size or conducting capacity of the valves 20 and 21 need not be very great. It is necessary only that they be of such size as to be capable of conducting the excess current which would otherwise flow to the lamps 14.

It will also be observed that the lamps 14 will function even though one or both of the valves 20 or 21 should become inoperative. In such case, the excess current, to a greater or lesser extent, would flow through the lamps 14, depending upon whether one or both of the valves 20 or 21 became inoperative. Although the life of the lamps 14 would be correspondingly shortened, they would still be available for illumination purposes, and thus complete reliance for illumination is not placed on the continuity of functioning of the valves 20 and 21.

Another embodiment of my invention is shown in Figure 2 of the drawings. As there shown, a regulator 50 of the static type is provided for operation from a three-phase alternating current generator 51. The regulator 50 may be connected to the generator 51 by means of conductors A, B and C. The regulator 50 is arranged to cause constant current to flow through load conductors X, Y and Z to arc rectifying devices 52, by means of which the three-phase constant current is rectified into direct current for energizing a load circuit comprising conductors 53 and 54 which are connected to energize a group of series connected incandescent lamps 55. A cutout 56 of the film type may be provided across the conductors 53 and 54 to protect against high voltages in the event of an open circuit, as described hereinbefore.

With a view to preventing the load current exceeding the predetermined constant value, a pair of grid controlled arc rectifying devices or valves 60 and 61 is provided, and they are inversely connected, as illustrated, between the conductors Y and Z. The valves 60 and 61 may be similar to the valves 20 and 21, described hereinbefore, having anodes 60*a* and 61*a*, hot cathodes 60*c* and 61*c*, and control electrodes 60*g* and 61*g*. A grid transformer, shown generally at 62, is provided having secondary windings 64 and 65 for energizing the control electrodes 60*g* and 61*g*, respectively. The transformer 62 is provided with a primary winding 66 which may be connected to a mid-tap 67 on an autotransformer 68 which may be connected between the conductors B and C, as illustrated. The other terminal of the primary winding 66 may be connected to a common connection 69 between a potentiometer 71, having a variable connection 72, and a variable inductor 73 forming a phase shifting circuit shown generally at 74. The phase shifting circuit 74 is connected for energization to taps 75 and 76 on the autotransformer 68.

A regulator, shown generally at 80, is provided for controlling the inductance of the inductor 73. As shown, the regulator 80 is provided with an armature 81 which is arranged to move within the turns of the winding forming the inductor 73. The armature 81 is mounted at one end of a lever arm 82 that is pivoted at 83 and which has, at its other end, an armature 84, the position of which is controlled by a winding 85 connected in series circuit relation with the lamps 55 and through which the direct current from the rectifiers 52 flows. A spring 86 is provided for cooperating with the armature 84 in controlling the position of the armature 81.

The functioning of the system shown in Figure 2 of the drawings is similar to that described hereinbefore in connection with Figure 1. As long as the current flowing through the lamps 55 and the winding 85 remains at or below the predetermined constant value, the valves 60 and 61 remain in the non-conducting state. However, if the load current tends to increase above this value, the voltage which is applied for energizing the primary winding 66 of the grid transformer 62 is shifted, due to the change in inductance of the inductor 73, and the valves 60 and 61 are rendered conducting in an amount depending upon the excess current which tends to flow in the load circuit. This excess current will be shunted through the valves 60 and 61, and the current flowing through the lamps 55 will remain at the normal constant value at which they are designed to operate most efficiently.

In some applications it is desirable to transform from a three-phase alternating current source into a constant current single-phase load circuit comprising the series connected incandescent lamps. This transformation can be effected and a balanced load applied on each of the phases of the three-phase system by use of the connections shown in Figure 3 of the drawings. The apparatus there shown is identical in certain respects with the apparatus shown in Figures 1 and 2 of the drawings.

As shown in Figure 3 of the drawings, a transformer, illustrated generally at 90, is provided having primary windings 91 and 92 for connection to the three phase source 51 of alternating

current. The primary windings 91 and 92 are connected to the source 51 by the well known Scott connection. The terminals of the primary winding 91 are connected to two of the phases of the source 51, while one terminal of the winding 92 is connected to the remaining phase. The other terminal of the primary winding 91 is connected to a mid-tap 93 on the primary winding 91. The transformer 90 is provided with secondary windings 94 and 95 in which voltages in quadrature with each other will be induced. The secondary winding 94 is connected directly across the supply terminals of the monocyclic square 10, while the secondary winding 95 is connected in series circuit relation with the load circuit including the incandescent lamps 14, and the combined circuit is connected across the load terminals of the monocyclic square 10 as illustrated. Since the voltage appearing across the load terminals of the monocyclic square 10 is in quadrature with the voltage impressed thereon from the secondary winding 94, the voltage induced in the secondary winding 95 may be readily combined therewith to cause the flow of constant current through the conductors 12 and 13 while maintaining a balanced load on each of the phases of the source 51 as is readily understood by those skilled in the art.

Since the current in the load circuit is maintained at a substantially constant value, a series transformer, shown generally at 96, may be provided having a primary winding 97 connected in the load circuit and a secondary winding 98 for energizing the phase shifting circuit 34. The primary winding 26 of the grid transformer 22 may be connected for energization between a mid-tap 99 on the secondary winding 98 and the common connection 29 between the variable inductor 33 and the variable resistor 31.

The current flowing in the load circuit is prevented from rising above the desired constant current value by the inversely connected valves 20 and 21 which are connected, as illustrated, across the conductors 12 and 13. The functioning of the valves 20 and 21 under the control of the regulator 40 will be the same as described hereinbefore in connection with the description of the functioning of the circuits shown in Figure 1 of the drawings. Therefore, this description will not be repeated.

Since certain further changes may be made in the foregoing constructions and different embodiments of the invention may be made without departing from the scope thereof, it is intended that all matter disclosed in the foregoing description or illustrated in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In combination, an alternating current supply circuit, a substantially constant current load circuit, a monocyclic square connecting said supply circuit with said load circuit, means for regulating the current in the load circuit by a variable by-pass directly in shunt across the constant current side of the monocyclic square comprising electric valve means, and means responsive to the current flow in said load circuit for controlling said electric valve means.

2. In combination, a substantially constant voltage alternating current supply circuit, a substantially constant current load circuit, means for transmitting energy therebetween, electric valve means directly connected in shunt across the load circuit to control the by-pass of current from said load circuit, and means responsive to a variable electrical characteristic of said load circuit for controlling said electric valve means.

3. In combination, an alternating current supply circuit, a substantially constant current load circuit, a transforming device connecting said circuits for transforming from constant voltage to constant current, electric valve means connected in shunt circuit relation to said load circuit to control the current of said supply circuit by variation of the conduction period thereof, a phase shifting network for controlling the conduction period of said electric valve means, and means responsive to the current flow in said load circuit for controlling said phase shifting network.

4. In combination, an alternating current supply circuit, a substantially constant current load circuit, a monocyclic square connecting said supply circuit with said load circuit, current regulating means for controlling the current of said supply circuit including electric valve means connected in shunt circuit relation to said load circuit, a phase shifting network for controlling the conduction period of said valve means, and means responsive to the current flow in said load circuit for controlling said phase shifting network.

5. In combination, an alternating current supply circuit, a substantially constant current load circuit, a monocyclic square connecting said supply circuit with said load circuit, current regulating means for controlling the current of said supply circuit comprising a plurality of grid controlled arc rectifying tubes connected between the load terminals of said monocyclic square, a phase shifting network coacting with the grids of said tubes for controlling the conduction period of each tube, and means responsive to the current of said load circuit for controlling said phase shifting network.

6. In combination, an alternating current supply circuit, a substantially constant current load circuit, means for transmitting energy therebetween, current regulating means for controlling the current of said supply circuit comprising electron tubes connected in shunt across the load circuit and effective to govern the by-pass of current in said load circuit, and means responsive to the current of said load circuit for controlling said electron tubes.

7. In combination, an alternating current supply circuit, a substantially constant current load circuit, a monocyclic square connecting said supply circuit with said load circuit, current regulating means for controlling the current of said load circuit comprising electron tubes connected in shunt across said load circuit, the conduction period of said electron tubes governing the by-pass of current from said load circuit, and means responsive to the current of said load circuit for controlling the conduction period of said tubes.

8. In combination, an alternating current supply circuit, a substantially constant current load circuit, means for transmitting energy therebetween, an electron tube directly connected in shunt circuit relation to said load circuit to control the flow of current therein, and means responsive to the current of said load circuit for controlling said electron tube.

9. In combination, an alternating current supply circuit, a substantially constant current load circuit, a monocyclic square connecting said supply circuit with said load circuit, current regulating means for controlling the current of said

load circuit comprising electron tubes directly connected across the load terminals of said monocyclic square and characterized by a controllable conduction period, the conduction period of said tubes governing said current regulating means, and means responsive to the current of said load circuit for controlling the conduction period of said tubes.

10. In a system of the class described, the combination of an alternating current supply circuit, a substantially constant current load circuit, a transforming device connecting said circuits for transforming from constant potential to constant current, current regulating means for controlling the current of said load circuit comprising an electric valve directly connected in shunt circuit relation to said load circuit, the conduction period of said valve governing the operation of said current regulating means, and means for controlling the conduction period of said valve.

11. A constant current system comprising, in combination, a device for transforming constant voltage energy from an alternating current source into constant current energy for a load circuit requiring substantially constant current, variable conducting means disposed to be directly connected across said load circuit, and regulating means disposed to be responsive to the current flow in said load circuit for controlling the conductivity of said variable conducting means.

12. A constant current system comprising, in combination, a monocyclic square disposed to be connected to an alternating current supply circuit the voltage of which is slightly variable and to energize a substantially constant current load circuit, a pair of inversely connected electric valves directly connected in shunt circuit relation to said load circuit, and means for controlling the conductivity of said valves in accordance with the current flowing in the load circuit to maintain the load current substantially constant on variation of the supply voltage and frequency.

13. A constant current system comprising, in combination, a monocyclic square disposed to be connected to an alternating current supply circuit the voltage of which is slightly variable and to energize a substantially constant current load circuit, a pair of inversely connected electric valves directly connected in shunt circuit relation to said load circuit, control electrode means in said valves, variable phase shift means connected to said control electrode means, and means connected to be responsive to the current flowing in said load circuit for controlling said phase shift means in such manner that the conductivity of said valves is varied to maintain the load current substantially constant.

14. A constant current system comprising, in combination, means for transforming constant voltage energy from a polyphase alternating current supply, the voltage of which is slightly variable, into constant current energy for a load circuit requiring substantially constant current, rectifying means interposed between said means and the load circuit for converting the polyphase current into direct current, variable conducting means disposed to be directly connected across one of the constant current phases of said means, and regulating means disposed to be responsive to the current flow in said load circuit for controlling the conductivity of said variable conducting means to maintain the load current substantially constant on variation of the supply voltage and frequency.

15. A constant current system comprising, in combination, means for transforming constant voltage energy from a polyphase alternating current supply, the voltage of which is slightly variable, into constant current energy for a load circuit requiring substantially constant current, rectifying means interposed between said means and the load circuit for converting the polyphase current into direct current, a pair of inversely connected electric valves directly connected across one of the constant current phases of said means, and means for controlling the conductivity of said valves in accordance with the current flowing in the load circuit to maintain the load current substantially constant on variation of the supply voltage and frequency.

16. A constant current system comprising, in combination, means for transforming constant voltage energy from a polyphase alternating current supply, the voltage of which is slightly variable, into constant current energy for a load circuit requiring substantially constant current, rectifying means interposed between said means and the load circuit for converting the polyphase current into direct current, a pair of inversely connected electric valves connected across one of the constant current phases of said means, control electrode means in said valves, adjustable phase shift means connected to said control electrodes to determine the time in each half cycle at which said valves are rendered conducting, and means for controlling said phase shift means in accordance with the direct current flowing in said load circuit.

17. A constant current system comprising, in combination, means for transforming constant voltage energy from a polyphase alternating current supply into constant current energy for a load circuit requiring substantially constant current, variable conducting means directly connected across said load circuit, and regulating means disposed to be responsive to the current flow in said load circuit for controlling the conductivity of said variable conducting means.

18. In combination, an alternating current supply circuit, a substantially constant current load circuit, means for transmitting current therebetween, normally substantially non-conductive electric valve means directly connected in shunt across said load circuit, and means rendering said valve means conductive for by-passing therethrough excess current responsive to tendency to increase of current in said load circuit in excess of a predetermined normal value.

19. In combination, a substantially constant current load circuit, normally substantially non-conductive electric valve means directly connected in shunt across said load circuit, and means rendering said valve means conductive for by-passing therethrough excess current responsive to tendency to increase of current in said load circuit in excess of a predetermined normal value.

20. In current control means for use with an electrical distribution system comprising a load circuit requiring substantially constant current, electric valve means for direct connection in shunt across said circuit, and means for association with said circuit effective for rendering said valve means normally substantially non-conductive and conductive for by-passing therethrough excess current responsive to tendency to increase of current in said load circuit in excess of a predetermined normal value.

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