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VARIABLE VOLTAGE RECTIFIER SYSTEM
FROM THREE PHASE LINE SOURCE
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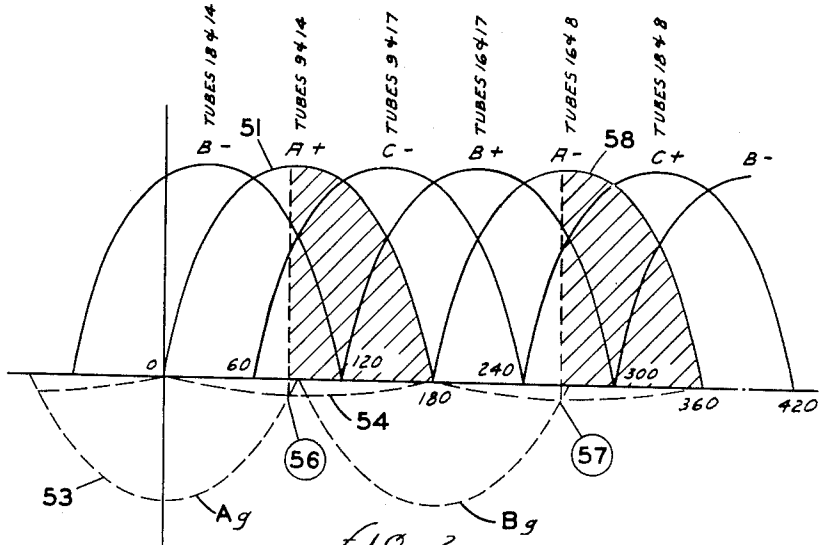


Fig. 2

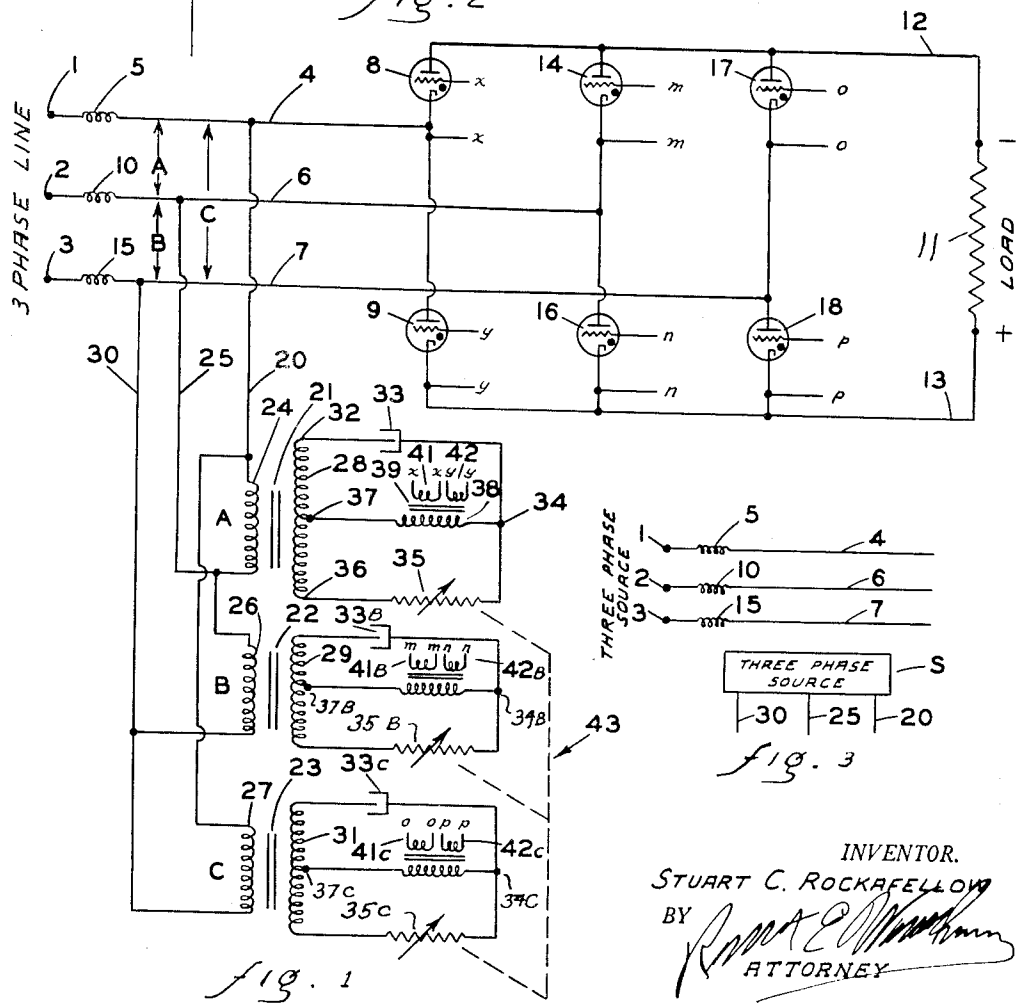


Fig. 1

Fig. 3

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VARIABLE VOLTAGE RECTIFIER SYSTEM FROM THREE PHASE LINE SOURCE

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3 Claims. (Cl. 321—40)

This invention relates to means for providing a variable direct current from a three-phase alternating source and it relates more particularly to a circuit supplying rectified current directly to a load from a three-phase line source without the interposition of transformers.

In present types of rectifiers used with three-phase line sources, transformers are interposed between the source and the load which involves substantial added cost and weight and requires considerable space. In some types of presently known circuits both transformers and added inductors are necessary for operation. In the circuit hereinafter set forth, only the lines from the regular three-phase source are used as a supply and the current goes directly from them through suitable electric discharge devices to the load. Although transformers are used in the present circuit, they do not carry the main current load and hence may be much smaller and less costly than the transformers required by presently known circuits.

Accordingly, a principal object of the invention is to provide a circuit for supplying a direct current from a three-phase alternating source without the use of transformers interposed between said source and the direct current load.

A further object of the invention is to provide a circuit, as aforesaid, wherein the direct current may readily be made of variable value.

A further object of the invention has been to provide a circuit, as aforesaid, wherein the value of said direct current may be controlled by a single manually responsive element.

A further object of the invention has been to provide a circuit, as aforesaid, having maximum simplicity.

A further object of the invention has been to provide a circuit, as aforesaid, having minimum maintenance requirements.

A further object of the invention has been to provide a circuit, as aforesaid, which is capable of being made from standard parts and all of which parts may be made extremely rugged and durable.

A further object of the invention has been to provide a circuit, as aforesaid, in which the control over the magnitude of the direct current will be exacting and precise and not subject to undesired variations independent of variations in the three-phase source.

Other objects and purposes of the invention will become apparent to persons acquainted with apparatus of this general type upon a reading of the following specification and inspection of the accompanying drawings.

In the drawings:

Figure 1 represents a circuit diagram of one embodiment of my invention.

Figure 2 represents a graph illustrating the relationship of certain potentials operating within the embodiment of my invention shown in Figure 1.

Figure 3 represents a fragmentary diagram of a modification.

General description

In general, the circuit of my invention comprises a rectifier portion and a phase shift portion. The rectifier portion comprises three pairs of grid controlled, gas filled, electric discharge devices. One of each of said pairs is connected on its anode side to one side of said load and the other of each of said pairs is connected on its cathode side to the other side of said load. A first pair of said devices is connected by the anode of the first of said pair and the cathode of the second of said pair to a first conductor of said three line source, a second pair of said devices is connected by the anode of the first thereof and the cathode of the second thereof to a second conductor of said three line source and the third of said devices is connected by the anode of the first thereof and the cathode of the second thereof to a third conductor of said three line source.

A first phase shift circuit is energized from the first and second of said conductors and its output is applied between the grid and cathode of each of the first pair of said devices, a similar phase shift circuit is energized by the second and third of said conductors and its output is applied between the grid and cathode of the second of said devices and a third phase shift circuit is energized by the first and third of said conductors and its output is applied between the grid and cathode of each of the third pair of said devices. Means are preferably, but not necessarily, provided for simultaneously and equally controlling the phase shift in the output of each of said phase shift circuits with respect to the input of each thereof.

Detailed description

Terminals **1**, **2** and **3** indicate line terminals to which may be connected any three phase line source of a desired voltage. The power conductors **4**, **6** and **7** lead respectively from each of said terminals for supplying the remainder of the hereinafter described apparatus. The letters A, B and C with their accompanying arrows indicate in a conventional manner the conductors between which the hereinafter mentioned phases are taken to exist.

For convenience in description, the grid controlled, gas filled, electric discharge devices which are utilized to control the flow of current from the respective phases of said line source are hereinafter referred to as "thyratrons" inasmuch as thyratrons are utilized in a preferred embodiment of the invention, but it will be understood that I can use any other tube having the characteristic that when an electron flow is once started between the principal electrodes it will continue regardless of the grid voltage applied so long as a voltage above a predetermined minimum is applied between its principal electrodes. It will also be recognized that any of several standard circuits may be used wherein ignitrons are provided as the principal current carrying tubes and thyratrons, or other tubes of similar characteristics, are merely utilized to control the conduction or non-conduction of said ignitrons.

Now considering the rectifier portion of the circuit, a first pair of thyratrons **8** and **9** are connected between the first power conductor **4** and the load **11**. Thyratron **8** is connected by its cathode to said first power conductor **4** and by its anode is connected through the first load conductor **12** to one side of the load **11**. Thyratron **9** is connected by its anode to the conductor **4** and by its cathode through the second load conductor **13** to the other side of said load.

A second pair of thyratrons **14** and **16** are similarly connected between the second power conductor **6** and the load **11**. Thyratron **14** is connected by its cathode to the second power conductor **6** and by its anode to the first load conductor **12** to said one side of the load **11**. Thyra-

tron 16 is connected by its anode to the second power conductor 6 and by its cathode through the second load conductor 13 to said other side of the load.

A third pair of thyratrons 17 and 18 are similarly connected between the third power conductor 7 and the load. Thyratron 17 is connected by its cathode to the third power conductor 7 and by its anode through the first load conductor 12 to said one side of said load 11. Thyratron 18 is connected by its anode to said third power conductor 7 and by its cathode through the second load conductor 13 to said other side of said load 11. By reason of such connections to said load, said one side of said load may be referred to as its "negative" side and said other side of said load may be referred to as its "positive" side, although it will be understood that such reference, where used, is for convenience in reference and is not limiting.

The control grids of each of said thyratrons are connected through potential sources, as the secondary windings of transformers hereinafter referred to in more detail, to the respective cathodes of said thyratrons.

Attention will now be directed toward the phase shift control portion of the circuit. Transformers 21, 22 and 23 are each connected by their respective primary windings 24, 26 and 27 across suitable sources of potential, each bearing a predetermined phase relationship with the phases of the line source. In the preferred embodiment here illustrated, said respective primary windings are connected directly across the respective phases of the line source. In the circuit shown in Figure 1 the primary winding 24 is connected across the phase A, the primary winding 26 is connected across phase B and the primary winding 27 is connected across phase C.

The respective secondary windings 28, 29 and 31 of said transformers 21, 22 and 23 are connected through conventional phase shift circuits to suitable output terminals. In the preferred embodiment of the invention shown in Figure 1, the terminal 32 of the secondary winding 28 is connected through a capacitor 33 to a terminal 34. Said terminal 34 is connected through a variable resistance 35 to the opposite terminal 36 of said secondary winding 28. A terminal 37 is connected to a center-tap on said secondary winding 28 and it, together with the terminal 34 comprises the output terminals of said phase shift circuit. Said terminals 34 and 37 are each connected to the primary winding 38 of a transformer 39 whose secondary windings 41 and 42 are each connected, respectively, to the grids of the thyratrons 8 and 9, the secondary winding 41 being connected between the grid and cathode of the thyratron 8 and the secondary winding 42 being connected between the grid and cathode of the thyratron 9.

Each of the phase shift circuits connected to the secondary windings 29 and 31 is identical with the phase shift circuit just described as connected to the secondary winding 28 and needs no separate description. The parts are designated by numerals identical with the numerals associated with the secondary winding 28 excepting for the addition of the letter B to those numerals associated with the secondary winding 29 and the addition of the letter C to those numerals identifying the parts associated with the primary winding 31. The secondary winding 41B is connected across the grid and cathode of the thyratron 14, the secondary winding 42B is connected across the grid and cathode of the thyratron 16, the secondary winding 41C is connected across the grid and cathode of the thyratron 17 and the secondary winding 42C is connected across the grid and cathode of the thyratron 18. The broken line 43 designates a common control for each of the variable resistors 35, 35B and 35C, which common control may be of any well known mechanical form or it may be of the type illustrated in my copending application Ser. No. 262,079, filed December 17, 1951.

Inductances 5, 10 and 15 may advantageously be applied in lines 4, 6 and 7 between said line terminals 1, 2 and 3 and the points of connection thereto of the phase shift circuits in order to absorb any possible shorting due to arc-back which might occur in the event that any of the thyratrons fail to operate properly. These inductors are relatively small, being used only as protection for the line, to absorb the short circuit for the time taken for external fuses or circuit breaker to act.

It will be noted that in the foregoing specific embodiment, the transformer primary windings 24, 26 and 27 derive their respective control potentials from the conductors 4, 6 and 7 and therefore said control potentials are exactly in phase with the potentials supplied to the load 11. It will be appreciated that while this is a preferred embodiment for most cases, there may be some circumstances, as indicated in Figure 3, in which it is desired to derive said control potentials from another source S. This may be done and will be within the scope of the broader aspects of the invention providing only that a definite phase relationship exists between the source S and the source supplying the line terminals 1, 2 and 3.

Operation

Assuming first that the control electrodes of the several thyratrons are unenergized, it will be recognized that a positive pulse in phase A will travel from the first power conductor 4 through the thyratron 9, thence through the load, thence back through the thyratron 14 to the second power conductor 6, and that a negative pulse in the same phase will travel through the thyratron 16 and the load 11, thence back to the conductor 4 through the thyratron 8. Similarly a positive pulse flowing in phase B will travel through thyratron 16, thence through the load 11 and back through thyratron 17 to the third power conductor 7. A negative pulse flowing in phase B will travel through the thyratron 18, thence through the load 11 and back through the thyratron 14 to the second power conductor 6. A positive pulse flowing in phase C will flow through thyratron 18, thence through the load 11 back through the thyratron 8 to the first power conductor 4, and a negative pulse flowing in said phase C will flow through the thyratron 9, thence through the load 11 and back through the thyratron 17 to the third power conductor 7.

Thus, without energization in the several control electrodes of said six thyratrons, a fully rectified direct current will flow through the load 11.

Considering now the effect of the phase shift circuit, the variable resistors 35, 35B and 35C will be assumed to be positioned so that, according to conventional and well known practice, the voltages in the several control electrodes of the six thyratrons will be exactly opposite to the voltage applied to their principal electrodes. In such condition none of the thyratrons will conduct and no current will be supplied to the load 11.

Now as the variable resistors 35, 35B and 35C are simultaneously adjusted to shift the phase of each of their respective output potentials forwardly with respect to the respectively connected line potentials, conduction will commence through the system and a potential will be supplied across the load 11. Inasmuch as the operation of the parts of the circuit connected to phases B and C are each identical to the operation of the part of the circuit connected to phase A of the line source, the following description will refer expressly only to phase A with the understanding that it will apply also to phases B and C.

Referring again to Figure 2, the broken line 53 represents the position of the grid potential applied to thyratrons 8 and 9 with respect to the potential of the phase A of the line source in a case taken, for example, where said grid potentials are advanced by 90°. The broken line 54 represents the minimum grid potential effective to block conduction through said thyratron at any given point in the wave form of the line voltage. Thus, at the

beginning of a positive pulse in phase A, a sufficiently negative voltage is applied to the grid of the thyratron **9**, that no conduction will occur. However, when the grid voltage has diminished to the critical point indicated at **56** in Figure 2, then conduction will commence through the thyratron **9** and continue for the balance of the positive half cycle in phase A as indicated by the shaded portion under line **51** in Figure 2. The current passes through the load **11** and back to the conductor **6** through the thyratron **14** which is already conducting due to the negative pulse of phase B. Thus, the thyratron **9** constitutes the sole control for the passage through the load of current resulting from a positive pulse in phase A.

The negative pulse from phase A traveling from the second power conductor **6** to the thyratron **16** will pass through said thyratron **16** inasmuch as this tube is already conducting by virtue of the overlapping positive pulse from phase B. It then flows through the load **11** and back through thyratron **8** as soon as the potential on the grid thereof drops below the cut-off point, as indicated at **57** in Figure 2. Current is thus started through this circuit under the control of thyratron **8**, and, when once started, it flows for the balance of the negative half cycle of phase A as indicated by the shaded portion under line **58** in Figure 2.

Each of the other pulses is controlled similarly. The positive pulse in phase B will pass first through thyratron **16**, by which the point of starting of the flow of said pulse is controlled, thence through the load **11** and back through the thyratron **17** which will be already conductive due to the conduction therethrough of the negative pulse from phase C, and return to the wire **6**. The negative pulse of phase B will travel first through the thyratron **18**, which is already conductive due to the passage of the positive pulse of phase C, thence through the load **11** and back to the thyratron **14**, by which its point of starting is controlled in the manner above described with respect to phase A, to the wire **6**. The positive pulse of phase C passes first through thyratron **18**, by which its point of starting is determined in the same manner as above described for phase A, thence through the load **11** and back to the wire **4** through the thyratron **8**, which latter thyratron is already conductive due to its conducting the negative pulse of phase A. The negative pulse of phase C passes from wire **4** through the thyratron **9**, which is already conductive due to the conducting therethrough of the positive pulse of phase A then through the load **11** and back through thyratron **17**, by which the commencement of the flow of said negative pulse of phase C is controlled in the same manner as above described for the other phases, and thence back to the wire **7**. Reference to Figure 2 will further assist in making these relationships clear.

However, upon inspection of Figure 2 it will be apparent that the starting of any given phase, as phase A for example, cannot be delayed beyond 120 degrees from the commencement of said phase for otherwise the tube **16** conducting the negative half cycle of phase B will have ceased to operate and the circuit therethrough for the positive pulse of phase A will be interrupted. The same relationship is true for the negative pulse of phase A as well for both the positive and negative pulses of each of the other two phases.

It will be apparent in view of the foregoing that by simultaneously and equally adjusting the phase at the output terminals of the several phase shift circuits with respective phases of the line supply, a rectified direct current of a wide range of voltage may be obtained in the load.

Therefore, in this manner, I obtain an accurate and precise control over the magnitude of the current flowing through said load and, further, the various other objects and purposes above set forth are accomplished. Although I have herein utilized certain specific embodiments of my invention for illustrative purposes, it will be

recognized that various modifications may be made which will be within the scope of the claims excepting as said claims expressly provide otherwise.

I claim:

1. A circuit for effecting variable voltage, full-wave, rectification from a three-phase source, the combination comprising: first, second and third power conductors connectible to each line respectively of said source; a pair of thyratrons, one connected by its cathode to said first power conductor and the other connected by its anode to said first power conductor, the anode of a first thyratron of said first pair thereof being connected to a first side of a load and the cathode of a second thyratron of said first pair thereof being connected to a second side of said source; a second pair of thyratrons, a first thereof being connected by its cathode to said second power conductor and a second thereof being connected by its anode to said second power conductor, the anode of said first of said second pair of thyratrons being connected to said first side of said load and the cathode of said second of said second pair of thyratrons being connected to said second side of said load; a third pair of thyratrons, a first thereof having its cathode connected to said third power conductor and the second thereof being connected by its anode to said third power conductor, the anode of said first of said third pair of thyratrons being connected to said first side of said load and the cathode of said second of said third pair of thyratrons being connected to the said second side of said load; a phase shift circuit simultaneously energizing the grids of said first pair of thyratrons with respect to their respective cathodes in a predetermined phase relationship with a potential existing between said first and second power conductors; a further phase shift circuit energizing the grids of said second pair of thyratrons with respect to their respective cathodes in a predetermined phase relationship with a potential existing between said second and third power conductors; a still further phase shift circuit energizing the grids of said third pair of thyratrons with respect to the cathodes of each thereof in a predetermined phase relationship with a potential existing between said third and first power conductors, and means for simultaneously and equally shifting the phase of the output of each of said phase shift circuits with respect to the input of each thereof respectively.

2. A circuit for effecting variable voltage, full-wave, rectification from a three-phase source, the combination comprising: first, second and third power conductors connectible to each line respectively of said source; a pair of thyratrons, one connected by its cathode to said first power conductor and the other connected by its anode to said first power conductor, the anode of a first thyratron of said first pair thereof being connected to a first side of a load and the cathode of a second thyratron of said first pair thereof being connected to a second side of said source; a second pair of thyratrons, a first thereof being connected by its cathode to said second power conductor and a second thereof being connected by its anode to said second power conductor, the anode of said first of said second pair of thyratrons being connected to said first side of said load and the cathode of said second of said second pair of thyratrons being connected to said second side of said load; a third pair of thyratrons, a first thereof having its cathode connected to said third power conductor and the second thereof being connected by its anode to said third power conductor, the anode of said first of said third pair of thyratrons being connected to said first side of said load and the cathode of said second of said third pair of thyratrons being connected to the said second side of said load; a first phase shift circuit and means energizing same from said first and second conductors; a second phase shift circuit and means energizing same from said second and third conductors; a third phase shift circuit and means energizing same from said third and first conductors; means utiliz-

ing the output of said first phase shift circuit for creating a potential between the grid and cathode of each of said first pair of thyratrons; means utilizing the output of said second phase shift circuit for creating a potential beween the grid and cathode of each of said second pair of thyratrons; and means utilizing the output of said third phase shift circuit for creating a potential between the grid and cathode of each of said third pair of thyratrons, and means for simultaneously and equally shifting the phase of the output of each of said phase shift circuits with respect to the input of each thereof respectively.

3. A circuit for effecting variable voltage, full-wave, rectification from a three-phase source, the combination comprising: three terminals connectible to a source of three phase power; three pairs of gas filled, grid controlled, electric discharge devices; means connecting the cathodes of the first of each of said pairs to the anode of the second of each of said pairs, and means connecting each of said terminals to points intermediate respective pairs of said connected cathodes and anodes; means connecting the anodes of said first of said pairs of devices to each other and to one side of said load and

means connecting the cathodes of the second of said pairs of devices to each other and to the other side of said load; means operative at selected times with respect to the periods of energization of said terminals for imposing a blocking potential between the grids and cathodes of each of said devices, said last named means being adapted for simultaneously shifting the phase relationship of energization of each of said grids respectively with respect to the phase of energization of said terminals.

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