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(54) Titre : GENERATRICE ELECTRIQUE DE VEHICULE PRODUISANT DEUX TENSIONS DE SORTIE
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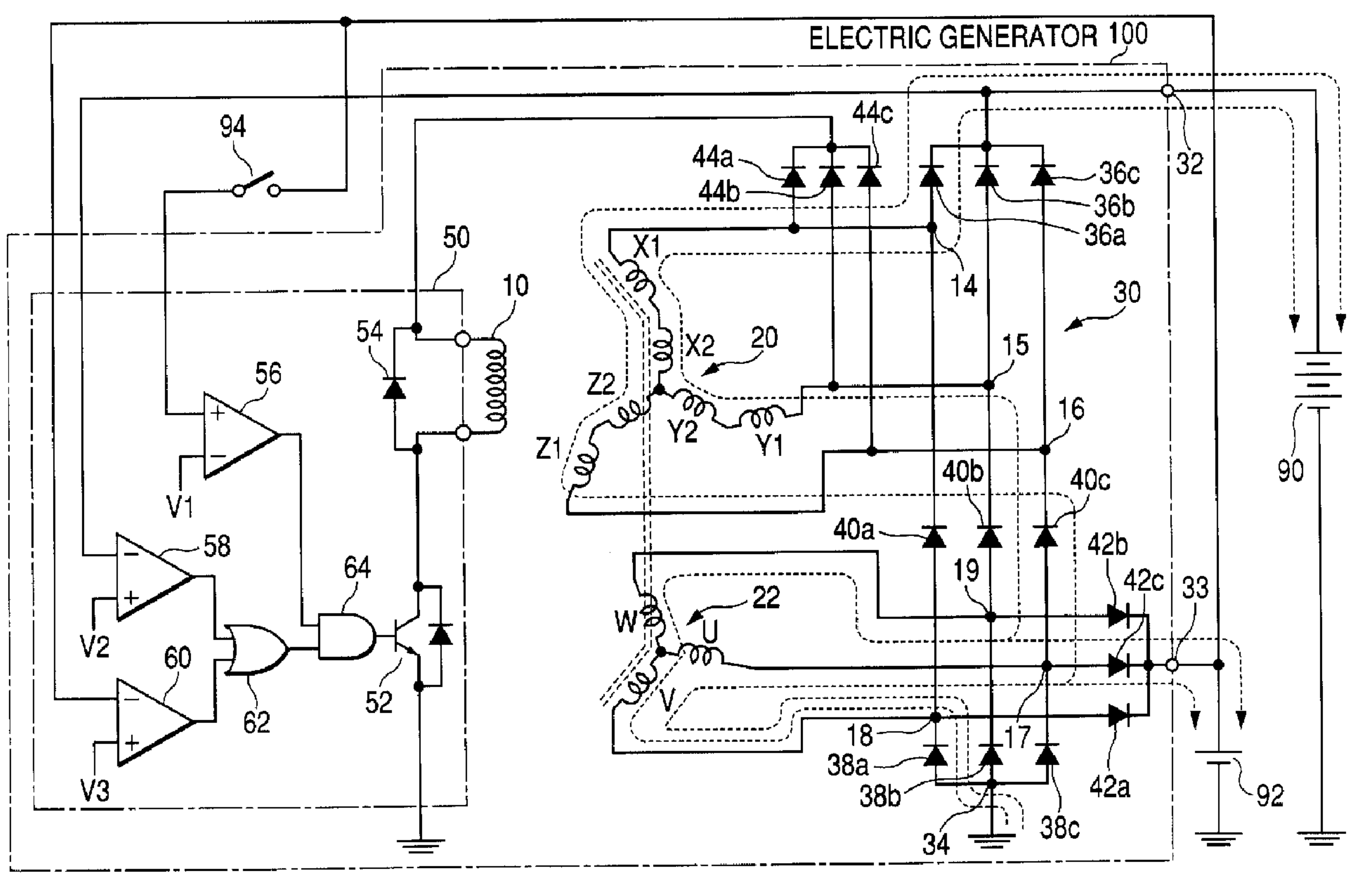

(57) Abrégé/Abstract:
An electric generator according to the invention includes a rotor, a stator, a rectifier, and a regulator. The rotor includes a field winding. The stator includes a first and a second three-phase winding, each of which has three output terminals corresponding to respective phases. The rectifier has a specially designed three-layer structure, to which the output terminals of the first and second three-phase windings are separately connected, and works to output two different DC voltages through rectifying outputs of the

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two three-phase windings. The regulator works to regulate the output voltages through controlling a field current supply to the field winding. With such a structure, the electric generator can reliably produce two different output voltages at the same time. Moreover, compared to existing electric generators producing dual output voltages, the structure of the electric generator is much simplified, thus reducing manufacturing cost and the internal impedance of the electric generator.

ABSTRACT OF THE DISCLOSURE

An electric generator according to the invention includes a rotor, a stator, a rectifier, and a regulator. The rotor includes a field winding. The stator includes a first and a second three-phase winding, each of which has three output terminals corresponding to respective phases. The rectifier has a specially designed three-layer structure, to which the output terminals of the first and second three-phase windings are separately connected, and works to output two different DC voltages through rectifying outputs of the two three-phase windings. The regulator works to regulate the output voltages through controlling a field current supply to the field winding. With such a structure, the electric generator can reliably produce two different output voltages at the same time. Moreover, compared to existing electric generators producing dual output voltages, the structure of the electric generator is much simplified, thus reducing manufacturing cost and the internal impedance of the electric generator.

ELECTRIC GENERATOR FOR VEHICLE PRODUCING DUAL OUTPUT VOLTAGES

BACKGROUND OF THE INVENTION

1 Technical Field of the Invention

The present invention relates generally to electric generators and chagrining systems for vehicles. More particularly, the invention relates to an electric generator for a vehicle, which produces two different output voltages at the same time.

2 Description of the Related Art

In recent automobiles, the use of electric loads that require large electric power, such as an electric power steering apparatus and an electric compressor, has increased. This results in introduction of high voltage (for example, 42V) power systems, which can largely contribute to miniaturization and efficiencies of power generation and supply apparatuses or devices on the vehicle.

On the other hand, filament loads, such as a headlamp, and DC apparatuses or devices that use a commutator, such as a wiper and a starter, are not suitable for use with a high voltage power system, in view of life time and increase of sparks in operation. Thus, low voltage (for example, 14V) power systems are still necessary for those filament loads and DC apparatuses or devices.

To meet both the high and low voltage requirements, a vehicle that includes an electric generator producing only a high output voltage may include a DC-DC converter to produce a low output voltage; otherwise, it may include an additional electric generator that produces a low output voltage.

However, the use of such additional devices as the DC-DC converter and the electric generator of low output voltage will increase manufacturing cost and require additional installment space on the vehicle.

To solve such a problem, an approach is disclosed, for example, in Japanese Patent First Publication No. H06 – 105512 and Japanese Patent No. 2946592. According to the approach, a single electric generator is allowed to include a plurality of stator windings so as to produce both a high and a low output voltage.

However, if an electric generator is designed to include two sets of stator winding and rectifier, one for producing a high output voltage and the other for producing a low output voltage, either one of the two sets will not be fully utilized when electric loads operating at the voltage produced thereby are decreased. Consequently, the cost/performance ratio of the electric generator will be high.

Further, an another approach may also be considered, according to which two circuits for producing respective output voltages are connected in series, so that a high output voltage, which is the vector sum of the output voltages of the two circuits, can be obtained.

However, in the above case, since the number of rectifier elements in the two circuits is large, the forward direction voltage drops due to rectifier elements and the internal impedance of the whole circuit will accordingly be large, so that it is difficult to provide a large power. Further, it is also difficult to suitably control the high and low output voltages of the whole circuit, so that both the output voltages cannot be reliably produced.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above-mentioned problem.

It is, therefore, a primary object of the present invention to provide an electric generator for a vehicle, which has a simple structure and can reliably produce two different output voltages at the same time.

According to the first aspect of the invention, an electric generator is provided which includes a rotor, a stator, a rectifier, and a regulator.

The rotor includes a field winding. The stator includes a first and a second three-phase winding, each of which has three output terminals corresponding to respective phases. The rectifier works to rectify outputs of the first and second three-phase windings. The regulator works to regulate the outputs of the first and second three-phase windings through controlling a field current supply to the field winding.

In the above electric generator, the rectifier includes:

three rectifier element groups each of which includes a first, a second, and a third rectifier element that are connected in series, the three rectifier element groups being connected in parallel so as to have a first common connection connecting free terminals of the three first rectifying elements and a second common connection connecting free terminals of the three third rectifying elements, all the rectifier elements of the three groups having the same forward direction from the second common connection to the first common connection; and

three fourth rectifier elements, each of which has one terminal connected to a connection between the second and third rectifying elements of a corresponding one of the three rectifier element groups and the other terminal connected to a third common connection, so as to have a forward direction from the connection to the third common connection.

Further, in the above electric generator,

each of the three output terminals of the first three-phase winding is connected to a connection between the first and second rectifying elements of a corresponding one of the three rectifier element groups;

each of the three output terminals of the second three-phase winding is connected to a connection between the second and third rectifying elements of a corresponding one of the three rectifier element groups; and

the first common connection serves as a high voltage output terminal to output a first voltage, and the third common connection serves as a low voltage output terminal to output a second voltage that is lower than the first voltage.

With the above arrangement, it is possible for the electric generator to produce two different output voltages at the same time employing a single rectifier.

Compared to an existing electric generator that includes two serially connected sets of three-phase winding and rectifier, the electric generator according to the invention has a much simpler structure, thus reducing the forward direction voltage drops due to diodes and the internal impedance of the electric generator.

According to the second aspect of the invention, in the above electric generator, the regulator controls the field current supply to the field winding so as to keep a voltage, which is a function of one of the first voltage and the second voltage, within a predetermined range.

Since the high and low voltage output terminals are linked with each other in the rectifier, the first and second voltages are tied to each other during power generation. Accordingly, it is possible to reliably produce both the first and second voltages through controlling the filed current supply to the field winding based on one of the two voltages.

According to the third aspect of the invention, in the above electric generator, the stator further includes a core having a first group of slots, in which the first three-phase winding is accommodated, and a second group of slots in which the second three-phase winding is accommodated. Further, a ratio of the number of slots in the first group to that in the second group is equal to a ratio of the number of turns in the first three-phase winding to that in the second three-phase winding.

With such an arrangement, it becomes possible to use a low-impedance bar conductor having rectangular cross section, the use of which generally requires a small number of windings in a slot, to form the two three-phase windings. Consequently, the two three-phase windings will have low impedance, thus improving the efficiency of the electric generator. Further, it also becomes possible to improve the space factor of the two three-phase windings without sacrificing insulation properties thereof.

According to the fourth aspect of the invention, in the above electric generator, the field winding may be connected to the low voltage output terminal.

As a result, the second voltage (i.e., the lower voltage) is applied to the field winding, thus suppressing corrosion of the field winding and other related components such as slip rings.

Otherwise, the rectifier may further include three fifth rectifier elements, each of which has one terminal connected to a connection between the first and second rectifier elements of a corresponding one of the three rectifier element groups and the other terminal connected to a fourth common connection, so as to have a forward direction from the connection to the fourth common connection, and the filed winding may be connected to the fourth common connection.

As a result, the first voltage (i.e., the higher voltage) is applied to the field winding, so that the ratio of the field current to the total output current will be small, thus improving the efficiency of the electric generator.

According to the fifth aspect of the invention, the above electric generator further includes a switch that is connected in series with one of the first and second three-phase windings, and the regulator turns the switch on when the electric generator rotates at a low speed and off when the electric generator rotates at a high speed.

As a result, through controlling on/off operation of the switch, it is possible to reduce the number of turns of effective winding in stages as the rotational speed of the electric generator increases, thus increasing the output of the electric generator. Moreover, it is also possible to reduce the internal impedance of the electric generator, thus suppressing decrease in the first voltage when a large load is connected to the high voltage output terminal. Furthermore, it is also possible to prevent drop in the second voltage, thus ensuring stability of the power generation.

According to the sixth aspect of the invention, in the above electric generator, a ratio of the number of turns in the second three-phase winding to that in the first three-phase winding is so set to be greater than V2 / (V1 – V2), where V1 and V2 are rated values of the first and second voltages, respectively.

As a result, it is possible to approximate the ratio of the second voltage to the first voltage to V2 / V1 when a large electric load is connected to the low voltage output terminal.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given hereinafter and from the accompanying drawings of the preferred embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments but are for the purpose of explanation and understanding only.

In the accompanying drawings:

FIG. 1 is a schematic view showing the overall configuration of an electric generator according to the first embodiment of the invention;

FIG. 2 is a view showing part of a rotor and a stator of the electric generator of FIG. 1 along the circumferential direction;

FIG. 3 is a schematic view showing the overall configuration of an electric generator according to the second embodiment of the invention;

FIG. 4 is a schematic view showing the overall configuration of an electric generator according to the third embodiment of the invention; and

FIG. 5 is a graphical representation showing the relationship between the rotational speed and output current of the electric generator of FIG. 4 in connection with on/off operation of switch groups S1 and S2 in the electric generator.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention will be described hereinafter with reference to FIGS. 1 - 5.

It should be noted that, for the sake of clarity and understanding, identical components having identical functions in different embodiments of the invention have been marked, where possible, with the same reference numerals in each of the figures.

[First Embodiment]

FIG. 1 shows the overall configuration of an electric generator (or alternator) 100 according to the first embodiment of the invention. The electric generator 100 is for use in an automobile.

As shown in FIG. 1, the electric generator 100 includes a field winding 10, a first three-phase winding 20, a second three-phase winding 22, a rectifier 30, and a voltage regulator 50.

The field winding 10 is provided in a rotor 1 of the electric generator 100.

The first and second three-phase windings 20 and 22 are provided in a stator 2 of the electric generator 100. The ratio of the number of turns in the first three-phase winding 20 to that in the second three-phase winding 22 is 2 : 1.

The rectifier 30 includes a plurality of diodes, which serve as rectifier elements, and is configured to full-wave rectify outputs of the first and second three-phase windings 20 and 22.

The voltage regulator 50 works to regulate output voltages of the electric generator 100 through controlling a field current supply to the filed winding 10.

The electric generator 100 further includes a high voltage output terminal 32 for outputting a high voltage of 42V and a low voltage output terminal 33 for outputting a low voltage of 14V. The high voltage output terminal 32 is connected with a high voltage battery 90 having a rated voltage of 42V, while the low voltage output terminal 33 is connected with a low voltage battery 92 having a rated voltage of 14V.

FIG. 2 shows part of the rotor 1 and stator 2 of the electric generator 100 along the circumferential direction.

The rotor 1 is a Lundell claw pole rotor with twelve poles 12. The field winding 10 is formed in the inner periphery of the rotor 1 and the number of turns of the field winding 10 is, for example, 500.

The stator 3 includes a core 26 that surrounds the rotor 1. The core 26 is formed by laminating thin electromagnetic steel sheets having a prescribed thickness, for example, of 0.35 mm and includes 108 slots 24 formed therein. Within each of the slots 24, two conductive wires 28 are wound and serially connected with each other.

Further, as shown in FIG. 2, for each of the poles 12, there are nine corresponding slots 24. The conductive wires 28 in the nine slots 24 make up windings X1, X2, -V, -Z1, -Z2, U, Y1, Y2, -W, respectively. Moreover, the windings X1 and X2 are serially connected with each other to form part of a X-phase winding of the first three-phase winding 20; the windings -Z1 and -Z2 are serially connected with each other to form part of a Z-phase winding of the first three-phase winding 20; and the windings Y1 and Y2 are connected with each other to form a Y-phase winding of the first three-phase winding 20. On the other hand, the windings -W, -V, U make up a W-phase, a V-phase, and a U-phase winding of the second three-phase winding 22, respectively. It should be noted that the minus sign here denotes reversed winding direction and thus reversed phase in voltage.

Consequently, the phase of voltage induced in the X-phase winding of the first three-phase winding 20 will be almost reverse to that of voltage induced in the V-phase winding of the second three-phase winding 22; the phase of voltage induced in the Y-phase winding of the first three-phase winding 20 will be almost reverse to that of voltage induced in the W-phase winding of the second three-phase winding 22; and the phase of voltage induced in the Z-phase winding of the first three-phase winding 20 will be almost reverse to that of voltage induced in the U-phase winding of the second three-phase winding 22.

Turning back to FIG. 1, the X, Y, and Z phase windings of the first three-phase winding 20 have respective output terminals 14, 15, and 16, which are connected to the rectifier 30. Similarly, the U, V, and W phase windings of the second three-phase winding

22 have respective output terminals 17, 18, and 19, which are connected to the rectifier 30.

The rectifier 30 has a three-layer structure. It includes three diode groups, each of which includes a positive terminal diode, a buffer diode, and a negative terminal diode that are connected in series.

Specifically, the first group includes a positive terminal diode 36a, a buffer diode 40a, and a negative terminal diode 38a; the second group includes a positive terminal diode 36b, a buffer diode 40b, and a negative terminal diode 38b; and the third group includes a positive terminal diode 36c, a buffer diode 40c, and a negative terminal diode 38c.

Further, the three diode groups are connected in parallel to have a first common connection connecting the anodes of the three positive terminal diodes 36a – 36c and a second common connection connecting the cathodes of the three negative terminal diodes 38a – 38c. As a result, all the diodes in the three diode groups have the same forward direction from the second common connection to the first common connection. The first common connection is connected to a high voltage output terminal 32 of the rectifier 30, while the second common connection is connected to a negative terminal 34 of the same. The high voltage output terminal 32 is further connected to the positive terminal of the high voltage battery 90.

Moreover, the output terminals 14, 15, and 16 of the X, Y, and Z phase windings of the first three-phase winding 20 are respectively connected between the diodes 36a and 40a, between the diodes 36b and 40b, and between the diodes 36c and 40c. On the other hand, the output terminals 17, 18, and 19 of the U, V, and W phase windings of the second three-phase winding 22 are respectively connected between the diodes 38c and 40c, between the diodes 38a and 40a, and between the diodes 38b and 40b.

The rectifier 30 further includes three diodes 42a - 42c, the cathodes of which are respectively connected between the diodes 38a and 40a, between the diodes 38b and 40b, and between the diodes 38c and 40c. On the other hand, the anodes of the three diodes 42a – 42c are connected to a third common connection that is connected to a low voltage output terminal 33 of the rectifier 30. The low voltage output terminal 33 is further connected to the positive terminal of the low voltage battery 92.

The rectifier 30 further includes three diodes 44a – 44c, the cathodes of which are respectively connected between the diodes 36a and 40a, between the diodes 36b and 40b, and between the diodes 36c and 40c. On the other hand, the anodes of the three diodes 44a – 44c are connected to a fourth common connection that is connected to the voltage regulator 50.

The voltage regulator 50 includes a switch 52, a freewheeling diode 54, three voltage comparators 56, 58, and 60, an OR circuit 62, and an AND circuit 64.

The switch 52 is connected in series with the filed winding 10 and configured to be selectively turned on and off so as to control the field current supply from the rectifier 30 to the filed winding 10.

The freewheeling diode 54 is connected in parallel with the field winding 10, so as to recover the field current flowing in the field winding 10 when the switch 52 is turned from on to off.

The voltage comparator 56 has a plus input terminal, to which the terminal voltage of the low voltage battery 92 is applied via an ignition switch 94, and a minus input terminal to which a reference voltage V1 is applied. The reference voltage V1 is so set to be lower than the terminal voltage of the low voltage battery 92, so that when the ignition switch 94 is turned on, a high level signal is outputted from the voltage comparator 56 to a first input terminal of the AND circuit 64.

The voltage comparator 58 has a minus input terminal, to which the terminal voltage of the high voltage battery 90 is applied, and a plus input terminal to which a reference voltage V2 is applied. The voltage comparator 58 outputs a high level signal to a first input terminal of the OR circuit 62 when the terminal voltage of the high voltage battery 90 is lower than the reference voltage V2. It should be noted that instead of the terminal voltage of the high voltage battery 90, the output voltage of the high voltage output terminal 32 of the rectifier 32 or a voltage that is a function of the output voltage of the terminal 32 may also be applied.

The voltage comparator 60 has a minus input terminal, to which the terminal voltage of the low voltage battery 92 is applied, and a plus input terminal to which a reference voltage V3 is applied. The voltage comparator 60 outputs a high level signal to a second input terminal of the OR circuit 62 when the terminal voltage of the low voltage battery 92 is lower than the reference voltage V3. It should be noted that instead of the terminal voltage of the low voltage battery 92, the output voltage of the low voltage output terminal 33 of the rectifier 30 or a voltage that is a function of the output voltage of the terminal 33 may also be applied.

The OR circuit 62 has the first and second input terminals, via which signals outputted from the voltage comparators 58 and 60 are respectively inputted, and outputs a high level signal to a second input terminal of the AND circuit 64 when at least one of the levels of the inputted signals is high. Consequently, when the terminal voltage of the high voltage battery 90 becomes lower than the reference voltage V2 or/and that of the low voltage battery 92 becomes lower than the reference voltage V3 so that at least one of the voltage comparators 58 and 60 outputs the high level signal, the OR circuit 62 outputs the high level signal to the AND circuit 64.

The AND circuit 64 has the first and second input terminals, via which signals outputted from the voltage comparator 56 and OR circuit 62 are inputted, and outputs a high level signal to the switch 52 when both the levels of the inputted signals are high. Since the comparator 56 continues to output the high level signal after the ignition switch 94 is turned on, the AND circuit 64 will output the high level signal to the switch 52 when the terminal voltage of the high voltage battery 90 becomes lower than the reference voltage V2 or/and that of the low voltage battery 92 becomes lower than the reference voltage V3.

Upon receiving the high level signal from the AND circuit 64, the switch 52 is turned on, so that the filed current is supplied from the rectifier 30 to the filed winding 10.

Having described the overall configuration of the electric generator 100, operation thereof will be described hereinafter.

First, the starting operation of the electric generator 100 is as follows.

When the ignition switch 94 is turned on, the electric generator 100 is driven by the engine (not shown) of the vehicle to rotate. At the same time, the voltage regulator 50 is supplied with electric power by a power supply circuit (not shown) so as to be able to operate.

Then, if the terminal voltage of the high voltage battery 90 is lower than the reference voltage V2 or/and that of the low voltage battery 92 is lower than the reference voltage V3, the switch 52 is turned on, so that the field winding 10 is supplied with the field current. Consequently, a rotating filed is created for the stator 2.

Referring again to FIG. 2, for each of the poles 12, there are nine corresponding slots 24 formed in the core 26; thus, the difference in phase between voltages induced in windings in adjacent slots 24 is equal to $\pi/9$.

Accordingly, the difference in phase between the voltage induced in the first three-phase winding 20 and that induced in the second three-phase winding 22 is equal to $\pi/6$. For example, the X-phase winding of the first three-phase winding 20 is formed by serially connecting the windings X1 and X2. Thus, the difference in phase between the voltage induced in the X-phase winding and that induced in the V-phase winding of the second three-winding 22 is equal to $(3/2\times\pi/9)$, i.e. $\pi/6$.

Moreover, since the ratio of the number of turns in the first three-phase winding 20 to that in the second three-phase winding 22 is equal to 2 : 1, the ratio of the voltage induced in the first three-phase winding 20 to that induced in the second three-phase winding 22 is accordingly equal to 2 : 1.

Further, as shown in FIG. 1, the voltage induced in the first three-phase winding 20 is added, via the buffer diodes 40a – 40c in the rectifier 30, to the voltage induced in the second three-phase winding 22. Consequently, an electric current path as indicated with dashed lines in FIG. 1 is formed, thereby outputting a high and a low DC voltage respectively from the high voltage output terminal 32 and low voltage output terminal 33. The ratio of the high voltage to the low voltage is thus equal to 3 : 1.

Then, the high voltage battery 90 and low voltage battery 92 are respectively charged with the high and low voltages, so that the terminal voltages of the batteries 90 and 92 reach suitable levels.

Next, the operation of the electric generator 100 for coping with electric load change is as follows.

As the electric load (not shown) that is connected, for example, to the high voltage battery 90 increases, more current is outputted from the high voltage battery 90 that has less internal impedance than the electrical generator 100, thus decreasing the terminal voltage of the high voltage battery 90.

Further, as the terminal voltage of the high voltage battery 90 decreases, the output voltage of the high voltage output terminal 32 also decreases. This causes the output voltage of the low voltage output terminal 33 also to decrease. However, since the two terminals 32 and 33 are electrically linked with each other in the rectifier 30, the ratio between the output voltages thereof will be kept at 3 : 1. Thus, when the output voltage of the terminal 32 remains in a suitable range thereof, that of the terminal 33 will also remain in a suitable range thereof.

However, when either of the output voltages of the terminals 32 and 33 drops below the suitable range thereof, at least one of the voltage comparators 58 and 60 outputs the high level signal. Then, the switch 52 is turned on, so that the field winding 10 is supplied with the field current. Consequently, the high and low voltages are induced and outputted from the terminals 32 and 33, thereby charging the high and low voltage batteries 90 and 92.

Moreover, when a large load is connected to one of the two batteries 90 and 92, the electric power supplied to the electric load and the battery to which the electric load is connected increases while that supplied to the other battery decreases, thus preventing overcharge of the latter battery.

For example, when a large electric load is connected to the high voltage battery 90, both the terminal voltage of the high voltage battery 90 and output voltage of the high voltage output terminal 32 drop considerably; thus, the electric potential at the cathodes of the three diodes 42a – 42c will also drop considerably. However, at the same time, without a large electric load connected thereto, the terminal voltage of the low voltage battery 92 will not decrease. Consequently, only slight current flows from the low voltage output terminal 33 to the low voltage battery 92, thus preventing overcharge of the battery 92. Accordingly, the electric power generated by the electric generator 100 is mainly supplied for the operation and charge of the large electric load and high voltage battery 90.

After both the terminal voltages of the batteries 90 and 92 return to the respective suitable ranges, both the voltage comparators 58 and 60 output a low level signal, so that the switch 52 is turned off, thereby stopping the field current supply to the field winding 10.

To sum up, in the electric generator 100 according to the present embodiment, the output terminals of the two three-phase windings 20 and 22 are separately connected to the single rectifier 30 that has the three-layer structure as described above, thereby producing two different output voltages at the same time.

Compared to an existing electric generator that includes two serially connected sets of three-phase winding and rectifier, the electric generator 100 has a much simpler structure, thus reducing the forward direction voltage drops due to diodes and the internal impedance of the electric generator 100.

Further, in the electric generator 100, the high voltage output terminal 32 and low voltage output terminal 33 are linked with each other in the rectifier 30, so that the output voltages of the two terminals 32 and 33 are tied to each other during power generation based on the ratio between the numbers of turns in the first and second three-phase windings 20 and 22. Accordingly, it is possible to reliably produce both the output voltages through controlling the filed current supply to the field winding 10 based on one of the two output voltages.

Additionally, in the electric generator 100, the core 26 of the stator 2 has, as shown in FIG. 2, a first group of slots (i.e., X1, X2, -Z1, -Z2, Y1, and Y2), in which the first three-phase winding 20 is accommodated, and a second group of slots (i.e., -V, U, and -W) in which the second three-phase winding 22 is accommodated. The ratio of the number of turns in the first three-phase winding 20 to that in the second three-phase winding 22 is equal to the ratio of the number of slots in the first group to that in the second group.

Since the first and second three-phase windings 20 and 22 are accommodated in different groups of slots, it becomes possible to use a low-impedance bar conductor having rectangular cross section, the use of which generally requires a small number of windings in a slot, to form the windings 20 and 22. Consequently, the resultant three-phase windings 20 and 22 will have low impedance, thus improving the efficiency of the electric generator 100. Further, it also becomes possible to improve the space factor of the three-phase windings 20 and 22 without sacrificing insulation properties thereof.

Moreover, in the electric generator 100, since the field current is supplied from the high voltage output terminal 32 to the field winding 10, the ratio of the field current to the total output current becomes small compared to the case of supplying the field current from the low voltage output terminal 33, thereby further improving the efficiency of the electric generator 100.

[Second Embodiment]

In the previous embodiment, the first three-phase winding 20 and second three-phase winding 22 are accommodated in different groups of slots. However, the two three-phase windings 20 and 22 may also be accommodated in the same slots.

FIG. 3 shows the overall configuration of an electric generator 100A according to the second embodiment of the invention. The electric generator 100A is for use in an automobile.

As shown in FIG. 3, the electric generator 100A includes a field winding 10, a first three-phase winding 20A, a second three-phase winding 22A, a rectifier 30A, and a voltage regulator 50. The field winding 10 is provided in a rotor of the electric generator 100A. The first and second three-phase windings 20A and 22A are provided in a stator of the electric generator 100A. The rectifier 30A includes a plurality of diodes to full-wave rectify the outputs of the three-phase windings. The voltage regulator 50 regulates the output voltages of the electric generator 100A through controlling the field current supply to the field winding 10.

In the present embodiment, the X-phase winding of the first three-phase winding 20A and the V-phase winding of the second three-phase winding 22A are formed in the same slots, in each of which part of the X-phase winding has the number of turns twice that of part of the V-phase winding. Similarly, the Y-phase winding of the first three-phase winding 20A and the W-phase winding of the second three-phase winding 22A are formed in the same slots, in each of which part of the Y-phase winding has the number of turns twice that of part of the W-phase winding. Further, the Z-phase winding of the first three-phase winding 20A and the U-phase winding of the second three-phase winding 22A are formed in the same slots, in each of which part of the Z-phase winding has the number of turns twice that of part of the U-phase winding.

With such a winding structure, the number of windings in a slot is increased, so that it becomes difficult to use a low-impedance bar conductor having rectangular cross section to form the windings, and thus the impedance of the resultant windings will be high. However, at the same time, fabrication of the core of the stator becomes easy, and the windings can be accommodated in the slots in simple manner due to the reduced number of winding units.

Moreover, in the present embodiment, the field current is supplied from the low voltage output terminal 33 to the field winding 10, so that a low voltage is applied to the field winding 10, thus suppressing corrosion of the field winding 10 and other related components such as slip rings.

Additionally, the electric generator 100A may also have the same configuration as the electric generator 100 according to the previous embodiment, except for the winding structure.

[Third Embodiment]

FIG. 4 shows an electric generator 100B according to the third embodiment of the invention, together with a DC motor (DCM) 96 that is supplied with a large power from a high voltage output terminal 32 of the electric generator 100B.

As shown in FIG. 4, the electric generator 100B includes a first three-phase winding 20B, a second three-phase winding 22B, a first switch group S1, a second switch group S2, a rectifier 30A, and a switch S3.

The first switch group S1 includes three switches, each of which is connected between the neutral point of the Y-wound first three-phase winding 20B and a corresponding phase winding of the same. The first switch group S1 connects all the phase windings of the first three-phase winding 20B together at the neutral point when turned on and disconnects when turned off.

Similarly, the second switch group S2 includes three switches, each of which is connected between the neutral point of the Y-wound second three-phase winding 22B and a corresponding phase winding of the same. The second switch group S2 connects all the phase windings of the second three-phase winding 22B together at the neutral point when turned on and disconnects when turned off.

The switch S3 is connected between a diode trio 42 and a low voltage output terminal 33.

In addition, the electric generator 100B further includes a voltage regulator 50 and a field winding 10, which are omitted from FIG. 4 and the same as those of the electric generator 100A shown in FIG. 3. It is also possible for the electric generator 100B to employ, instead of the rectifier 30A, the rectifier 30 of the electric generator 100 shown in FIG. 1.

FIG. 5 shows the relationship between the rotational speed and output current of the electric generator 100B in connection with on/off operation of the switch groups S1 and S2.

As shown in FIG. 5, when the electric generator 100B rotates at low speed, both the switch groups S1 and S2 are turned on. In this case, operation of the electric generator 100B is the same as that of the electric generator 100 shown in FIG. 1. Consequently, a high voltage, which is derived from both the voltages induced in the first and second three-phase windings 20B and 22B, is outputted from the high voltage output terminal 32, while a low voltage, which is derived from the voltage induced in the second three-phase winding 22B, is outputted from the low voltage output terminal 33.

Further, when the electric generator 100B rotates at medium speed, only the switch group S1 is turned on. In this case, only the first three-phase winding 20B is effective in generating electricity. Consequently, compared to the above case of turning on both the switch groups S1 and S2, the number of turns of effective winding is decreased to 2/3, so that the electrical generator 100B becomes able to generate more electricity at higher speed.

Moreover, the internal impedance of the electrical generator 100B is also decreased, so that when a large load such as the DC motor 96 is connected to the high voltage output terminal 32, decrease in the output voltage of the terminal 32 can be effectively suppressed. In addition, since the second three-phase winding 22B is not effective, the electric potential at the cathodes of the diode trio 42 will drop to almost the ground level. However, the terminal voltage of the low voltage battery 92 will not drop due to existence of the diode trio 42.

Furthermore, when the electric generator 100 operates at high speed, only the switch group S2 is turned on. In this case, only the second three-phase winding 22B is effective in generating electricity. Consequently, compared to the case of turning on both the switch groups S1 and S2, the number of turns of effective winding is decreased to 1/3, so that the electrical generator 100B becomes able to generate more electricity at further higher speed. Moreover, the internal impedance of the electrical generator 100B is further decreased, so that when a large load such as the DC motor 96 is connected to the high voltage output terminal 32, decrease in the output voltage of the terminal 32 can be further effectively suppressed. Additionally, in this case, since the second three-phase winding 22B is effective, the electric potential at the cathodes of the diode trio 42 will rise. Thus, to prevent application of the output voltage of the second three-phase winding 22B to the low voltage battery 92, the switch S3 is turned off at, for example, the same time as the turning off of the switch group S1.

Accordingly, through controlling the on/off operation of the switch groups S1 and S2, it is possible to reduce the number of turns of effective winding in stages as the rotational speed of the electric generator 100B increases, thus increasing the output of the electric generator 100B. Moreover, it is also possible to reduce the internal impedance of the electric generator 100B, thus effectively suppressing decrease in the output voltage of the high voltage output terminal 32 when a large load is connected to the terminal 32. Furthermore, it is also possible to prevent drop in the output voltage of the low voltage output terminal 33, thus ensuring stability of the power generation.

While the above particular embodiments of the invention have been shown and described, it will be understood by those who practice the invention and those skilled in the art that various modifications, changes, and improvements may be made to the invention without departing from the spirit of the disclosed concept.

For example, in the previous embodiments, the high voltage of 42V and the low voltage of 14V are respectively outputted from the two voltage output terminals 32 and 33.

However, other combinations of high and low voltages are also possible. For example, a high voltage of 28V and a low voltage of 14V may also be produced using two three-phase windings having the same number of turns.

Moreover, in the first and second embodiments, the high and low voltage terminals 32 and 33 are respectively connected to the high and low voltage batteries 90 and 92.

However, it is also possible to substitute a capacitor for one of the two batteries or connect electric loads directly to the two voltage output terminals 32 and 33 without any battery.

Further, the two batteries 90 and 92 may be of the same type (e.g., both are lead-battery), or different types (e.g., one is lead-battery and the other is nickel metal-hydride battery).

Furthermore, in the previous embodiments, the ratio of the number of turns in the second three-phase winding to that in the first three-phase winding is 1 : 2, so that the ratio of a rated voltage V2 of the low voltage output terminal 33 to a rated voltage V1 of the high voltage output terminal 32 is accordingly equal to 1 : 3. In other words, the ratio of the number of turns in the second three-phase winding to that in the first three-phase winding is equal to V2 / (V1-V2).

However, when a large electric load is connected to the low voltage output terminal 32, the voltage drop across the second three-phase winding will be large, thus decreasing the output voltage of the terminal 32.

Accordingly, considering the voltage drop across the second three-phase winding, the ratio of the number of turns in the second three-phase winding to that in the first three-phase winding is preferably so set to be greater than V2 / (V1-V2). (For example, 3 : 5 that is greater than 1 : 2).

As a result, it is possible to approximate the ratio of the output voltage of the low voltage output terminal 33 to that of the high voltage output terminal 32 to 1 : 3 (i.e., V2 / V1) when a large electric load is connected to the low voltage output terminal 33.

Such modifications, changes, and improvements within the skill of the art are intended to be covered by the appended claims.

WHAT IS CLAIMED IS:

1. An electric generator comprising:

a rotor including a field winding;

a stator including a first and a second three-phase winding, each of which has three output terminals corresponding to respective phases;

a rectifier working to rectify outputs of the first and second three-phase windings; and

a regulator working to regulate the outputs of the first and second three-phase windings through controlling a field current supply to the field winding,

wherein said rectifier includes:

three rectifier element groups each of which includes a first, a second, and a third rectifier element that are connected in series, the three rectifier element groups being connected in parallel so as to have a first common connection connecting free terminals of the three first rectifying elements and a second common connection connecting free terminals of the three third rectifying elements, all the rectifier elements of the three groups having the same forward direction from the second common connection to the first common connection; and

three fourth rectifier elements, each of which has one terminal connected to a connection between the second and third rectifying elements of a corresponding one of the three rectifier element groups and the other terminal connected to a third common connection, so as to have a forward direction from the connection to the third common connection,

and wherein

each of the three output terminals of the first three-phase winding is connected to a connection between the first and second rectifying elements of a corresponding one of the three rectifier element groups;

each of the three output terminals of the second three-phase winding is connected to a connection between the second and third rectifying elements of a corresponding one of the three rectifier element groups; and

the first common connection serves as a high voltage output terminal to output a first voltage, and the third common connection serves as a low voltage output terminal to output a second voltage that is lower than the first voltage.

2. The electric generator as set forth in Claim 1, wherein the regulator controls the field current supply to the field winding so as to keep a voltage, which is a function of one of the first voltage and the second voltage, within a predetermined range.

3. The electric generator as set forth in Claim 2, wherein the stator further includes a core having a first group of slots, in which the first three-phase winding is accommodated, and a second group of slots in which the second three-phase winding is accommodated, and wherein a ratio of the number of slots in the first group to that in the second group is equal to a ratio of the number of turns in the first three-phase winding to that in the

second three-phase winding.

4. The electric generator as set forth in Claim 3, wherein the field winding is connected to the low voltage output terminal.

5. The electric generator as set forth in Claim 4 further comprising a switch that is connected in series with one of the first and second three-phase windings, wherein said regulator turns said switch on when the electric generator rotates at a low speed and off when the electric generator rotates at a high speed.

6. The electric generator as set forth in Claim 5, wherein a ratio of the number of turns in the second three-phase winding to that in the first three-phase winding is so set to be greater than V2 / (V1 – V2), where V1 and V2 are rated values of the first and second voltages, respectively.

7. The electric generator as set forth in Claim 3, wherein said rectifier further includes three fifth rectifier elements, each of which has one terminal connected to a connection between the first and second rectifier elements of a corresponding one of the three rectifier element groups and the other terminal connected to a fourth common connection, so as to have a forward direction from the connection to the fourth common connection, and wherein the filed winding is connected to the fourth common connection.

8. The electric generator as set forth in Claim 7 further comprising a switch that is connected in series with one of the first and second three-phase windings, wherein said regulator turns

said switch on when the electric generator rotates at a low speed and off when the electric generator rotates at a high speed.

9. The electric generator as set forth in Claim 8, wherein a ratio of the number of turns in the second three-phase winding to that in the first three-phase winding is so set to be greater than V2 / (V1 - V2), where V1 and V2 are rated values of the first and second voltages, respectively.

10. The electric generator as set forth in Claim 1, wherein the stator further includes a core having a first group of slots, in which the first three-phase winding is accommodated, and a second group of slots in which the second three-phase winding is accommodated, and wherein a ratio of the number of slots in the first group to that in the second group is equal to a ratio of the number of turns in the first three-phase winding to that in the second three-phase winding.

11. The electric generator as set forth in Claim 1, wherein the field winding is connected to the low voltage output terminal.

12. The electric generator as set forth in Claim 1, wherein said rectifier further includes three fifth rectifier elements, each of which has one terminal connected to a connection between the first and second rectifier elements of a corresponding one of the three rectifier element groups and the other terminal connected to a fourth common connection, so as to have a forward direction from the connection to the fourth common connection, and wherein the filed winding is connected to the fourth common

connection.

13. The electric generator as set forth in Claim 1 further comprising a switch that is connected in series with one of the first and second three-phase windings, wherein said regulator turns said switch on when the electric generator rotates at a low speed and off when the electric generator rotates at a high speed.

14. The electric generator as set forth in Claim 1, wherein a ratio of the number of turns in the second three-phase winding to that in the first three-phase winding is so set to be greater than V2 / (V1 – V2), where V1 and V2 are rated values of the first and second voltages, respectively.

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FIG. 1

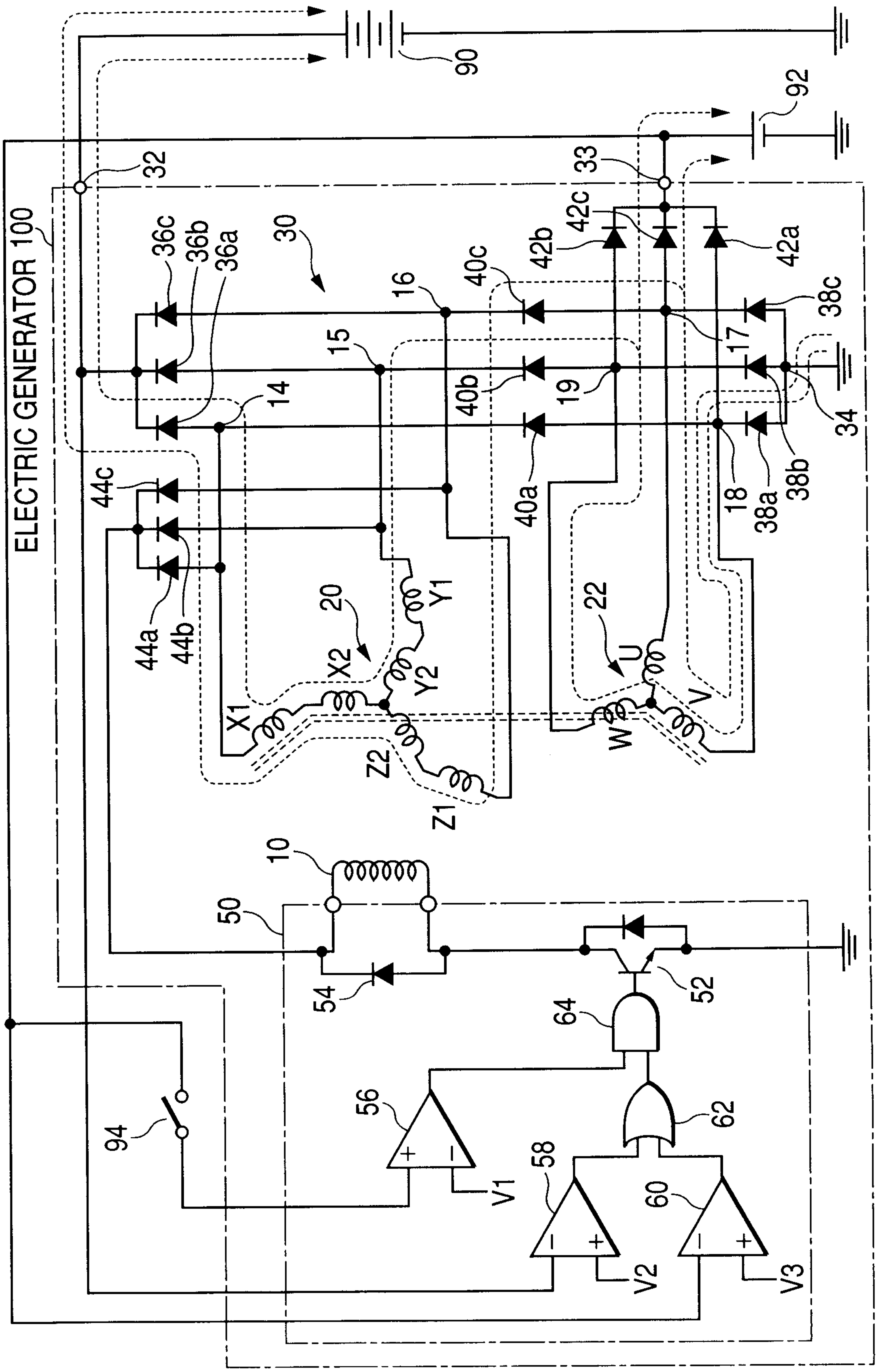

ELECTRIC GENERATOR 100
90
92
32
33
34
30
36a
36b
36c
38a
38b
38c
40a
40b
40c
42a
42b
42c
44a
44b
44c
14
15
16
17
18
19
20
22
X1
X2
Y1
Y2
Z1
Z2
U
V
W
10
50
52
54
56
58
60
62
64
94
V1
V2
V3

FIG. 2

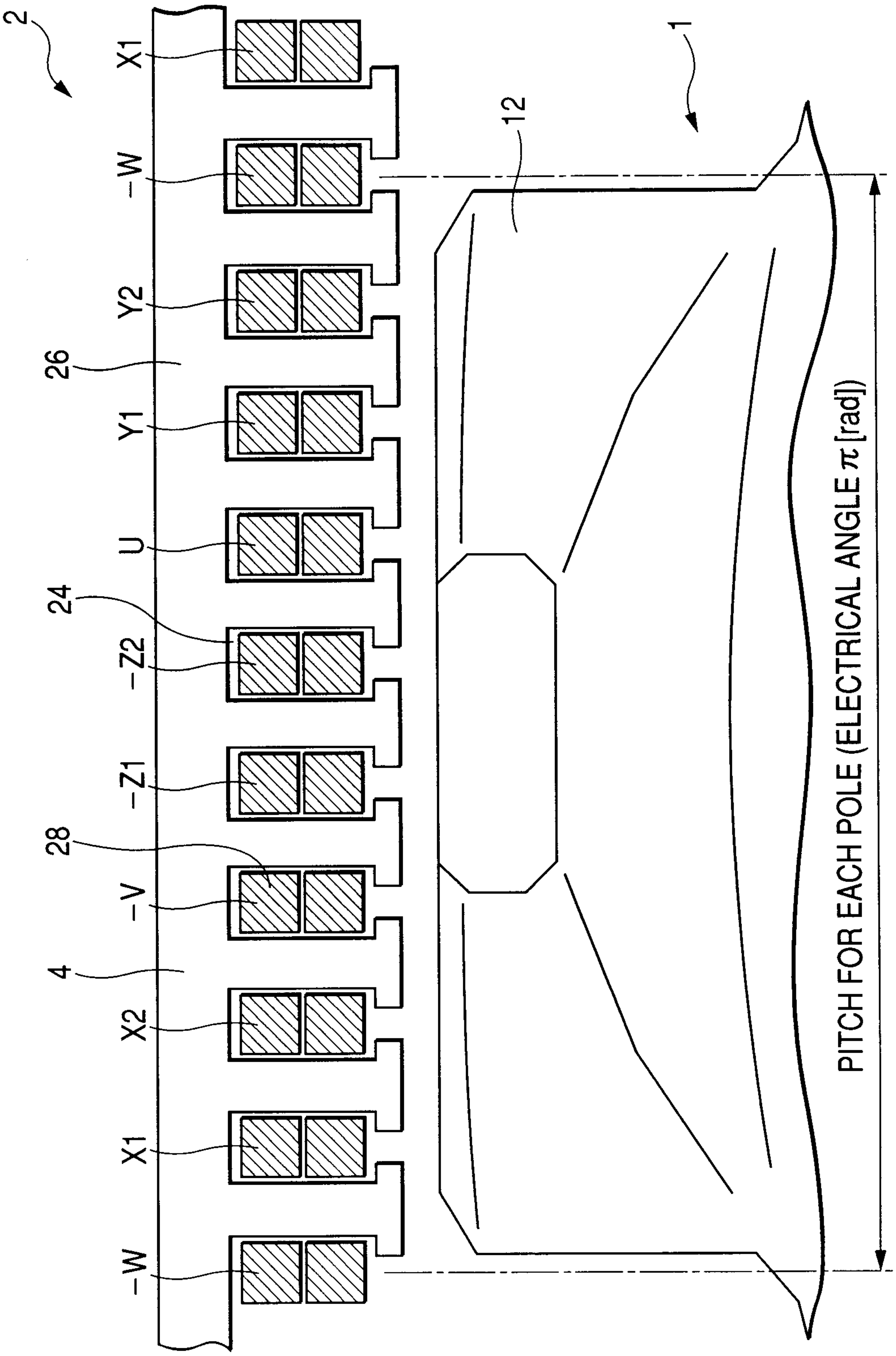

2
1
12
26
24
28
4
X1
-W
Y2
Y1
U
-Z2
-Z1
-V
X2
X1
-W
PITCH FOR EACH POLE (ELECTRICAL ANGLE π [rad])

FIG. 3

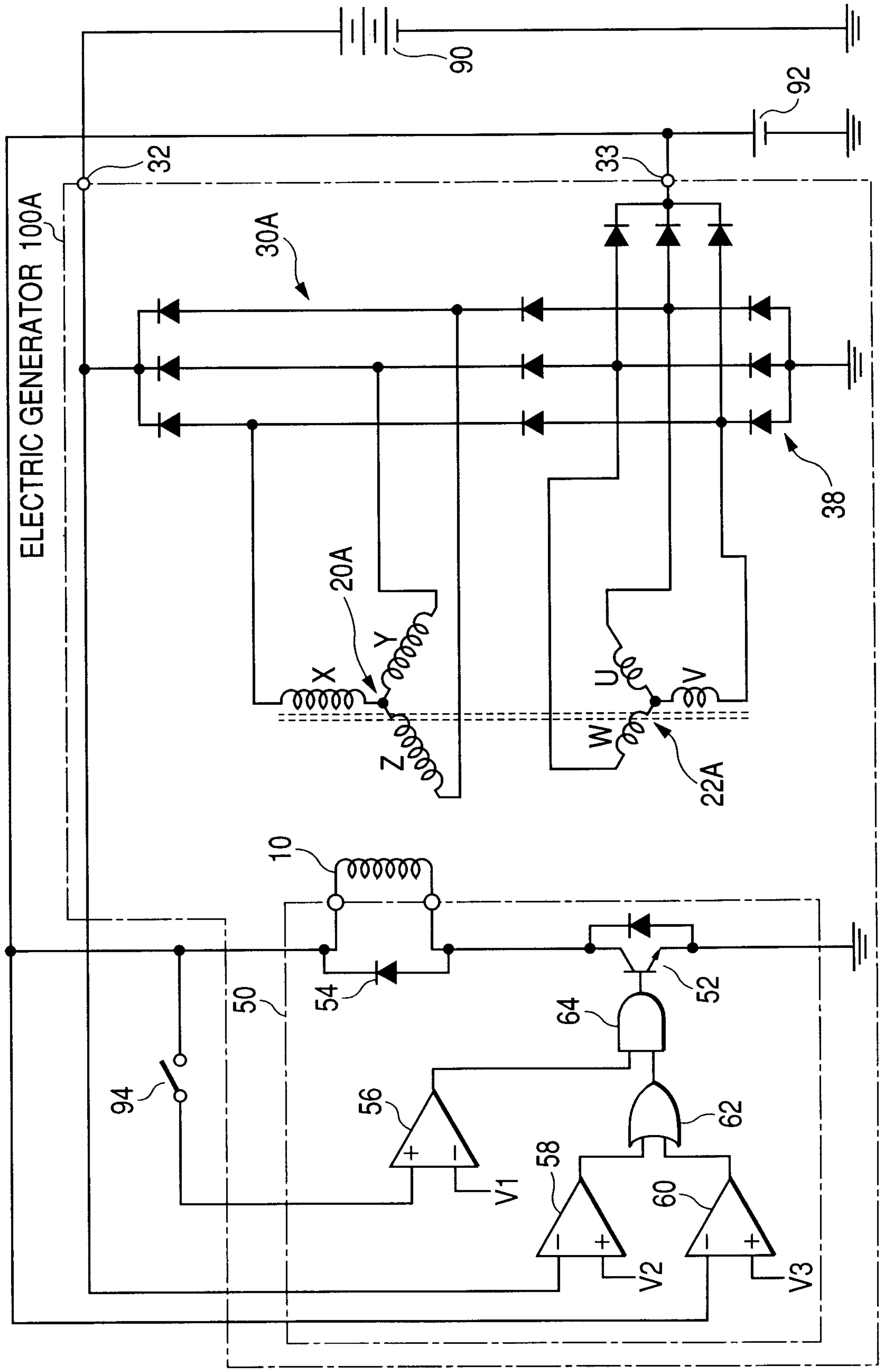

ELECTRIC GENERATOR 100A
30A
32
33
90
92
38
20A
X
Y
Z
U
V
W
22A
10
50
54
52
64
94
56
62
58
60
V1
V2
V3

FIG. 4

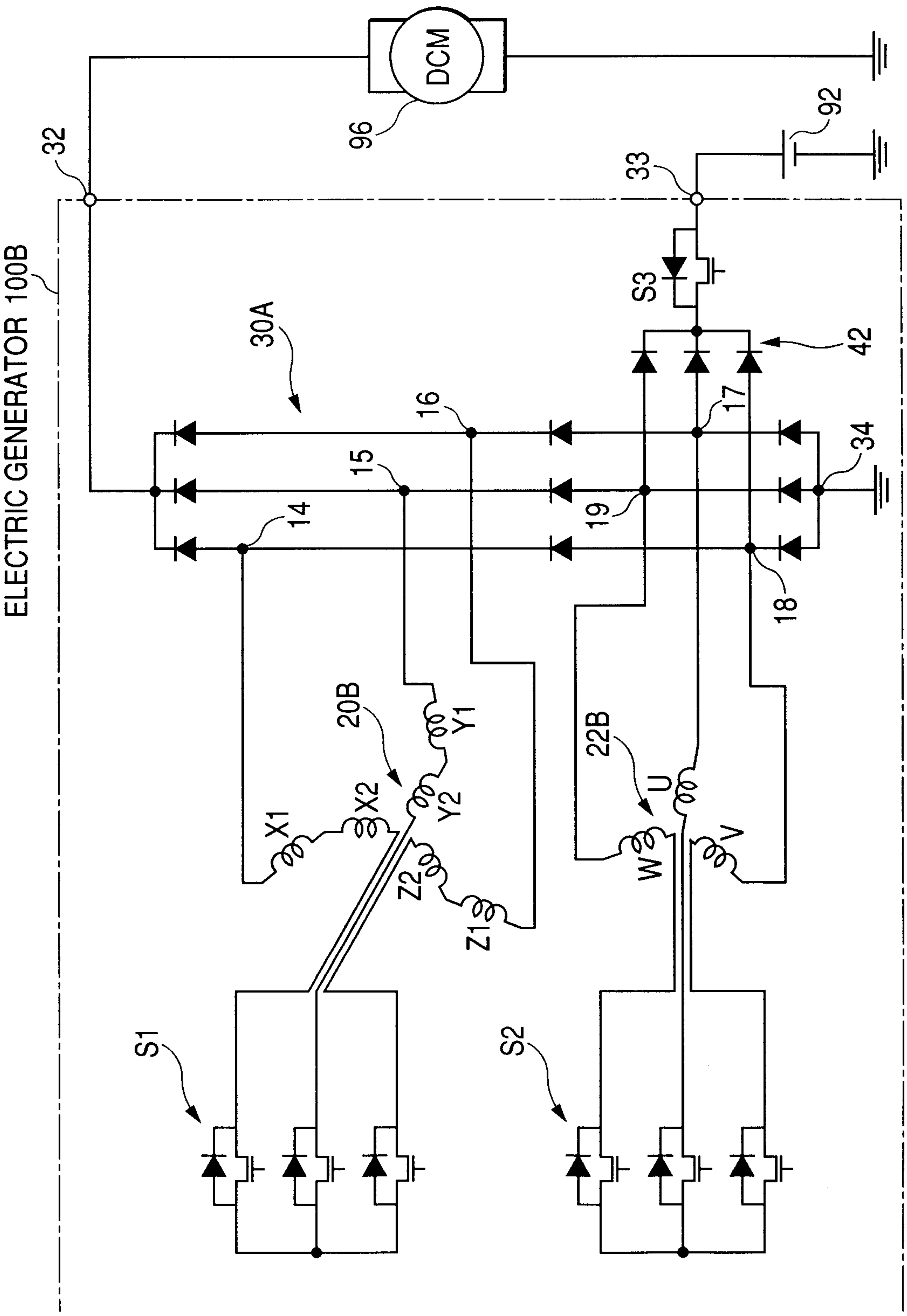
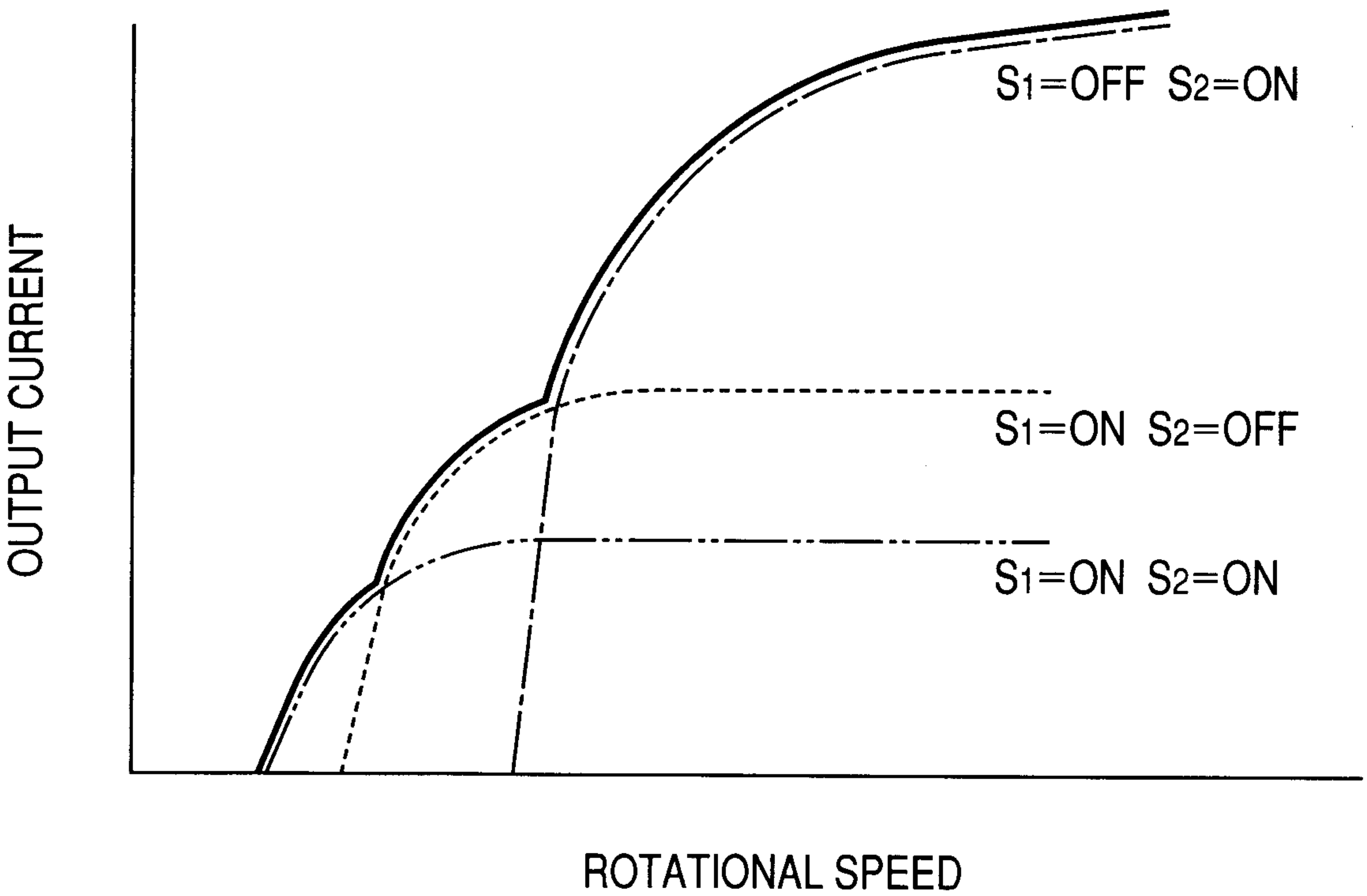
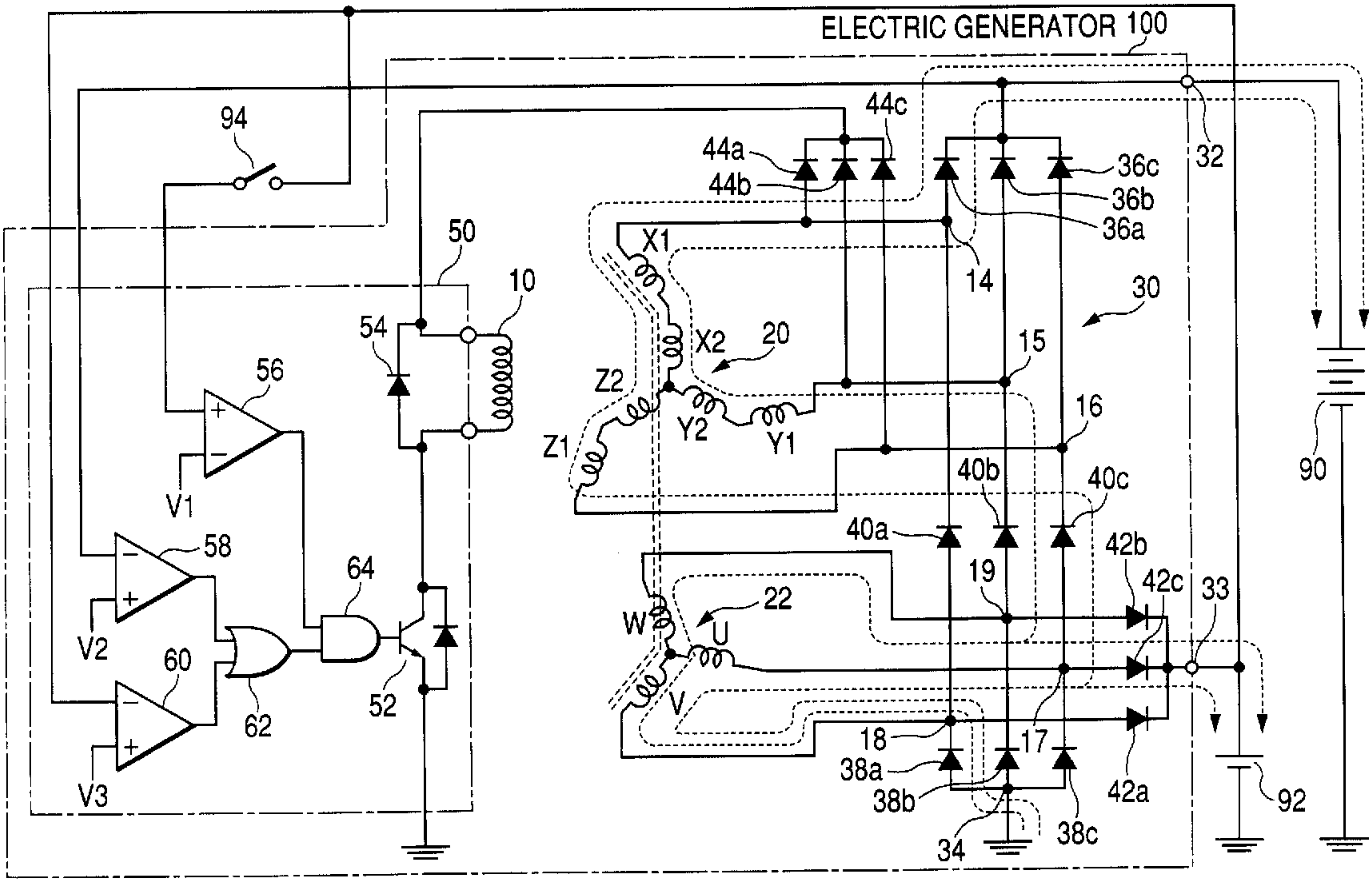

ELECTRIC GENERATOR 100B
DCM
96
32
33
92
30A
S3
42
14
15
16
17
18
19
34
20B
X1
X2
Y1
Y2
Z1
Z2
22B
U
V
W
S1
S2

FIG. 5


S1=OFF S2=ON
S1=ON S2=OFF
S1=ON S2=ON
OUTPUT CURRENT
ROTATIONAL SPEED


ELECTRIC GENERATOR 100
94
44a
44b
44c
36a
36b
36c
32
50
10
X1
X2
14
30
54
20
15
56
Z2
Y2
Y1
16
Z1
V1
40a
40b
40c
42b
42c
58
64
19
33
W
U
22
V2
60
V
52
62
18
17
V3
38a
38b
38c
42a
34
90
92