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REGULATED POWER SUPPLY

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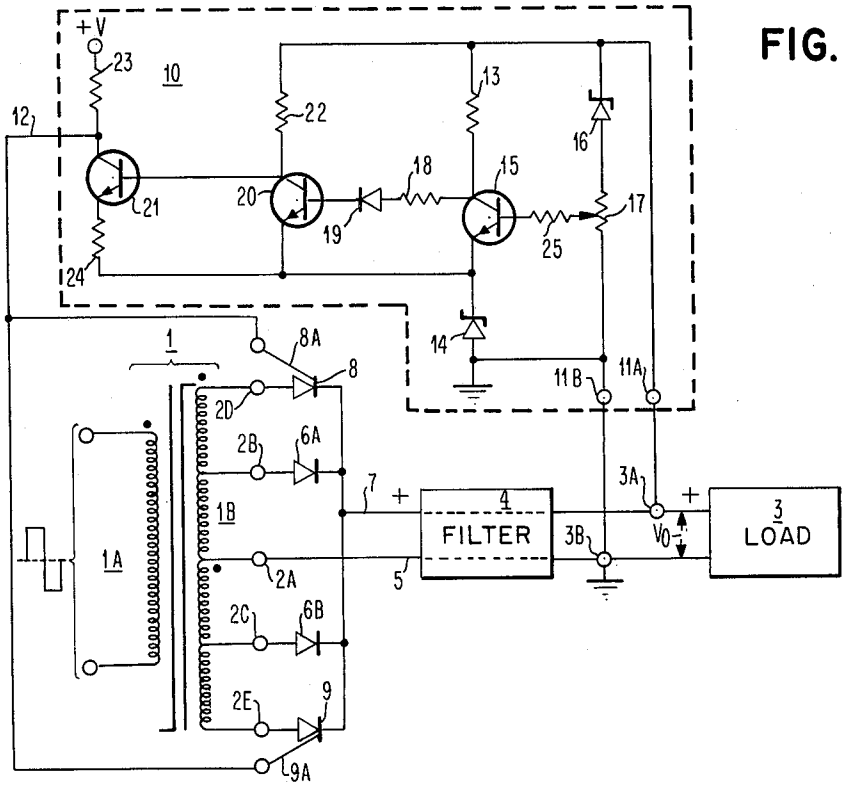


FIG. 1

FIG. 2

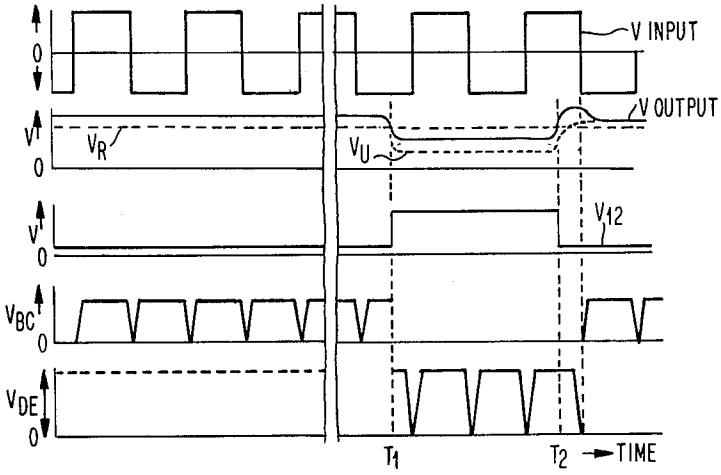


FIG. 2a

FIG. 2b

FIG. 2c

FIG. 2d

FIG. 2e

INVENTORS
EDWARD R. Mc NULTY
EDWARD A. MENARD
BY
ATTORNEY

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REGULATED POWER SUPPLY

Edward R. McNulty, Saugerties, and Edward A. Menard, Ruby, N.Y., assignors to International Business Machines Corporation, New York, N.Y., a corporation of New York

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The present invention relates to a power supply which furnishes direct current to a load at regulated voltage, and particularly to such a supply in which in-phase pulsating current is delivered at first and second source taps, at first and second higher voltages, respectively. In the contemplated supply, one tap at a time is to be selectively connected to the lead in accordance with the voltage requirements of the load.

In the past, tap changing regulators of the type mentioned above have been provided in which electromechanical switching gear has been used to effect selective connection between any of multiple taps and a load. Such gear has the inherent disadvantages of being bulky, slow, and relatively expensive. While other tap changing regulators have been provided in which non-mechanical apparatus is used to effect the switching function, such apparatus usually has the inherent disadvantage of being both complex and expensive.

Accordingly, it is an object of the present invention to provide a new and improved direct current supply.

Another object of the present invention is to provide an improved current supply of the tap changing type wherein the voltage delivered may be changed by simple and easily controlled components.

Another object of the present invention is to provide a tap changing regulator for furnishing voltage at various levels without resorting to the use of electro-mechanical devices.

Another object of the present invention is to provide a new and improved power supply of the tap changing type which employs controlled rectifiers as switching elements wherein advantage is taken of the inherent ability of unidirectionally conductive devices to become nonconductive when back-biased.

The foregoing and other objects, features, and advantages of the invention will be apparent from the following, more particular description of a preferred embodiment of the invention as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 represents a schematic diagram of the preferred embodiment of a regulated, tap changing direct current power supply;

FIGS. 2A through 2E represent voltages at various points in the system, hereinafter described, with respect to a common time base.

Turning to FIG. 1, there is shown transformer 1 having a primary winding 1A which is connected to an alternating current source (not shown). The alternating current source produces a square wave voltage of substantially uniform amplitude (level) and frequency represented in FIG. 2A. In the following description, it is assumed that there is substantially no variation in input voltage amplitude with changes in the amount of power passed through transformer 1.

Secondary winding 1B of transformer 1 has a center tap 2A as well as a first pair of taps, 2B and 2C, which are balanced with respect to tap 2A, so that transformer 1 delivers at taps 2B and 2C a signal having a substantially square wave voltage in which the positive and negative-going excursions about a reference potential at tap 2A are substantially identical. The amplitude of the positive-going voltage excursions at taps 2B and 2C with

respect to tap 2A is represented in FIG. 2D. A second pair of taps, 2D and 2E is provided on secondary winding 1B, taps 2D and 2E also being balanced with respect to center tap 2A and delivering substantially square wave output voltage at a second level that is substantially in-phase with, but at a voltage higher than that delivered at taps 2B and 2C. The amplitude of the positive-going excursions at taps 2D and 2E with respect to tap 2A is represented in FIG. 2E. For reasons that are to be made apparent, each of taps 2B through 2E is to be regarded as a source of voltage pulses which are positive-going with respect to tap 2A when observed during appropriate, alternate cycle halves of the output signal developed across winding 1B. Such power pulses from selected pairs of secondary winding 1B taps are to be delivered to load 3 by means hereinafter described.

Load 3 has input terminals of 3A and 3B to which current from transformer 1 is delivered. The nature of load 3 is such that it uses power in varying amounts, and that power is to be delivered to terminals 3A and 3B at a voltage only slightly below a predetermined minimum value, indicated as V_R in FIG. 2B, which represents the voltage delivered at terminals 3A and 3B. The value of V_R is slightly less than the voltage amplitude indicated in FIG. 2D. If it is assumed for the moment: (1) that only taps 2B and 2C are connected to terminal 3A and 3B by diodes 6A and 6B in full wave rectifier configuration, (2) that power normally is being delivered at a fixed rate to load 3; and (3) that an increased amount of power is consumed by load 3 between times T1 and T2, indicated on the time of axis of FIG. 2E, then it follows that between times T1 and T2, the voltage at terminals 3A and 3B would decrease and might drop substantially below the value V_R in the manner represented by the dotted portion of the curve indicated as V_U in FIG. 2B. In order to minimize excursions of voltage at terminals 3A and 3B below V_R, the next described means is provided to couple tap 2A and a selected pair of taps 2B–2C and 2D–2E to terminals 3A and 3B. The last named means includes filter 4, which may be of any of a number of conventional, commercially available types which have metallic paths indicated in the drawing by dotted lines which serially connect conductors 5 and 7 to terminals 3B and 3A, respectively.

In the contemplated configuration, the means coupling the above-identified pair of tap sources 2B–2C as well as tap 2A across conductor 5 and 7 (and hence across terminals 3A and 3B) comprises a first pair of unidirectionally conductive devices, such as diodes 6A and 6B, serially connected in full wave rectifier configuration between tap 2B and conductor 7 and between tap 2C and conductor 7, respectively (i.e., the diodes are poled to be conductive during the positive going halves of signals appearing at taps 2B and 2C). Diodes 6A and 6B are of the dry plate type, and are normally (i.e., in the absence of a back-biasing potential which maintains the cathode positive with respect to the anode) effective to conduct current in the forward direction, i.e., from anode to cathode during the time that taps 2C and 2D are positive with respect to tap 2A. Consequently, power normally is delivered by diodes 6A and 6B via conductor 7 to tap 3A of load 3 and returned via conductor 5 and tap 2A at a voltage observed at terminal 3A which is positive with respect to terminal 3B and ground potential.

The above mentioned means also includes a pair of controllable, unidirectionally conductive devices, i.e., controlled rectifiers 8 and 9, which may be of any commercially available type. The main anodes of rectifiers 8 and 9 are connected to taps 2D and 2E while the cathodes are connected to conductor 7. It is to be seen that means is provided for establishing a metallic path which connects the cathodes of rectifiers 8 and 9 in parallel with

the cathodes of diodes 6A and 6B. Thus rectifiers 8 and 9 serve as switches, and when operative i.e., conductive, serve to connect source taps 2D–2E and tap 2A to load input terminals 3A and 3B in the same manner that diodes 6A–6B connect taps 2B–2C to the load terminals.

Controlled rectifiers 8 and 9 have starting anodes or control electrodes 8A and 9A, respectively, and each becomes conductive in the forward direction when both its main anode and starting anode become positive with respect to its cathode. Once rendered conductive, each of rectifiers 8 and 9 remains conductive until its cathode becomes positive with respect to its anode.

Control electrodes 8A and 9A are connected together and to input conductor 12 which normally is maintained by sensing means 10 at a voltage less positive than the average voltage produced at taps 2B and 2C, sensing means 10 being hereinafter described. It is assumed for the moment that means 10 also is operable to produce on conductor 12 a signal which is more positive with respect to the above mentioned normal signal and the voltage contributed to conductor 7 from taps 2B and 2C, so that the latter signal makes control electrodes 8A and 9A positive with respect to conductor 7 and to the cathodes of rectifiers 8 and 9. With this arrangement, rectifiers 8 and 9 normally are maintained in nonconductive state and are selectively made operative upon the appearance of the above described positive signal on conductor 12.

Sensing means 10 produces a continuing, positive-going signal on its output conductor 12 in response to the reduction in voltage applied to its input terminals 11A and 11B below a predetermined minimum. The relationship is to be seen by comparing FIG. 2C (which shows the voltage present on conductor 12) to FIG. 2B. While means 10 may be chosen from any of a number of commonly available designs, for purposes of illustrating the present invention the configuration of apparatus shown in FIG. 1 is preferred. Input terminals 11A and 11B are connected directly to terminals 3A and 3B, respectively. Voltage appearing across the input terminals of load 3 therefore is applied to the emitter-collector circuit of NPN type transistors 15 and 20 via resistors 13 and 20, respectively, and via common zener diode 14, which serves to clamp the emitters of transistors 15 and 20 at a fixed positive voltage with respect to terminals 11B and 3B. A dropping circuit is placed across terminals 11A and 11B and includes zener diode 16 and potentiometer 17. The tap of potentiometer 17 is coupled via resistor 25 to the base of transistor 15. When the voltage applied to terminals 11A and 11B is greater than the above mentioned voltage V_R, diode 16 is conductive, and the resulting voltage at the base of transistor 15 is sufficiently positive with respect to its emitter to hold transistor 15 in a saturated state. As a consequence of the saturation of transistor 15, the collector thereof, as well as the base of transistor 20 (which is connected to the transistor 15 collector via resistor 18 and diode 19) are maintained substantially at the voltage present on the emitter of transistor 20: i.e., at the voltage developed across clamping diode 14. At this voltage across the base and emitter of transistor 20, transistor 20 is maintained in its cutoff state, so that substantially no current flows in its emitter-collector circuit. Consequently, the voltage present at the collector of transistor 20 and the base of NPN type transistor 21 (which is directly coupled to the collector of transistor 20) are maintained at a voltage which is positive with respect to ground and to the emitter of transistor 21 and which approaches the value of the voltage present on terminal 3A. The emitter-collector circuit of transistor 21 is connected across the voltage source +V and diode 14 via resistor 23 and emitter-follower resistor 24. With the base of transistor 21 maintained positive with respect to its emitter, transistor 21 is driven into saturation. As a result, the collector of transistor 21 is maintained at relatively low positive voltage with respect to the terminal 3B (which, it will be recalled, is at ground potential). Since output conductor 12 is directly connected to the collector of transistor 21, the voltage present on conductor 12 normally is maintained slightly positive with respect to ground and more negative than the average voltage appearing on conductors 7.

When the voltage present at terminals 3A and 3B, and consequently terminals 11A and 11B, drops below the predetermined positive value V_R, zener diode 16 becomes nonconductive, therewith allowing the voltage applied to the base of transistor 15 to become sufficiently negative with respect to the emitter of transistor 15 to drive transistor 15 beyond cutoff. As a consequence, transistor 15 substantially stops conducting current through its emitter-collector circuit and allows the voltage at the base of transistor 20 to become positive with respect to its emitter to the point where transistor 20 goes into saturation. As the result of driving transistor 20 into saturation, the collector thereof as well as the base of transistor 21 become sufficiently negative with respect to the emitter of transistor 21 to drive transistor 21 beyond cutoff. Transistor 21 at this time ceases to conduct in its emitter-collector circuit, so that voltage appearing on output conductor 12 becomes positive and approaches the value of source +V. Should the voltage across terminals 11A and 11B later rise to a value greater than V_R, transistor 15 is again driven into saturation, therewith making transistor 20 effective to make transistor 21 conductive in its emitter-collector circuit in the above described manner. The value of the more positive signal on conductor 12 is of sufficient amplitude to make control electrodes 8A and 9A positive with respect to the voltage present on conductor 7 and therewith renders rectifiers 8 and 9 operative to conduct current.

From the foregoing description it is to be seen that during the time the normal signal is present on conductor 12, controlled rectifiers 8 and 9 are maintained nonconductive, so that diodes 6A and 6B pass current to load 3 at a voltage sufficient to maintain input terminal 3A at a positive voltage with respect to 3B which is greater than V_R. However, as the power requirements of load 3 increase (as at time T1) to the point where the voltage at terminal 3A would with respect to terminal 3B drop to a value less than V_R, sensing means 10 becomes effective to produce the above-described more-positive signal to conductor 12 and to control electrodes 8A and 9A. Consequently, each of rectifiers 8 and 9 is rendered conductive as taps 2D and 2E, respectively, become positive with respect to tap 2A. Since the voltage delivered at taps 2D and 2E is in phase with and at voltage substantially higher than the voltage delivered at taps 2B and 2C, the voltage appearing at the cathodes of rectifiers 8 and 9 during the intervals that those rectifiers are conductive is substantially higher than the voltage delivered to the anodes of diodes 6A and 6B. Therefore, diodes 6A and 6B are back-biased (hence, nonconductive) during the periods that rectifiers 8 and 9 are conductive. This relationship is to be seen by comparing FIGS. 2D and 2E, which represent the voltage of power pulses supplied to conductor 7 via diodes 6A–6B and via rectifiers 8–9, respectively.

Referring to FIGS. 2B through 2E, if it is assumed for the moment that the voltage at terminal 3A–3B has dropped slightly below the V_R (owing to an increased demand for power within load 3) at time T1 and that sensing means 10 has thereupon generated a positive signal on conductor 12 (represented in FIG. 3C), then the one of rectifiers 8 and 9 connected to the currently-positive one of taps 2D and 2E becomes conductive, therewith back-biasing and rendering nonconductive the one of diodes 6A and 6B which is connected to the currently-positive one of taps 2B and 2C. Consequently, power at the higher voltage delivered at taps 2D and 2E is applied across terminals 3A and 3B of load 3, and power from taps 2B and 2C is shut off upon the back-biasing of

diodes 6A and 6B. Current continues to flow alternately through rectifiers 8 and 9 during the time that the positive signal is maintained on conductor 12. It is assumed that at time T2 the power requirement of load 3 decreases, so that the voltage across terminals 3A and 3B returns to a value greater than V_R. Consequently, sensing means 10 replaces the more positive signal on conductor 12 with the normal level signal. Upon removal of the more positive signal from conductor 12, the currently-conducting one of rectifiers 8 and 9 remains operative and continues to pass current to conductor 7 until the voltage applied to the main anode thereof becomes negative with respect to its cathode. Thereupon the back-biasing voltage is removed from diodes 6A and 6B, so that upon the occurrence of the next positive going signal on one of taps 2B and 2C, the appropriate one of diodes 6A and 6B again becomes conductive. Thereafter, diodes 6A and 6B supply power to load 3 until sensing means 10 again applies the low voltage-indicating signal to conductor 12 with the above noted effects.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made variant without departing from the spirit and scope of the invention.

What is claimed is:

1. In a supply to deliver direct current to first and second input terminals of a load,

a transformer having a primary winding coupled to an alternating current source and a secondary winding,

said secondary winding having a common return tap as well as first and second taps to furnish current of like polarity and phase at a first voltage and a second, higher voltage, respectively,

means to directly connect said common tap to said first load terminal and to directly connect said first and said second transformer taps to said second load terminal,

said means including a diode serially connected between said first tap and said second load terminal normally effective to conduct current therethrough in a forward direction to said load,

said means also including a rectifier having a control anode,

means connected across said load terminals effective in response to the reduction of voltage thereat below a predetermined value to apply a signal to said control anode,

said rectifier being serially connected between said second transformer tap and said second load terminal and effective upon the application of a signal to said electrode to conduct current therethrough in the same direction with respect to said load as said diode,

said rectifier being effective in conductive state to provide current to said load,

and means coupling said rectifier to said diode to apply reverse voltage to said first diode during the time said rectifier is conducting current.

2. In a supply to deliver direct current to first and second input terminals of a load,

a transformer having a primary winding coupled to an alternating current source and a secondary winding,

said secondary winding having a center tap as well as first and second pairs of taps, said taps in each of said pairs being disposed on opposing sides of and being balanced with respect to said center tap,

first and said second pairs of taps being disposed to deliver current at a first voltage and at a second, higher voltage, respectively,

means connecting said center tap to said first load terminal to form a common return path to said transformer secondary winding,

means comprising a pair of diodes connected in series between said first pair taps and said second load terminal poled to form a path to conduct current in a fixed direction from said first pair taps to said second load terminal during alternate halves of said voltage cycle produced in said secondary winding by said source,

means comprising a pair of controlled rectifiers, each of said rectifiers having a main anode and a cathode connected in series between said second pair of taps and said second load terminal and also having a control anode,

means connected across said load input taps effective in response to the reduction of voltage thereat below a predetermined value to apply a signal to said control anodes,

said controlled rectifiers being responsive upon the application of a signal to said control anodes thereat to conduct current from said main anode to said cathode in a forward direction in the same direction with respect to said load as said diodes from said second pair of taps to said load,

and means coupling said rectifiers to said diodes to apply reverse voltage to said first pair diodes during the time said rectifiers are conductive.

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LLOYD McCOLLUM, *Primary Examiner.*