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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

[Continued on next page]

(54) **Title:** METHODS AND APPARATUS FOR THREE-PHASE INVERTER WITH REDUCED ENERGY STORAGE

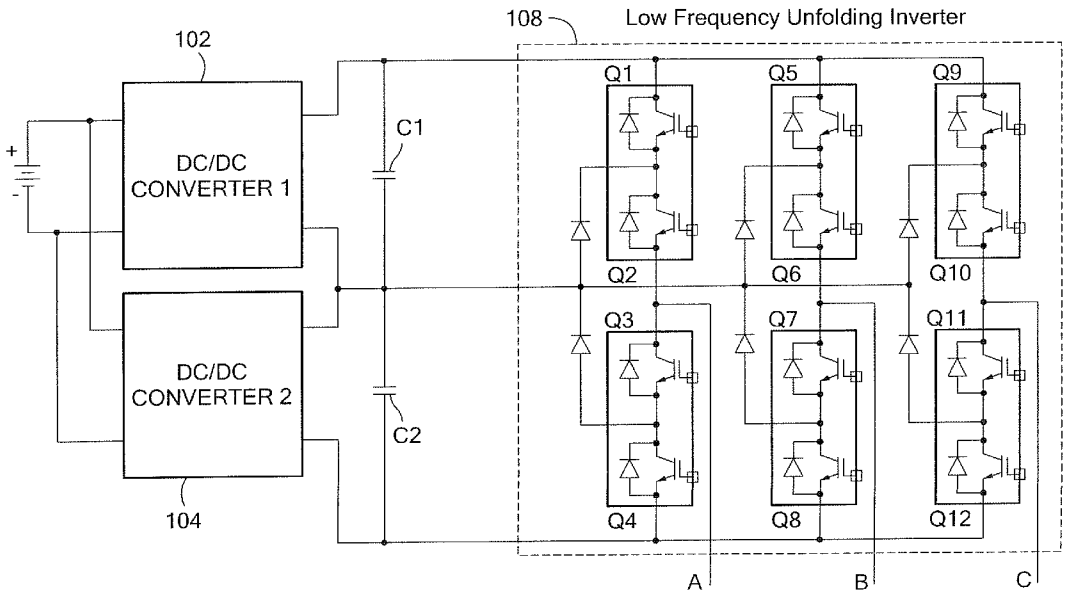


FIG. 7

(57) **Abstract:** Methods and apparatus for a circuit including first and second energy sources, a rectifier coupled to the first and second energy sources, first and second energy storage devices coupled end-to-end across the positive and negative rails, and a single three-level inverter coupled to the rectifier for providing three-phase sinusoidal output voltages.

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METHODS AND APPARATUS FOR THREE-PHASE INVERTER WITH REDUCED ENERGY STORAGE

BACKGROUND

As is known in the art, pulse-width modulated (PWM) inverters are conventionally employed for DC/AC (direct current/alternating current) power conversion applications. If an application requires galvanic isolation and/or voltage transformation, an isolated, high frequency DC/DC converter is conventionally added as inverter front end. Two power conversion stages along with extra DC link energy storage components result in significantly increased size and weight of such systems. Other drawbacks of conventional systems are low efficiency and high EMI emissions typical for hard-commutated PWM inverters.

Various embodiments of quasi-single-stage, high-frequency link, single-phase inverters have attempted to overcome the drawbacks of conventional, two-stage systems. These quasi-single-stage inverters utilize an isolated DC/DC converter to generate a sine wave modulated DC output voltage or current. The modulated DC waveform is then converted into AC by a low frequency unfolding inverter. By eliminating large DC link energy storage components and high-frequency switching in the unfolding inverter significant improvements in weight, size, efficiency, and EMI can be achieved. However, three-phase implementation of known quasi-single-stage, high-frequency link inverters is much less advantageous, since it requires three isolated DC/DC converters and three single-phase unfolding inverters.

SUMMARY

The present invention provides methods and apparatus for a three-phase inverter having reduced energy storage requirements. With this arrangement, an inverter does not require high frequency switching or energy storage at the DC link for a compact design while providing a three-phase sinusoidal output by utilizing a single unfolding inverter.

In one aspect of the invention, a circuit includes first and second energy sources coupled in series and having a positive rail, a negative rail, and a neutral, first and second energy storage devices coupled to the first and second energy sources, and a single multi-level inverter coupled to the positive rail, negative rail, and neutral for providing three-phase sinusoidal output voltages.

In another aspect of the invention, a method includes generating first and second modulated DC waveforms, with each segment of the modulated waveforms corresponding to a specific 60° segment of the fundamental frequency sinusoid, and then unfolding and summing the modulated DC waveforms using a three-level, three-phase inverter utilizing a specific switching scheme for the inverter switches.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing features of this invention, as well as the invention itself, may be more fully understood from the following description of the drawings in which:

FIG. 1 is a schematic depiction of a prior art inverter;

FIG. 2 is a further schematic depiction of a prior art inverter;

FIG. 3 is a waveform diagram showing signals for the prior art inverter of FIG. 1;

FIG. 4 is a circuit diagram of a unit of the prior art inverter of FIG. 1;

FIG. 5 is a waveform diagram for the prior art inverter of FIG. 2;

FIG. 6 is a circuit diagram of a unit of the prior art inverter of FIG. 2;

FIG. 7 is a schematic representation of a high-frequency linked inverter in accordance with exemplary embodiments of the invention;

FIG. 8 is a waveform diagram showing modulated DC and output AC voltages for the inverter of FIG. 7; and

FIG. 9 is a flow diagram showing an exemplary sequence of steps for implementing a three-phase inverter in accordance with exemplary embodiments of the invention.

DETAILED DESCRIPTION

In general, the present invention provides a high-frequency linked three-phase inverter topology that is efficient, e.g., may exceed 99%, compact, low weight, and easily controlled. Unlike conventional three-phase PWM inverters, the inventive low frequency inverter embodiments do not use high frequency switching or energy storage at the DC link. Exemplary embodiments of the invention utilize modulated DC voltages generated by two DC energy sources and unfolded by a three-level, three-phase inverter to generate three-phase, sinusoidal output.

Before describing the invention in detail some introductory material is provided. In K. Oguchi, E. Tsukiori, " A Three-Phase Sine Wave Inverter System Using Multiple Phase-Shifted Single-Phase Resonant Inverters," IEEE Transactions on Industry Applications, vol. 29, No. 4, pp. 1076-1083, Nov/Dec 1993 (hereinafter Oguchi), which is incorporated herein by reference, there is described two implementations of a three-phase quasi-single-stage, high-frequency link inverters. The schemes employ two isolated resonant DC/DC converters, referred to as "multiple phase-shifted single-phase resonant inverters," to generate two modulated, non-sinusoidal DC output voltages (currents). These modulated DC waveforms are unfolded by two three-phase, low frequency inverters and then summed to produce sinusoidal three-phase voltages (currents).

FIG. 1 shows a prior art three-phase quasi-single stage, high frequency link inverter 10. First and second high frequency (HF) inverters 12, 14 provide, via first and second isolation transformers 16, 18, amplitude-modulated high frequency outputs to respective first and second high frequency rectifiers 20, 22. The rectifier

outputs are filtered by respective first and second high frequency filters 24, 26 and converted to alternating currents by first and second low frequency inverters 28, 30.

FIG. 2 shows a second prior art inverter 50 having some similarity with the inverter 10 of FIG. 1 except for the isolation/summing transformers. High frequency outputs of inverters 52, 54 are rectified by rectifiers 56, 58 and filtered by high frequency filters 60, 62. The filtered signals are converted to alternating currents/voltages by respective low frequency inverters 64, 66 and then summed by low frequency transformers 68, 69.

Waveforms in FIG. 3 show operation of the inverter 10 of FIG. 1, which is referred to herein as a "120° type" since two modulated DC link currents i_{D1}, i_{D2} have a period of 120°. The high-frequency single-phase inverter generates current i_H that is amplitude-modulated. The output is rectified to become i_D and then is filtered to form the input DC current i_d for an unfolding three-phase inverter. The resulting output current i_U is obtained as follows:

$$0° \le \omega t \le 60°$$

$$i_U = i_{U2} = \left(2/\sqrt{3}\right) I_m \sin \omega t$$

$$60° \le \omega t \le 120°$$

$$i_U = i_{U1} + i_{U2} = \left(2/\sqrt{3}\right) I_m \sin(\omega t + 60°) + \left(2/\sqrt{3}\right) I_m \sin(\omega t - 60°) = \left(2/\sqrt{3}\right) I_m \sin \omega t$$

$$120° \le \omega t \le 180°$$

$$i_U = i_{U1} = \left(2/\sqrt{3}\right) I_m \sin \omega t$$

where ω is the angular frequency of the fundamental output, and I_m is the amplitude of inverter output phase current. Thus, the resulting output current i_U is shown to be a sine wave. It can easily be shown that the currents of the two phases i_V and i_W are also sinusoidal. FIG. 4 shows an example of a circuit implementation for one unit of the inverter 10 of FIG. 1

It should be noted that the system is only applicable to a current source output because the resulting outputs are obtained from a direct summation of unit outputs.

Waveforms in FIG. 5 show operation of the inverter 50 of FIG. 2, which is referred to herein as a "60° type", since two modulated DC link voltages have a period of 60°. Each output of the two units is summed with the output transformers. It can easily be shown that the resulting output waveform is sinusoidal:

$$0° \le \omega t \le 30°$$

$$i_U = i_{U2} = \left(2/\sqrt{3}\right)E_m \sin\omega t$$

$$30° \le \omega t \le 60°$$

$$v_U = v_{U1} + v_{U2} = \left(2/\sqrt{3}\right)E_m \sin(\omega t - 30°) + \left(2/\sqrt{3}\right)I_m \sin(\omega t + 120°) = \left(2/\sqrt{3}\right)E_m \sin\omega t$$

$$60° \le \omega t \le 90°$$

$$v_U = v_{U1} + v_{U2} = 2E_m \sin(\omega t + 90°) + \left(4/\sqrt{3}\right)E_m \sin(\omega t - 60°)$$
$$= \left(2/\sqrt{3}\right)E_m \sin\omega t$$

Note that the inverter 50 of FIG. 2 is applicable to either voltage or current source because the outputs of the two units are combined by two output transformers. FIG. 6 shows an exemplary circuit implementation for one unit of the inverter of FIG. 2

Significant drawbacks of the known three-phase inverters 10, 50 described above are present as a result of the schemes used for the summation of the modulated voltages or currents. The 120 degree type uses direct summation of the modulated currents to obtain a three-phase, sinusoidal output. While it may be simple, this technique is applicable only to current source inverters, which significantly limits its use.

The 60 degree scheme is applicable to both voltage and current source inverters but it requires two low-frequency transformers, which practically negates the advantages of the high-frequency link approach.

FIG. 7 shows an exemplary embodiment of a high-frequency linked three-phase inverter 100 in accordance with exemplary embodiments of the invention. First and second high-frequency, isolated DC-DC converters 102, 104 work as current

sources to generate two modulated DC voltage waveforms on first and second capacitors C1, C2.

In the exemplary embodiment of FIG. 7, two current source DC-DC converters are coupled in series to form a positive rail, a negative rail, and a neutral.

In the illustrated embodiment, first capacitor C_1 is coupled end-to-end across the positive rail and the neutral; second capacitor C_2 is coupled end-to-end across the negative rail and the neutral.

The voltage waveforms are then unfolded and summed by a three-level inverter 108 switched at 60 Hz to produce 60 Hz, three-phase output voltages.

The inverter 108 coupled to the positive rail, negative rail, and neutral and includes twelve switches Q1-Q12 with four switches coupled end-to-end for each leg A, B, C of the inverter. It is understood that multi-level inverters are well known to one of ordinary skill in the art.

FIGs. 8a-d show waveforms for operation of the inverter 100 of FIG. 7. FIG. 8a shows the first current source DC-DC converter current 800 and the second current source DC-DC converter current 802. FIG. 8b shows the first capacitor voltage 810 and the second capacitor voltage 812. FIG. 8c shows the inverter neutral voltage 820 referenced to ground. FIG. 8d shows the three phase output voltages 830, 832, 834.

Each segment of the modulated waveforms 810, 812 corresponds to a specific 60° segment of the 60 Hz sinusoid. The two modulated waveforms are phase-shifted relative to each other by 60° of the 60 Hz cycle. Table 1 shows the definition of the modulated waveforms for each 60° segment of the 360° cycle.

ωt	**0 - 60°**	**60° - 120°**	**120° - 180°**	**180° - 240°**	**240° - 300°**	**300° - 360°**
V_{C1}	$V_m\sin(\omega t + 120°)$	$V_m\sin(\omega t - 60°)$	$V_m\sin(\omega t)$	$-V_m\sin(\omega t)$	$V_m\sin(\omega t - 120°)$	$V_m\sin(\omega t + 60°)$
V_{C2}	$V_m\sin(\omega t)$	$V_m\sin(\omega t + 60°)$	$V_m\sin(\omega t - 120°)$	$V_m\sin(\omega t - 60°)$	$V_m\sin(\omega t + 120°)$	$-V_m\sin(\omega t)$

where ω is the angular frequency of the fundamental output, V_{C1} and V_{C2} are voltages across the first and second capacitors, and V_m is an amplitude of the inverter output line-to-line voltages.

The resulting 60 Hz voltages 830, 832, 834 are purely sinusoidal and are described by the following functions:

$0° \leq \omega t \leq 60°$:

$V_{AB} = V_{C2} = V_m * \sin(\omega t)$,

where Vm is the amplitude of the inverter output line-to-line voltage;

$60° \leq \omega t \leq 120°$:

$V_{AB} = V_{C1} + V_{C2} = V_m \sin(\omega t) + V_m \sin(\omega t + 120°) = V_m \sin(\omega t + 60°)$; and

$120° \leq \omega t \leq 180°$:

$V_{AB} = V_{C1} = V_m \sin(\omega t + 120°)$

where V_{C1} is the voltage on the first capacitor C_1, V_{C2} is the voltage on the second capacitor C_2, and ω is the angular frequency of the fundamental output, and V_m is the amplitude of inverter output line-to-line voltages, and V_{AB}. is the inverter output line-to-line voltage.

The process is repeated in a mirror-image fashion for the 180°-360° interval. Phases B and C voltages are generated similarly, but shifted relative to phase A by 120° and 240° respectively. Table 2 shows the distribution of V_{C1}, V_{C2} voltages between the inverter phases for a complete 360° cycle.

Table 2 Distribution of V_{C1}, V_{C2}

	0 - 60°	**60° - 120°**	**120° - 180°**	**180° - 240°**	**240° - 300°**	**300° - 360°**
A	0	V_{C1}	V_{C1}	0	$-V_{C2}$	$-V_{C2}$
B	$-V_{C2}$	$-V_{C2}$	0	V_{C1}	V_{C1}	0
C	V_{C1}	0	$-V_{C2}$	$-V_{C2}$	0	V_{C1}

Table 3 below shows the switching scheme for the inverter switches within one 60 Hz cycle.

Table 3

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
0 - 60°		X	X				X	X	X	X		
60° - 120°	X	X					X	X		X	X	
120° - 180°	X	X				X	X				X	X
180° - 240°		X	X		X	X					X	X
240° - 300°			X	X	X	X				X	X	
300° - 360°			X	X		X	X		X	X		

As can be seen from the DC-DC converter current waveforms 800, 802, DC-DC converter currents are essentially DC with approximately 25% 180 Hz ripple.

Unlike a conventional PWM inverter, in an inventive inverter embodiment switches commutate only once per 60 Hz cycle. Owed to low switching frequency, low-speed devices with lower saturation voltage can be used in the inverter, thus further increasing the inverter efficiency. In addition, capacitors C1, C2 act not as typical DC bus capacitors, but as the inverter output low-pass filter. Note that this filter is significantly simpler and smaller, compared to a conventional low-pass filter due to the absence of the filter inductors and reduced number of filter capacitors, e.g., two instead of three. Unlike the conventional filter, voltage across the capacitors is unipolar, which allows to use smaller, DC-rated capacitors.

It is understood that the inventive inverter is useful for any isolated DC/DC converter topology as current source, modulated DC output can be realized by implementing an appropriate current feedback or by using a converter topology with inherently current source characteristics. Exemplary applications include solid state

replacement of conventional utility transformers, distributed power systems, and motor drives.

FIG. 9 shows an exemplary sequence of steps for providing a three phase inverter in accordance with exemplary embodiments of the invention. In step 900, first and second energy sources are provided in series where each of the energy sources has a positive rail, a negative rail, and a neutral. In step 902, the first and second energy storage devices are coupled to the first and second energy sources. Voltages VC1, VC2, such as those listed in Table 1, are generated across energy storage devices, e.g., C1, C2, in step 903. In step 904, voltages VC1, VC2 are coupled to a positive terminal, a negative terminal, and a neutral of a three-level inverter. In step 906, switches of the three-level inverter are controlled once per cycle of output frequency, as shown for example, in Table 3. In step 908, the voltages VC1, VC2 are distributed between output phases of the three-level inverter to generate output voltages, such as according to Table 3.

In one embodiment, the first and second energy sources are current sources. In one particular embodiment, the first and second energy storage devices are capacitors.

Exemplary embodiments of the invention provide a three-phase inverter utilizes a simple three-phase, three-level inverter for unfolding two modulated DC waveforms into three-phase, sinusoidal voltages. The inventive scheme eliminates the drawbacks of conventional systems, such as Oguchi. Advantages of the inventive high-frequency linked three-phase inverter include simplicity in use of a single three-phase, three-level inverter instead of two two-level inverters, and reduced size and weight as it does not require a low-frequency transformer.

Having described exemplary embodiments of the invention, it will now become apparent to one of ordinary skill in the art that other embodiments incorporating their concepts may also be used. The embodiments contained herein should not be limited to disclosed embodiments but rather should be limited only by

the spirit and scope of the appended claims. All publications and references cited herein are expressly incorporated herein by reference in their entirety.

What is claimed is:

1. A circuit, comprising:

first and second energy sources coupled in series and having a positive rail, a negative rail, and a neutral;

first and second energy storage devices coupled to the first and second energy sources; and

a single multi-level inverter coupled to the positive rail, negative rail, and neutral for providing three-phase sinusoidal output voltages.

2. The circuit according to claim 1, wherein the first and second energy sources include current source DC-DC converters.

3. The circuit according to claim 2, wherein the first and second energy storage devices are capacitive; the first energy storage device is coupled end-to-end across the positive rail and the neutral; and the second energy storage device is coupled end-to-end across the negative rail and the neutral.

4. The circuit according to claim 1, wherein the three-phase output signals are about 60 Hz

5. The circuit according to claim 1, wherein the three-phase output signals are about 50 Hz.

6. The circuit according to claim 1, wherein the three-phase output signals are about 400 Hz.

7. The circuit according to claim 1, wherein the frequency of the three-phase output signals varies from zero to a predetermined maximum frequency.

8. The circuit according to claim 1, wherein the inverter includes switches to commutate once per cycle of the output frequency.

9. The circuit according to claim 3, wherein the voltages of the first and second capacitive energy storage devices are described as follows:

ωt	0 - 60°	60° - 120°	120° - 180°	180° - 240°	240° - 300°	300° - 360°
V_{C1}	$V_m\sin(\omega t + 120°)$	$V_m\sin(\omega t - 60°)$	$V_m\sin(\omega t)$	$-V_m\sin(\omega t)$	$V_m\sin(\omega t - 120°)$	$V_m\sin(\omega t + 60°)$
V_{C2}	$V_m\sin(\omega t)$	$V_m\sin(\omega t + 60°)$	$V_m\sin(\omega t - 120°)$	$V_m\sin(\omega t - 60°)$	$V_m\sin(\omega t + 120°)$	$-V_m\sin(\omega t)$

where ω is the angular frequency of the fundamental output, V_{C1} is a voltage across the first capacitive energy storage and V_{C2}, is a voltage across the second capacitive energy storage, and V_m is an amplitude of the inverter output line-to-line voltages.

10. The circuit according to claim 1, wherein the multi-level inverter output phase voltages are described as follows:

	0 - 60°	60° - 120°	120° - 180°	180° - 240°	240° - 300°	300° - 360°
V_A	0	V_{C1}	V_{C1}	0	$-V_{C2}$	$-V_{C2}$
V_B	$-V_{C2}$	$-V_{C2}$	0	V_{C1}	V_{C1}	0
V_C	V_{C1}	0	$-V_{C2}$	$-V_{C2}$	0	V_{C1}

where ω is the angular frequency of the fundamental output, V_A, V_B, V_C are multi-level inverter output phase voltages, V_{C1} is a voltage across the first capacitive energy storage and V_{C2}, is a voltage across the second capacitive energy storage, and V_m is an amplitude of the inverter output phase voltages.

11. The circuit according to claim 1, wherein the first and second energy sources are bidirectional.

12. A method comprising:

coupling first and second energy sources in series and having a positive rail, a negative rail, and a neutral;

coupling first and second energy storage devices to the first and second energy sources; and

coupling a single three-level inverter to the positive rail, negative rail, and neutral for providing three-phase sinusoidal output voltages.

13. The method according to claim 12, wherein the first and second energy sources are current sources.

14. The method according to claim 12, wherein the first and second energy storage devices are capacitors

15. The method according to claim 12, wherein the three-phase output signals are about 60 Hz.

16. The method according to claim 12, wherein the three-phase output signals are about 50 Hz.

17. The method according to claim 12, wherein the three-phase output signals are about 400 Hz.

18. The method according to claim 12, wherein the frequency of the three-phase output signals varies from zero to a predetermined maximum frequency.

19. The method according to claim 12, wherein the first energy source generates a first modulated DC voltage waveform on a first energy storage element and the second energy source generates a second modulated DC voltage waveform on a second energy storage element, wherein the first energy storage device is coupled end-to-end across the positive rail and the neutral; the second energy storage device is coupled end-to-end across the negative rail and the neutral; and

generating sinusoidal three-phase output voltages with a single three-level inverter coupled to the positive rail, negative rail, and neutral.

20. The method according to claim 12, wherein the voltages of the first and second capacitive energy storage devices are described as follows:

ωt	0 - 60°	60° - 120°	120° - 180°	180° - 240°	240° - 300°	300° - 360°
V_{C1}	$V_m\sin(\omega t + 120°)$	$V_m\sin(\omega t - 60°)$	$V_m\sin(\omega t)$	$-V_m\sin(\omega t)$	$V_m\sin(\omega t - 120°)$	$V_m\sin(\omega t + 60°)$
V_{C2}	$V_m\sin(\omega t)$	$V_m\sin(\omega t + 60°)$	$V_m\sin(\omega t - 120°)$	$V_m\sin(\omega t - 60°)$	$V_m\sin(\omega t + 120°)$	$-V_m\sin(\omega t)$

where ω is the angular frequency of the fundamental output, V_{C1} is a voltage across the first capacitive energy storage and V_{C2}, is a voltage across the second capacitive energy storage, and V_m is an amplitude of the inverter output line-to-line voltages.

21. The method according to claim 12, wherein the inverter includes switches to commutate once per cycle of the output frequency.

22. The method according to claim 12, wherein the inverter includes switches to commutate once per cycle of the output frequency according to the table below.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
0 - 60°		X	X				X	X	X	X		
60° - 120°	X	X					X	X		X	X	
120° - 180°	X	X				X	X				X	X
180° - 240°		X	X		X	X					X	X
240° - 300°			X	X	X	X				X	X	
300° - 360°			X	X		X	X		X	X		

23. The method according to claim 12, wherein the multi-level inverter output phase voltages result from summation of two voltages V_{C1}, V_{C2} and are described as follows:

	0 - 60°	**60° - 120°**	**120° - 180°**	**180° - 240°**	**240° - 300°**	**300° - 360°**
V_A	0	V_{C1}	V_{C1}	0	$-V_{C2}$	$-V_{C2}$
V_B	$-V_{C2}$	$-V_{C2}$	0	V_{C1}	V_{C1}	0
V_C	V_{C1}	0	$-V_{C2}$	$-V_{C2}$	0	V_{C1}

where ω is the angular frequency of the fundamental output, V_A, V_B, V_C are multi-level inverter output phase voltages, V_{C1} is a voltage across the first capacitive energy storage and V_{C2}, is a voltage across the second capacitive energy storage, and V_m is an amplitude of the inverter output phase voltages.

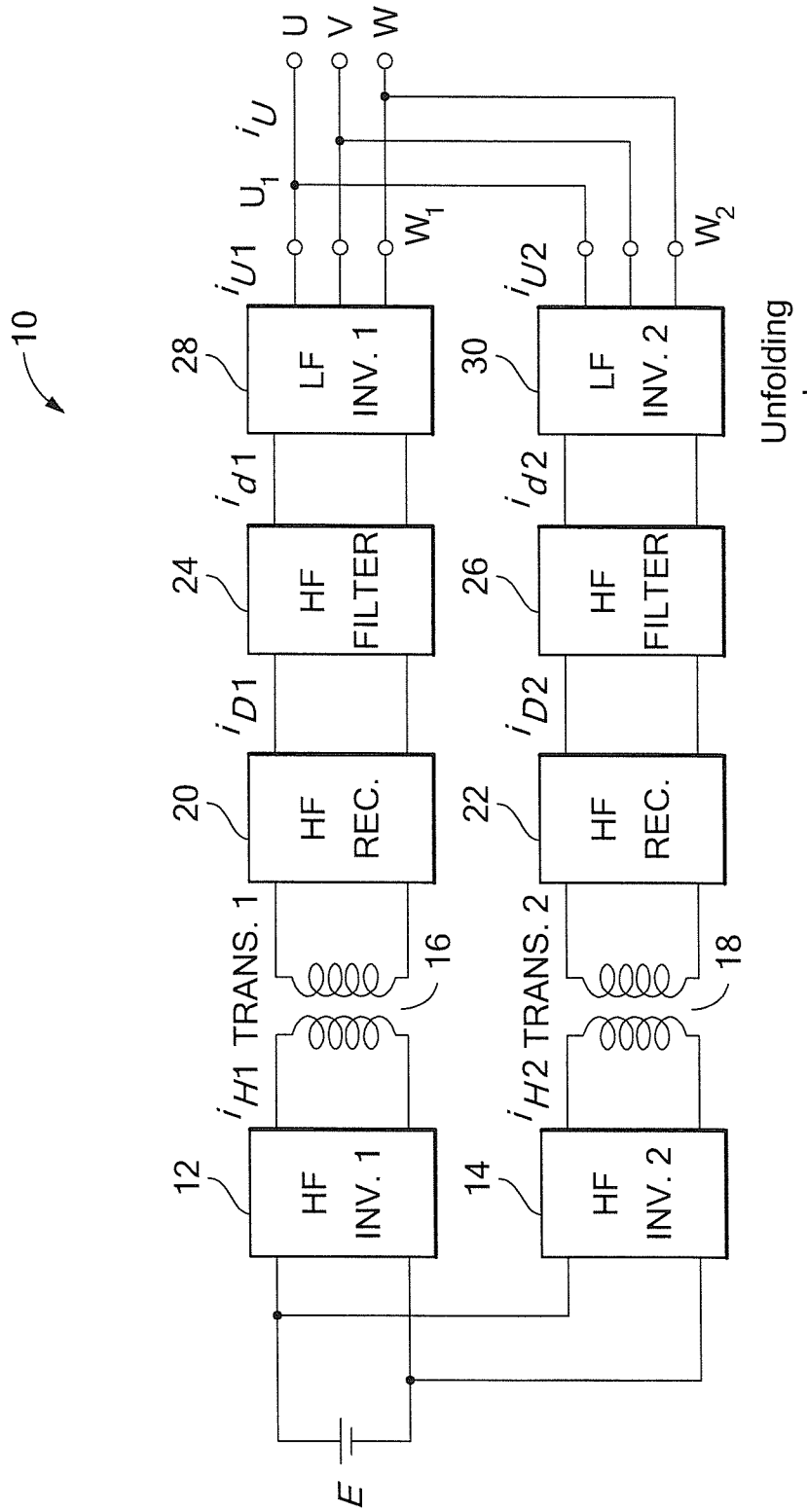


FIG. 1
PRIOR ART

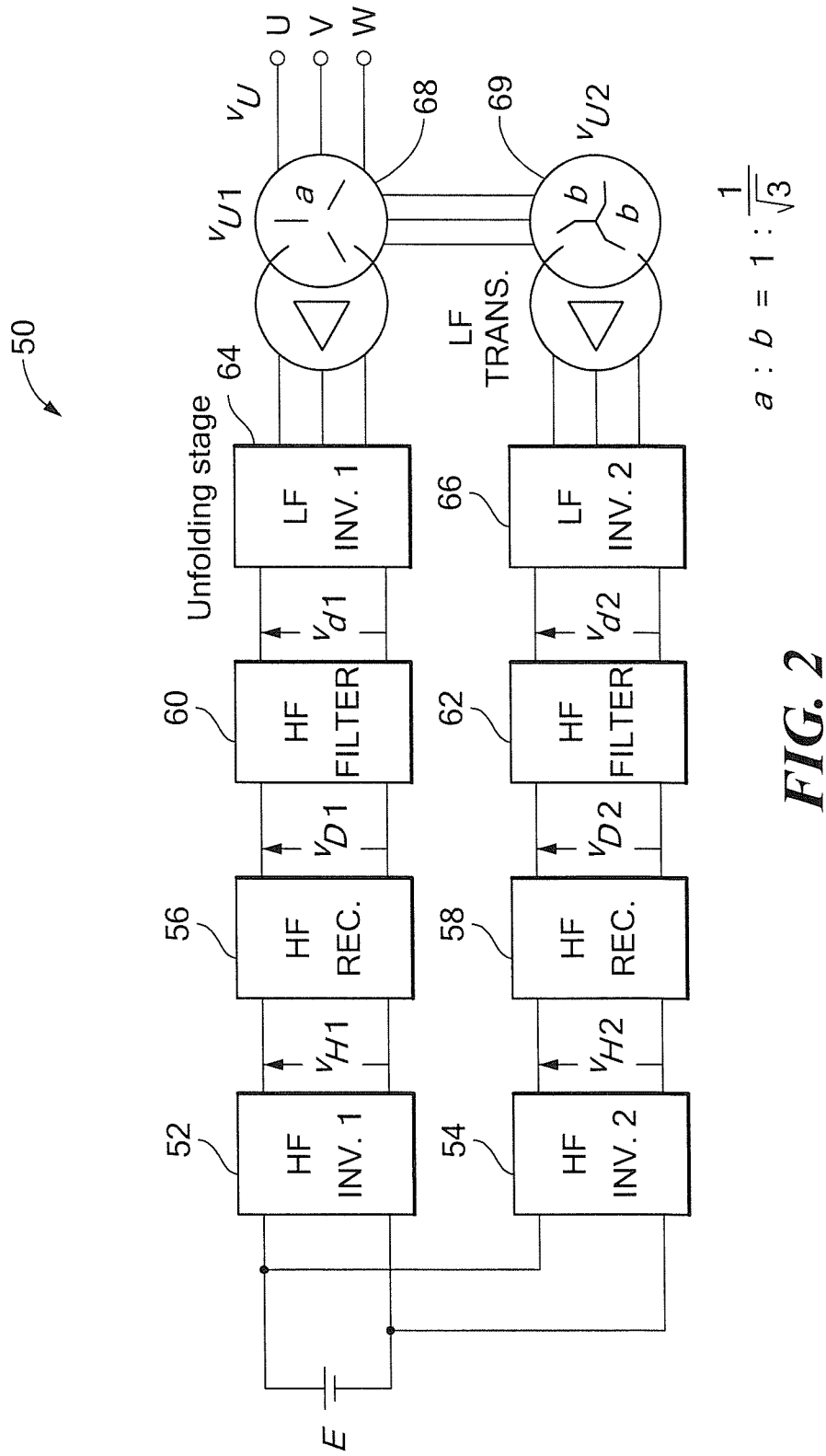


FIG. 2
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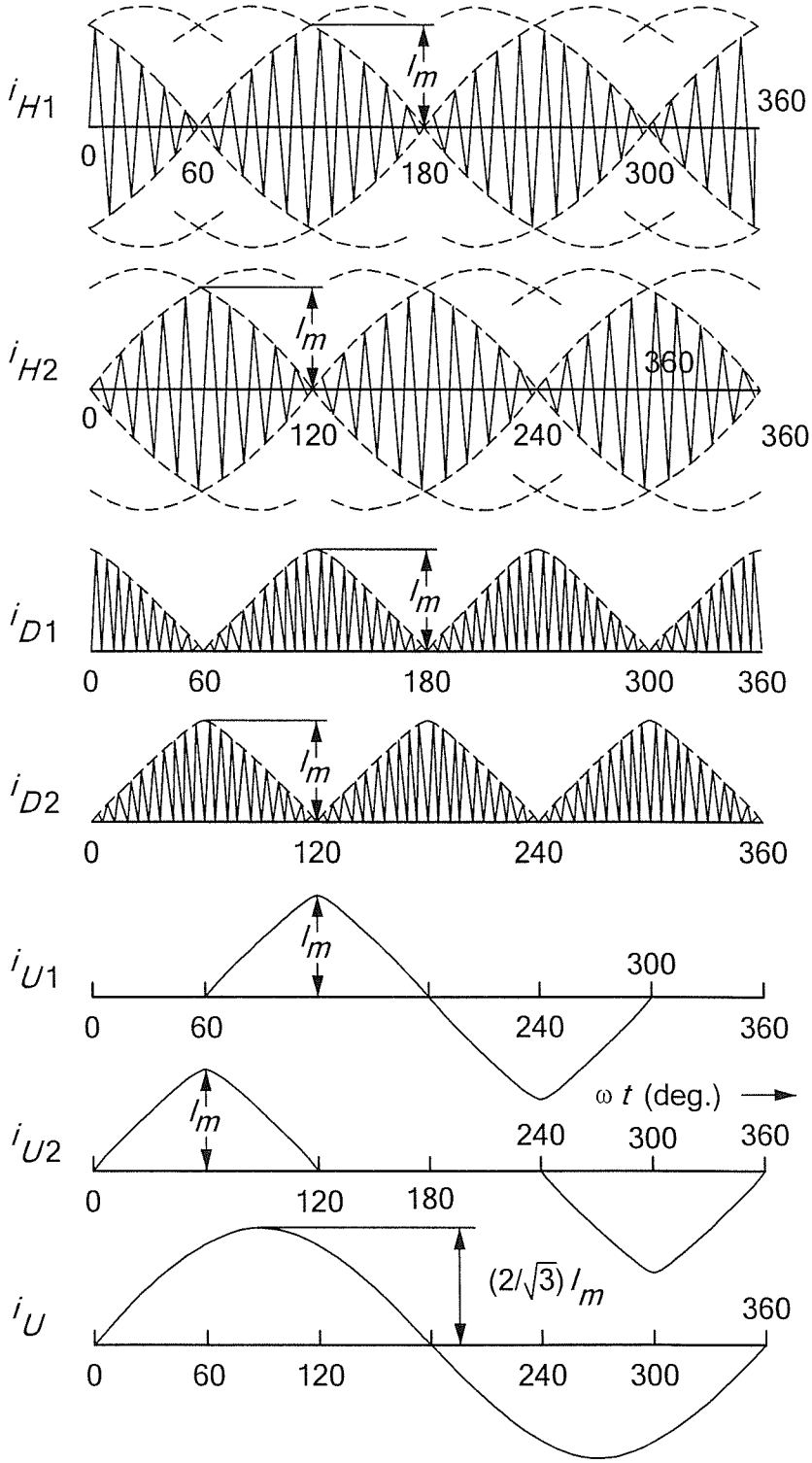


FIG. 3

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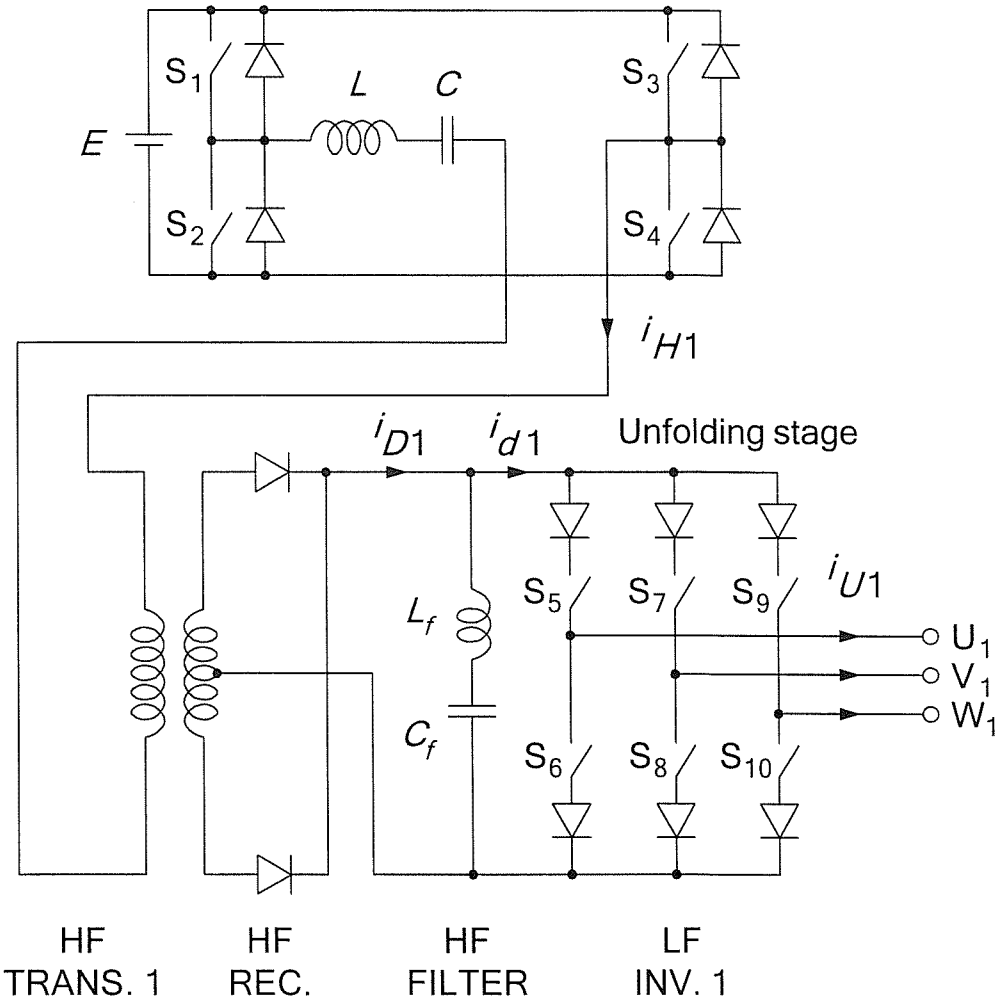


FIG. 4

PRIOR ART

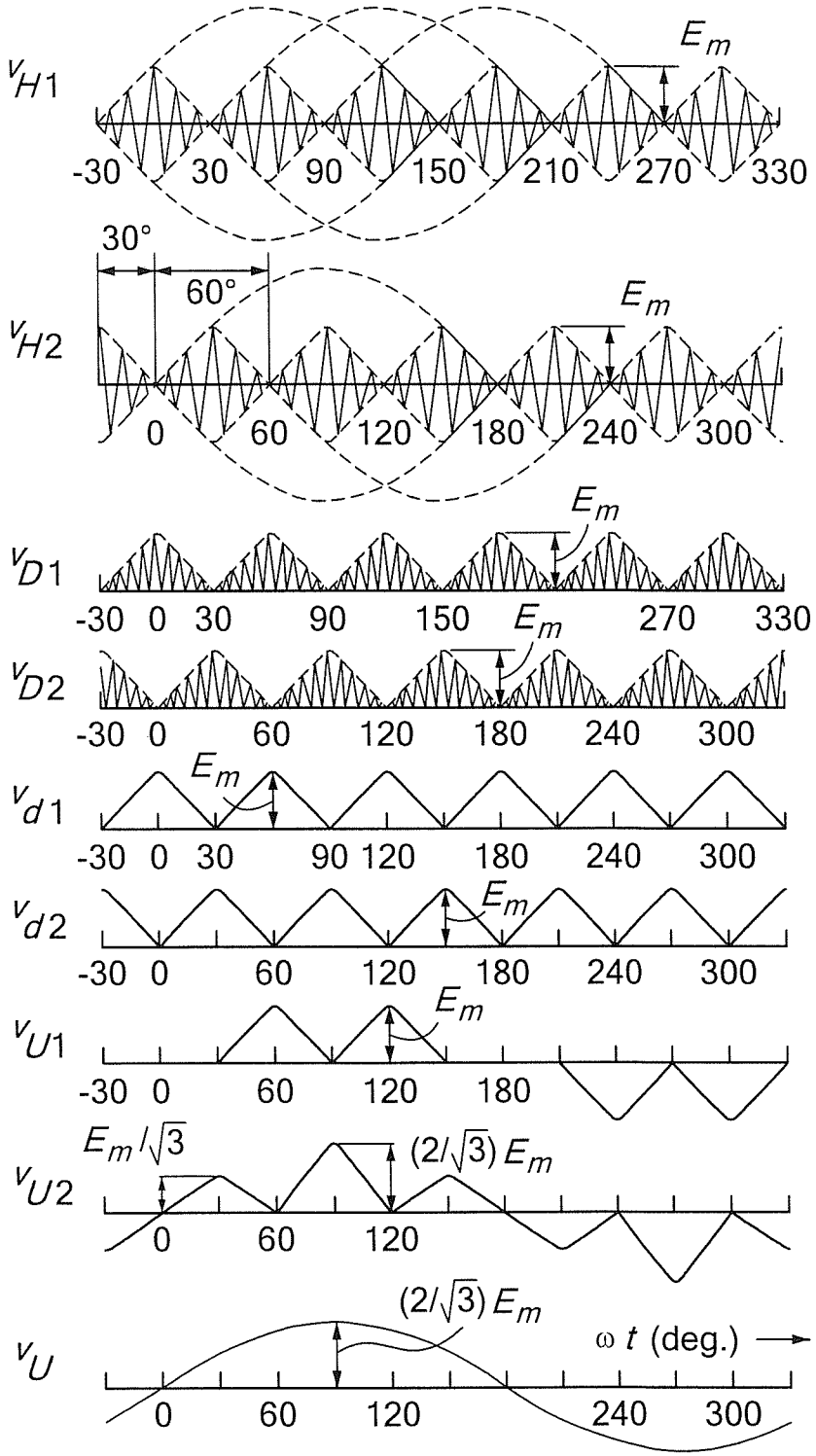


FIG. 5

PRIOR ART

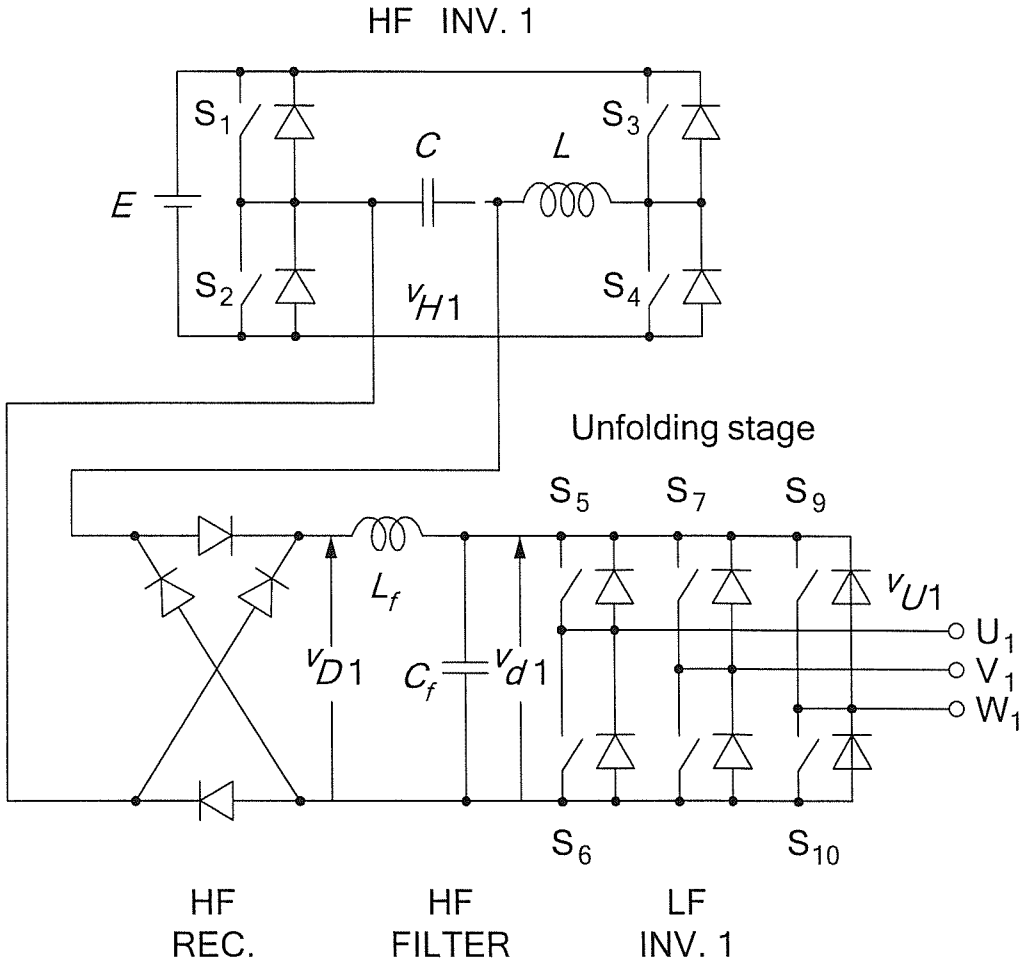

HF INV. 1
S1
S3
C
L
E
S2
vH1
S4
Unfolding stage
S5
S7
S9
Lf
vU1
U1
V1
W1
vD1
Cf
vd1
S6
S10
HF REC.
HF FILTER
LF INV. 1

FIG. 6

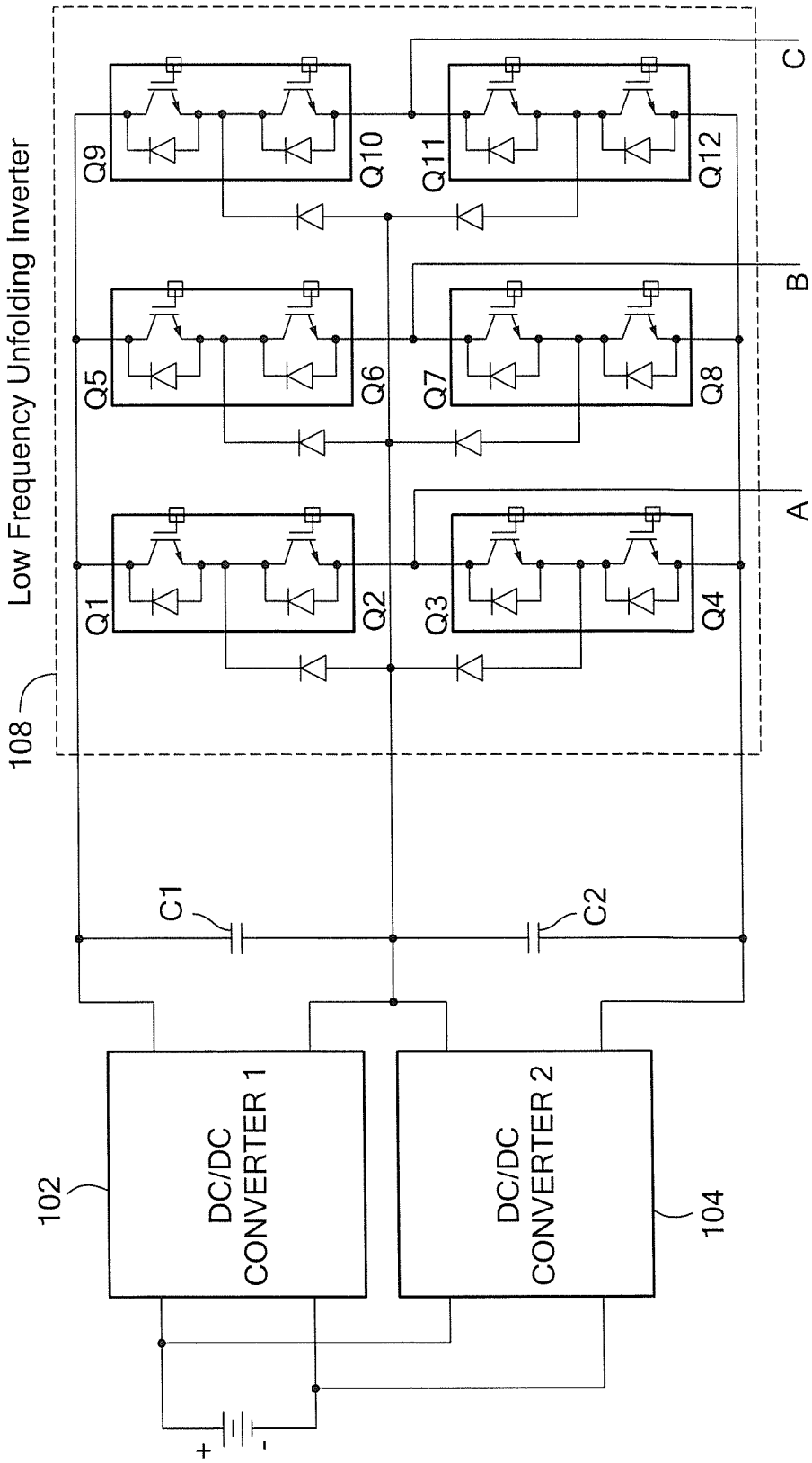

Low Frequency Unfolding Inverter
108
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
A
B
C
C1
C2
DC/DC CONVERTER 1
DC/DC CONVERTER 2
102
104
+
-

FIG. 7

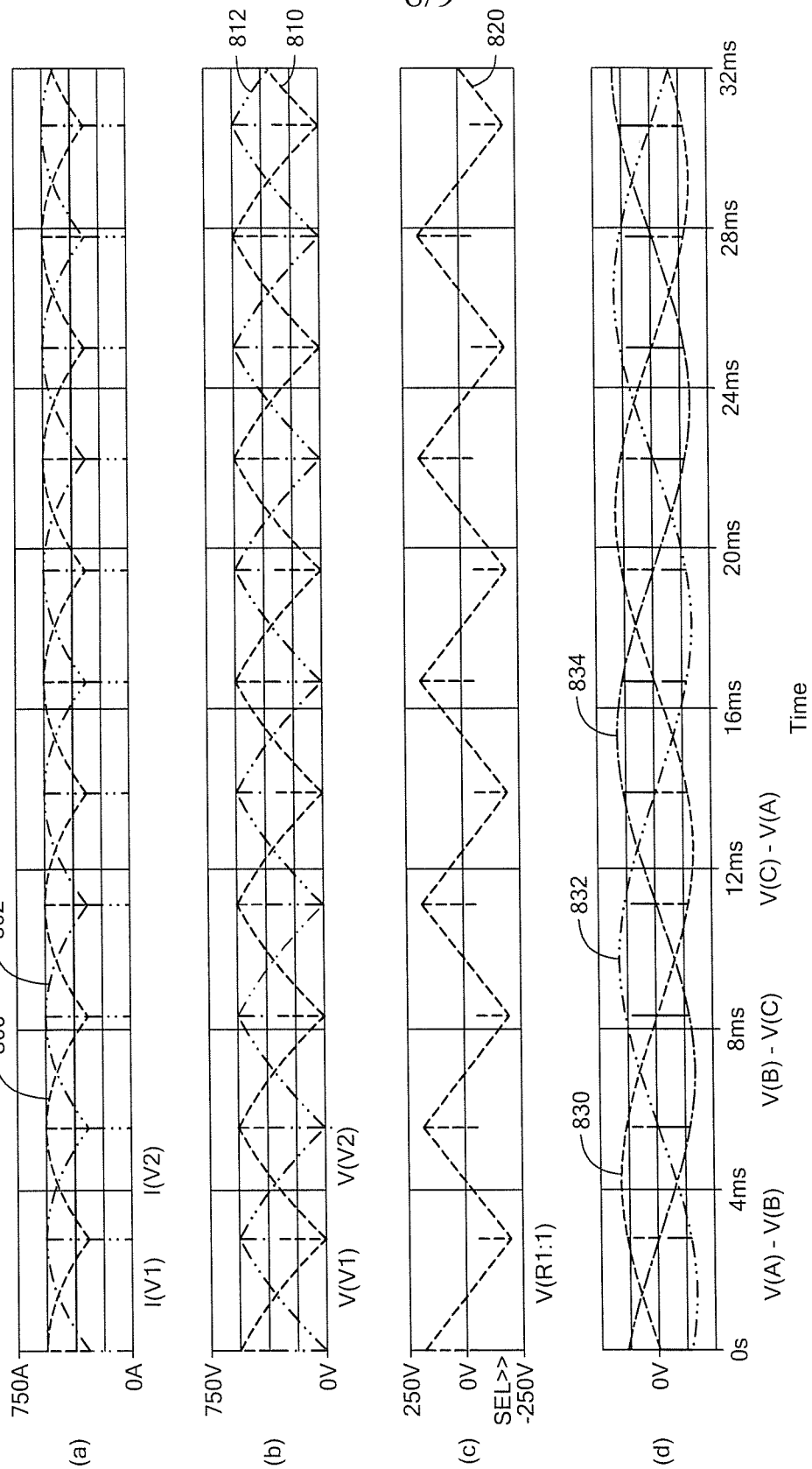

800
802
750A
0A
I(V1)
I(V2)
(a)
812
810
750V
0V
V(V1)
V(V2)
(b)
820
250V
0V
SEL>>
-250V
V(R1:1)
(c)
834
832
830
0V
(d)
0s
4ms
8ms
12ms
16ms
20ms
24ms
28ms
32ms
Time
V(A) - V(B)
V(B) - V(C)
V(C) - V(A)

FIG. 8

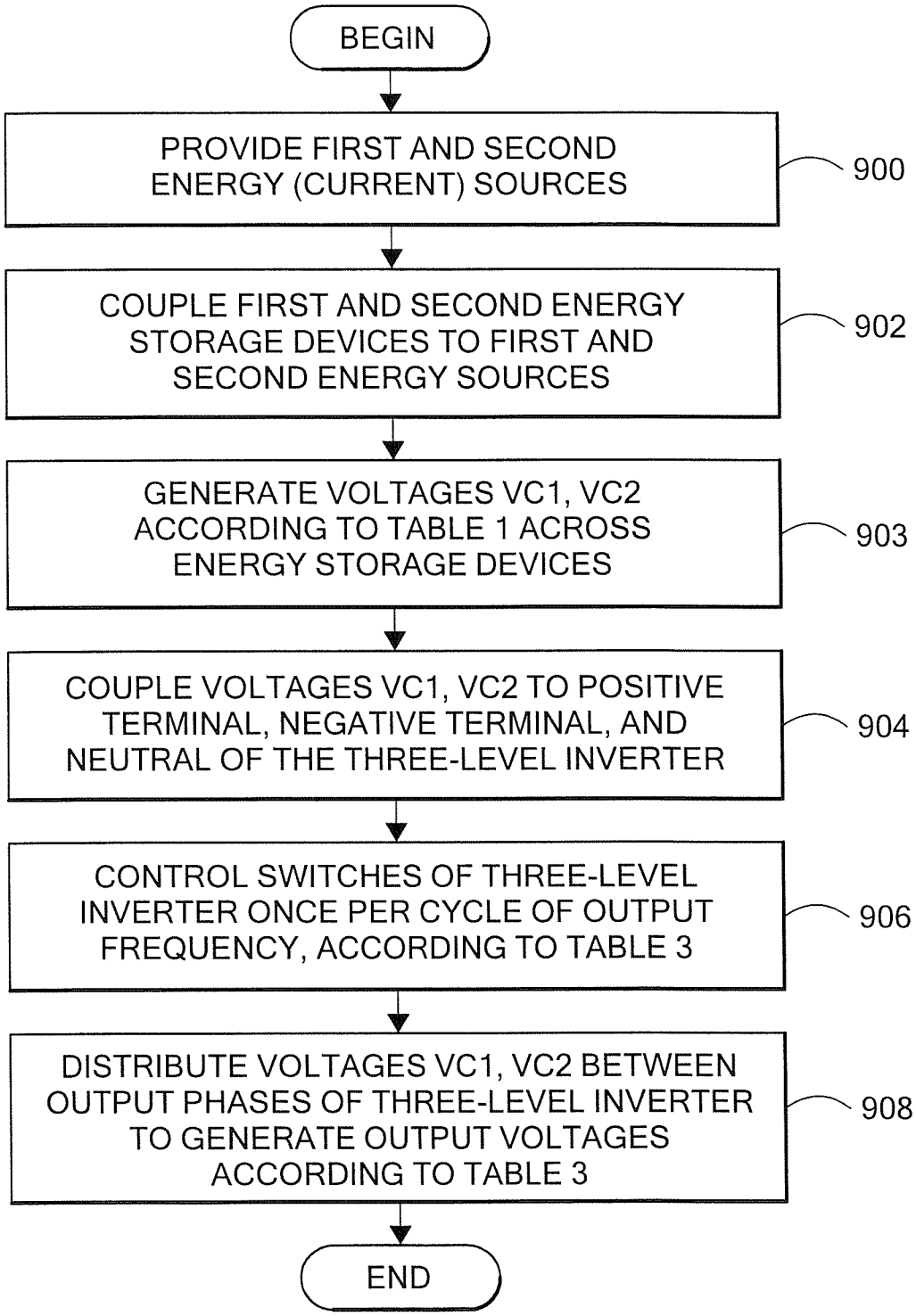

BEGIN
PROVIDE FIRST AND SECOND ENERGY (CURRENT) SOURCES
900
COUPLE FIRST AND SECOND ENERGY STORAGE DEVICES TO FIRST AND SECOND ENERGY SOURCES
902
GENERATE VOLTAGES VC1, VC2 ACCORDING TO TABLE 1 ACROSS ENERGY STORAGE DEVICES
903
COUPLE VOLTAGES VC1, VC2 TO POSITIVE TERMINAL, NEGATIVE TERMINAL, AND NEUTRAL OF THE THREE-LEVEL INVERTER
904
CONTROL SWITCHES OF THREE-LEVEL INVERTER ONCE PER CYCLE OF OUTPUT FREQUENCY, ACCORDING TO TABLE 3
906
DISTRIBUTE VOLTAGES VC1, VC2 BETWEEN OUTPUT PHASES OF THREE-LEVEL INVERTER TO GENERATE OUTPUT VOLTAGES ACCORDING TO TABLE 3
908
END

FIG. 9