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(54) Title: AC/AC CONVERTER FOR CONVERSION BETWEEN THREE PHASE AND SINGLE PHASE POWER SUPPLIES

(57) Abstract: A bi-directional AC/AC converter is designed to provide improved AC/AC power conversion along with reduced switching losses, reduced harmonic distortion and improved power factor. The converter is characterized by bi-directional switches comprising IGBTs that are selectively turned ON to generate an output AC voltage having a frequency in the range of 50 Hz to 30 kHz. The conduction of IGBTs for each phase of a three phase supply is controlled by a control circuit provided therein.



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TITLE: AC/AC CONVERTER FOR CONVERSION BETWEEN THREE PHASE AND SINGLE PHASE POWER SUPPLIES

FIELD OF THE DISCLOSURE

The present disclosure generally relates to AC/AC converters.

BACKGROUND

Many industrial applications require AC/AC power conversion. AC/AC converters convert an AC waveform into another AC waveform having a predetermined voltage and frequency.

AC/AC converters based on various topologies including voltage-source inverter converters, current-source inverter converters, cyclo-converters and matrix converters are known in the art. Voltage-source inverter converters and current-source inverter converters are generally associated with conduction losses and poor power factor which reduces their efficiency. Cyclo-converters find limited use, typically in systems wherein output frequency is required to be lower than input frequency. Generally, AC/AC matrix converters comprise at least nine bi-directional semiconductor switches along with other circuit components. The topology of matrix converters known in the art is complex and expensive, and necessitates the use of a large number of components. Various parameters such as switching frequency, total harmonic distortion, switching losses, harmonic generation and speed and response are critical to the development of power converters for different applications.

Therefore, there is felt a need to provide an efficient direct bi-directional AC/AC converter that incorporates lesser number of components and also provides the desired high output frequency.

OBJECTS

Some of the objects of the present disclosure which at least one embodiment is adapted to provide, are described herein below:

It is an object of the present disclosure to ameliorate one or more problems of the prior art or to at least provide a useful alternative.

An object of the present disclosure is to provide a bi-directional AC/AC converter with lesser number of bi-directional switches.

Another object of the present disclosure is to provide a bi-directional AC/AC converter that provides high frequency output voltage using lesser number of bi-directional switches.

Still another object of the present disclosure is to provide an optimized bi-directional AC/AC converter with reduced switching losses.

Yet another object of the present disclosure is to provide a simple optimized bi-directional AC/AC converter.

Still another object of the present disclosure is to provide an efficient optimized bi-directional AC/AC converter.

One more object of the present disclosure is to provide an optimized bi-directional AC/AC converter that eliminates the need for energy storage elements.

Further, an object of the present disclosure is to provide an optimized bi-directional AC/AC converter with improved power factor.

One more objective of the present disclosure is to provide an optimized bi-directional AC/AC converter with reduced total harmonic distortion.

Other objects and advantages of the present disclosure will be more apparent from the following description when read in conjunction with the accompanying figures, which are not intended to limit the scope of the present disclosure.

SUMMARY

In accordance with the present disclosure, there is provided a converter selectively converting an input AC voltage into an output AC voltage, the converter connected between the terminals of a three phase AC supply and the terminals of a single phase AC supply, the converter comprising:

- a first switch set comprising three bidirectional switches connected in a one to one correspondence with the terminals of the three phase AC supply at one end and the other end being connected to a terminal of the single phase AC supply;
- a second switch set comprising three bidirectional switches connected in a one to one correspondence with the terminals of the three phase AC supply at one end and the other end being connected to another terminal of the single phase AC supply; and

- a controller connected to each switch of the switch pairs constituting each of the bidirectional switches, the controller adapted to sequentially turn ON one switch of the switch pair of a predetermined bidirectional switch of the first switch set and another switch of the switch pair of a predetermined bidirectional switch of the second switch set, for every phase angle displacement of 60 degrees corresponding to the input AC voltage thereby generating the output AC voltage having a frequency in the range of 50Hz to 30kHz.

The converter can be a single stage converter wherein the frequency of said single phase AC output is in the range of 1 kHz to 30 kHz. However, it could be higher or lower depending on the frequency capability of the power devices, losses and application. Theoretically, there is no limit to the frequency or frequency range.

In accordance with the converter of the present disclosure, the converter comprises bi-directional switches that are sequentially turned ON to provide bi-directional flow of power. For instance, when the input AC voltage is a three phase AC voltage, the output AC voltage is a high frequency single phase AC voltage. Alternatively, when the input AC voltage is a single phase AC voltage, the output AC voltage is a high frequency three phase AC voltage.

The bi-directional switch constituting the switch pair can be a pair of antiparallel common emitter configuration of IGBTs with series diode.

Further, in accordance with the present disclosure, the controller as described herein above comprises:

- a plurality of comparators, each of the comparators being adapted to compare a carrier waveform with at least one reference signal

corresponding to a phase of the three phase AC supply and generate a unipolar switching signal (SPWM);

- a plurality of AND-ing means, each of the AND-ing means being adapted to logically AND the unipolar switching signal with a frequency signal to generate a signal corresponding to each of the switches constituting the bi-directional switches; and
- a plurality of OR-ing means, each of the OR-ing means being adapted to receive and logically OR the signals corresponding to switches constituting each of the pairs and further adapted to generate trigger signals for the sequential turning ON of switches.

In accordance with present disclosure, there is provided a method for converting an input AC voltage into an output AC voltage comprising the steps of:

- defining a first switch set comprising three bidirectional switches;
- connecting each of the bidirectional switches of the first switch set in a one to one correspondence to terminals of a three phase AC supply at one end;
- connecting the other end of each of the bidirectional switches of the first switch set to a terminal of a single phase AC supply at the other end;
- defining a second switch set comprising three bidirectional switches;
- connecting each of the bidirectional switches of the second switch set in a one to one correspondence to terminals of the three phase AC supply at one end;
- connecting the other end of each of the bidirectional switches of the second switch set to another terminal of the single phase AC supply at the other end; and
- sequentially turning ON one switch of a switch pair constituting a pre-determined bidirectional switch from each of the first switch set and the

second switch set, for every phase angle displacement of 60 degree thereby generating the AC output voltage having a frequency in the range of 50Hz to 30 kHz.

The step of sequentially turning ON one switch, referred herein above, can further comprise the following steps:

- comparing a triangular carrier waveform with a sinusoidal positive reference signal and a sinusoidal negative reference signal respectively, the positive reference signal and the negative reference signal corresponding to a phase of the three phase AC supply;
- generating a unipolar switching signal (SPWM);
- performing at least one of (i) selectively logical AND-ing the unipolar switching signal with a square wave frequency signal and (ii) selectively logical AND-ing the unipolar switching signal with an inverted signal of the square wave frequency signal corresponding to a desired frequency of the AC output voltage, to generate a signal corresponding to each of the switches constituting the bi-directional switches;
- logically OR-ing the signals corresponding to switches constituting each of the pairs; and
- generating trigger signals for the sequential turning ON of switches.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS:

A bi-directional AC/AC converter of the present disclosure will now be explained in relation to the accompanying drawings, in which:

FIGURE 1 illustrates a conventional indirect AC-AC converter topology;

FIGURE 2 illustrates a direct AC/AC converter topology;

FIGURE 3 illustrates a power circuit of a bi-directional AC/AC converter in accordance with an embodiment of the present disclosure;

FIGURE 4 is a control circuit diagram that illustrates generation of trigger signals for bi-directional switches of FIGURE 3;

FIGURE 5 illustrates a single phase output voltage waveform across a load; and

FIGURE 6 and FIGURE 7 illustrate output voltage waveforms corresponding to different input voltages applied to a bi-directional AC/AC converter in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE ACCOMPANYING DRAWINGS

A bi-directional AC/AC converter will now be described with reference to the accompanying drawings which do not limit the scope and ambit of the disclosure. The description provided is purely by way of example and illustration.

The embodiments herein and the various features and advantageous details thereof are explained with reference to the non-limiting embodiments in the following description. Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the embodiments herein. The examples used herein are intended merely to facilitate an understanding of ways in which the embodiments herein may be practiced and to further enable those of skill in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of the embodiments herein.

FIGURE 1 illustrates a conventional indirect AC-AC converter topology. As illustrated in the figure, the topology implements an energy storage element (10), typically a capacitor or an inductor. In this topology, an AC input to the converter is first converted into a DC output which is stored in the energy storage element (10). The energy stored by the energy storage element (10) is then further converted into a desired AC output to be supplied to a connected load.

It is apparent from the aforementioned description of FIGURE 1 that the topology requires at least two stages of power conversion, thereby necessitating the use of more power semiconductor devices. Moreover, increased conduction and switching losses lead to higher total harmonic distortion, low power factor and poor efficiency in converters based on indirect AC-AC converter topology.

FIGURE 2 illustrates a direct AC/AC converter topology. As illustrated, this converter topology is used to convert an AC input voltage into another AC output voltage without any direct DC link as required in the conventional indirect AC-AC converter described in FIGURE 1. This topology overcomes the limitations of a conventional indirect AC-AC converter of FIGURE 1 by replacing the multiple conversion stages and an intermediate energy storage element by a single power conversion stage, therefore reducing losses in converters based on matrix converter topology.

FIGURE 3 illustrates a power circuit of a bi-directional AC/AC converter in accordance with an embodiment of the present disclosure. The converter is connected between the terminals of a three phase AC supply and the terminals of a single phase AC supply. The power circuit (300) comprises six bi-directional switches, each switch comprising a pair of antiparallel common emitter configuration of IGBTs with series diode. The six bi-directional

switches are grouped in to two switch sets. The three bi-directional switches constituting the first switch set are connected to one of the phases of the three phase AC input at one end, in a one to one correspondence, and at the other end connected to a terminal (302) of the single phase AC supply. The three bi-directional switches constituting the second switch set are connected to one of the phases of the three phase AC input at one end, in a one to one correspondence, and at the other end to another terminal (304) of the single phase AC supply.

For ease of explanation, the various components involved are generally referenced alphanumerically as given below in the description.

A first bi-directional switch comprises IGBTs T1 and T2 along with series diodes D1 and D2 respectively, a second bi-directional switch comprises IGBTs T3 and T4 along with series diodes D3 and D4 respectively, a third bi-directional switch comprises IGBTs T5 and T6 along with series diodes D5 and D6 respectively, a fourth bi-directional switch comprises IGBTs T7 and T8 along with series diodes D7 and D8 respectively, a fifth bi-directional switch comprises IGBTs T9 and T10 along with series diodes D9 and D10 respectively and a sixth bi-directional switch comprises IGBTs T11 and T12 along with series diodes D11 and D12 respectively.

A controller is connected to each switch of the switch pairs constituting each of the bidirectional switches. The controller sequentially turns ON one switch of the switch pair of a predetermined bidirectional switch of the first switch set and another switch of the switch pair of a predetermined bidirectional switch of the second switch set, for every phase angle displacement of 60 degrees corresponding to the input AC voltage thereby generating the output AC voltage having a frequency in the range of 50Hz to 30kHz.

In a 360 degree cycle of the input AC waveform, only two switches of the 12 switches constituting the 6 bidirectional switches conduct in a sequential pattern in each of the six time intervals (I, II, III, IV, V, VI) based on trigger signals generated by the controller. The switching pattern of each switch is pre-determined in accordance with Table 1 provided herein below.

Table 1

Phase connected	RY	YB	BR	RB	BY	YR
Interval	I	II	III	IV	V	VI
Switches						
T1	ON	0	0	0	0	0
T2	0	0	0	0	0	ON
T3	0	ON	0	0	0	0
T4	0	0	0	0	ON	0
T5	0	0	ON	0	0	0
T6	0	0	0	ON	0	0
T7	0	0	0	ON	0	0
T8	0	0	ON	0	0	0
T9	0	0	0	0	0	ON
T10	ON	0	0	0	0	0
T11	0	0	0	0	ON	0
T12	0	ON	0	0	0	0

In the first interval (I) corresponding to 0-60 degrees of the AC waveform, R and Y phases are connected to the input power supply, IGBTs T1 and T10 are turned ON and provide an output to the terminals (302) and (304) respectively.

Accordingly, in the second interval (II) corresponding to 60-120 degrees of the AC waveform, Y and B phases are connected to the input power supply, IGBTs T3 and T12 are turned ON and provide an output to the terminals (302) and (304) respectively.

Accordingly, in the third interval (III) corresponding to 120-180 degrees of the AC waveform, B and R phases are connected to the input power supply, IGBTs T5 and T8 are turned ON and provide an output to the terminals (302) and (304) respectively.

In the fourth interval (IV) corresponding to 180-240 degrees of the AC waveform, R and B phases are connected to the input power supply, IGBTs T6 and T7 are turned ON and provide an output to the terminals (302) and (304) respectively.

In the fifth interval (V) corresponding to 240-300 degrees of the AC waveform, B and Y phases are connected to the input power supply, IGBTs T4 and T11 are turned ON and provide an output to the terminals (302) and (304) respectively.

In the sixth interval (VI) corresponding to 300-360 degrees of the AC waveform, Y and R phases are connected to the input power supply, IGBTs T2 and T9 are turned ON and provide an output to the terminals (302) and (304) respectively.

The description provided herein above may be interpreted to refer to conversion of a three phase input AC voltage to a single phase output AC voltage.

FIGURE 4 is a control circuit (400) that illustrates generation of trigger signals for bi-directional switches of FIGURE 3. The circuit (400) illustrates an integration of the power circuit of FIGURE 3 with the control circuits (phase R,

phase Y and phase B respectively) for the converter of FIGURE 3. The control circuit associated with each phase comprises two comparators comp1 and comp2. Each of the comparators comp1 and comp2 receive a positive reference signal and a negative reference signal respectively at one input and a carrier voltage signal CV, generally a triangular waveform, at the second input. The positive reference signal is connected to a non-inverting terminal of the comparator comp1 and the negative reference signal is connected to a non-inverting terminal of the comparator comp2. The comparators comp1 and comp2 compare the reference signals with the carrier voltage signal CV and generate unipolar voltage switching signals SPWM at the output. The unipolar voltage switching signals SPWM along with a frequency logic signal (f logic) are provided to two pairs of AND-ing means, typically AND gates. Each AND gate receives an SPWM signal at one input terminal and the frequency logic (f logic), at the other input terminal. One pair of AND gates receives the frequency logic signal (f logic) and the other pair of AND gates receives the inverted frequency logic signal (f logic). The frequency logic signal (f logic), generally, a square wave, determines the output frequency of the bi-directional AC/AC converter. The output of the AND gates of the control circuits associated with each phase of the three phase AC supply are further provided as inputs to OR-ing means, typically OR gates for logically OR-ing the signals corresponding to switches constituting each of the bidirectional switch pairs and generate trigger signals for the sequential turning ON of switches in accordance with the predetermined switching sequence of Table 1 provided herein above. The circuit (400) incorporates OR gates configured to connect:

- output of control circuit associated with phase R to IGBTs T1, T2, T7, and T8 respectively;
- output of control circuit associated with phase Y to IGBTs T3, T4, T9, and T10 respectively; and

- output of control circuit associated with phase B to IGBTs T5, T6, T11, and T12 respectively.

The implementation of bi-directional switches, the connection scheme and the switching sequence enable the converter of the present disclosure to be applicable for bi-directional power flow, thereby making the converter of the present disclosure suitable to regenerate energy back to the utility. Accordingly, when the input AC voltage is a three phase AC voltage, the output AC voltage is a single phase AC voltage and vice versa.

The converter of the present disclosure is particular capable of generating high frequency output AC voltage in the range of 1kHz to 30kHz.

In the scenario wherein a single phase AC input voltage is required to be converted into a three phase AC output voltage, a single phase high frequency AC input power is fed to the power circuit comprising switching devices and a three phase AC output with fundamental line frequency is fed to the AC mains supply. The generated three phase AC output is line synchronized, thereby necessitating the presence (grid connectivity) of mains supply to the bi-directional AC/AC converter of the present disclosure.

FIGURE 5 illustrates a single phase output voltage waveform across a load, the single phase output voltage being obtained from a three phase input voltage supply.

FIGURE 6 and FIGURE 7 illustrate output voltage waveforms corresponding to different input voltages applied to a bi-directional AC/AC converter in accordance with an embodiment of the present disclosure. The waveforms corresponding to each phase is displaced by 120 degrees.

The AC/AC converters of the present disclosure typically find application in traction locomotives, DC motor control in process industries (DC drives), AC motor control (AC drives), battery chargers, rectifiers – high voltage for electrostatic precipitations, rectifiers – high current for electrochemical applications, rectifiers – metal finishing rectifiers, HV DC transmission, renewable energy sources and regeneration of electrical supply.

A comparison of prior art AC/AC Converters with the bi-directional AC/AC converter of present disclosure is provided herein below in Table 2 to particularly elucidate the technical advance of the converter of the present disclosure.

Table 2

Sr. No	Parameter	Prior art AC/AC Converter	Bi-directional AC/AC converter	Remark
1	No of Stages	2 stages	1 Stage	Prior art converter - AC-DC stage 1 - Storage element - DC-AC stage 2 Direct converter- AC-AC
2	Storage Element (capacitor / inductor)	Required	Not Required	Capacitor or/ and inductor for storage are required in indirect conversion, Direct converter storage elements are not required
3	Size	Bulky	Compact (@	Due to storage element size

			40% reduction compared to indirect conversion.	is bulky for indirect converter.
4	Efficiency	89.00%	92.00%	Better efficiency due to losses avoided in storage element
5	Compactness	Less compact	More compact	Due to no energy storage element AC-AC matrix converter is compact.
6	Regeneration Capability	NO	Yes	Being bidirectional conversion, regeneration capability is achieve with Bi-directional AC/AC converter.
7	THD at Input	@30%	< 10%	Being line frequency rectification and capacitive filter at DC link, prior art converter has higher THD.
8	Cost		Target cost reduction @ 10% is estimated	

TEST DATA

A test report of a prototype of a bi-directional AC/AC converter of the present disclosure is provided herein below in Table 3.

Output frequency: 30 KHz

Triangular frequency: 7 KHz.

Load: Resistive (twelve number of 500 ohm/1200W)

Power rating: 3 Kw

Table 3- Readings:

Sr. Input No	Volt.	Line Voltage			Line Current			O/P Voltage (Freq 30KHz)	O/P current	Power Factor
		VR	VY	VB	IR	IY	IB			
1	50	48.8	47.69	47.87	0.57	0.46	0.45	42	0.8	0.9
2	100	96.4	95.3	91.1	0.7	0.6	0.56	91	1.3	0.85
3	150	135.1	144.2	142.5	1.9	1.27	1.53	130	2.8	0.85
4	200	199.2	198.5	199.23	2.93	2.82	2.89	191	3.7	0.85
5	250	249	248.47	249.84	3.21	3.12	3.61	234	4.06	0.85
6	300	299.1	298.56	297.22	4.37	4.03	4.1	279.57	5.1	0.85
7	400	398.56	397.76	397.12	4.67	4.54	4.32	374.51	5.67	0.85

TECHNICAL ADVANCEMENTS AND ECONOMICAL SIGNIFICANCE

The technical advancements offered by the present disclosure include the realization of:

- a bi-directional AC/AC converter with lesser number of bi-directional switches;
- a bi-directional AC/AC converter that provides high output frequency using lesser number of bi-directional switches;
- an optimized bi-directional AC/AC converter with reduced switching losses;
- a simple-optimized bi-directional AC/AC converter;
- an efficient optimized bi-directional AC/AC converter;
- an optimized bi-directional AC/AC converter that eliminates the need for energy storage elements;
- an optimized bi-directional AC/AC converter with increased power factor; and
- an optimized bi-directional AC/AC converter with reduced total harmonic distortion.

Throughout this specification the word “comprise”, or variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated

element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

The use of the expression “at least” or “at least one” suggests the use of one or more elements or ingredients or quantities, as the use may be in the embodiment of the disclosure to achieve one or more of the desired objects or results.

The numerical values mentioned for the various physical parameters, dimensions or quantities are only approximations and it is envisaged that the values higher/lower than the numerical values assigned to the parameters, dimensions or quantities fall within the scope of the disclosure, unless there is a statement in the specification specific to the contrary.

Wherever a range of values is specified, a value up to 10% below and above the lowest and highest numerical value respectively, of the specified range, is included in the scope of the disclosure.

The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred embodiments, those skilled in the art will recognize that the embodiments herein can be practiced with modification within the spirit and scope of the embodiments as described herein.

Claims:

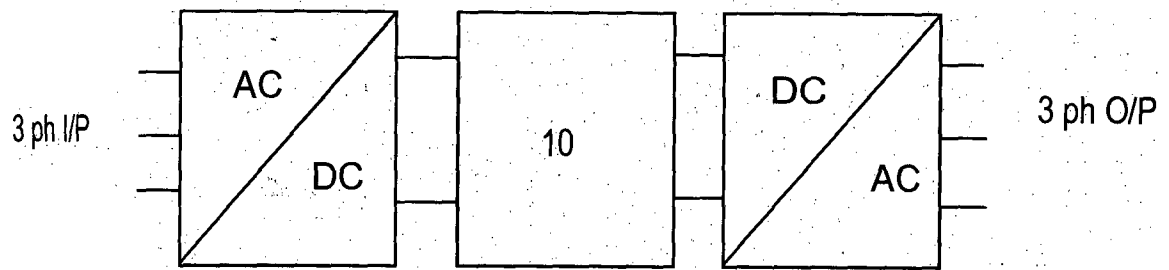
1. A converter adapted to selectively convert an input AC voltage into an output AC voltage, said converter adapted to be connected between the terminals of a three phase AC supply and the terminals of a single phase AC supply, said converter comprising:
 - a first switch set comprising three bidirectional switches connected in a one to one correspondence with the terminals of the three phase AC supply at one end and the other end being connected to a terminal of the single phase AC supply;
 - a second switch set comprising three bidirectional switches connected in a one to one correspondence with the terminals of the three phase AC supply at one end and the other end being connected to another terminal of the single phase AC supply; and
 - a controller connected to each switch of the switch pairs constituting each of said bidirectional switches, said controller adapted to sequentially turn ON one switch of said switch pair of a predetermined bidirectional switch of said first switch set and another switch of said switch pair of a predetermined bidirectional switch of said second switch set, for every phase angle displacement of 60 degrees corresponding to the input AC voltage thereby generating the output AC voltage having a frequency in the range of 50Hz to 30kHz.
2. The converter as claimed in claim 1, wherein said converter is a single stage converter.

3. The converter as claimed in claim 1, wherein the input AC voltage is a three phase AC voltage and the output AC voltage is a single phase AC voltage.
4. The converter as claimed in claim 1, wherein the input AC voltage is a single phase AC voltage and the output AC voltage is a three phase AC voltage.
5. The converter as claimed in claim 1, wherein the frequency of the output AC voltage is in the range of 1kHz to 30kHz.
6. The converter as claimed in claim 1, wherein said switch pair is a pair of antiparallel common emitter configuration of IGBTs with series diode.
7. The converter as claimed in claim 1, wherein said controller comprises:
 - a plurality of comparators, each of said comparators being adapted to compare a carrier waveform with at least one reference signal corresponding to a phase of the three phase AC supply and generate a unipolar switching signal (SPWM);
 - a plurality of AND-ing means, each of said AND-ing means being adapted to logically AND said unipolar switching signal with a frequency signal to generate a signal corresponding to each of the switches constituting said bi-directional switches; and
 - a plurality of OR-ing means, each of said OR-ing means being adapted to receive and logically OR said signals corresponding to switches constituting each of said pairs and further adapted to generate trigger signals for said sequential turning ON of switches.

8. A method of converting an input AC voltage into an output AC voltage, said method comprising the steps of:
- defining a first switch set comprising three bidirectional switches;
 - connecting each of said bidirectional switches of said first switch set in a one to one correspondence to terminals of a three phase AC supply at one end;
 - connecting the other end of each of said bidirectional switches of said first switch set to a terminal of a single phase AC supply at the other end;
 - defining a second switch set comprising three bidirectional switches;
 - connecting each of said bidirectional switches of said second switch set in a one to one correspondence to terminals of the three phase AC supply at one end;
 - connecting the other end of each of said bidirectional switches of said second switch set to another terminal of the single phase AC supply at the other end; and
 - sequentially turning ON one switch of a switch pair constituting a pre-determined bidirectional switch from each of said first switch set and said second switch set, for every phase angle displacement of 60 degree thereby generating the AC output voltage having a frequency in the range of 50Hz to 30 kHz.
9. The method as claimed in claim 8, wherein the step of sequentially turning ON one switch further comprises the following steps:
- comparing a triangular carrier waveform with a sinusoidal positive reference signal and a sinusoidal negative reference signal respectively, said positive reference signal and said negative

reference signal corresponding to a phase of the three phase AC supply;

- generating a unipolar switching signal (SPWM);
- performing at least one of (i) selectively logical AND-ing said unipolar switching signal with a square wave frequency signal and (ii) selectively logical AND-ing said unipolar switching signal with an inverted signal of said square wave frequency signal corresponding to a desired frequency of the AC output voltage, to generate a signal corresponding to each of the switches constituting said bi-directional switches;
- logically OR-ing said signals corresponding to switches constituting each of said pairs; and
- generating trigger signals for said sequential turning ON of switches.



(PRIOR ART)
FIGURE 1

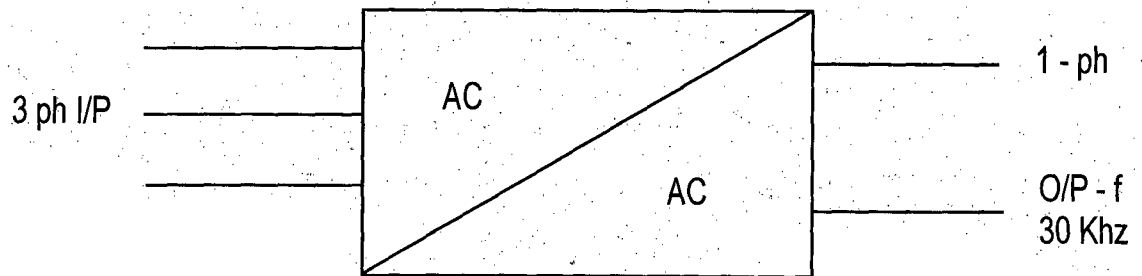


FIGURE 2

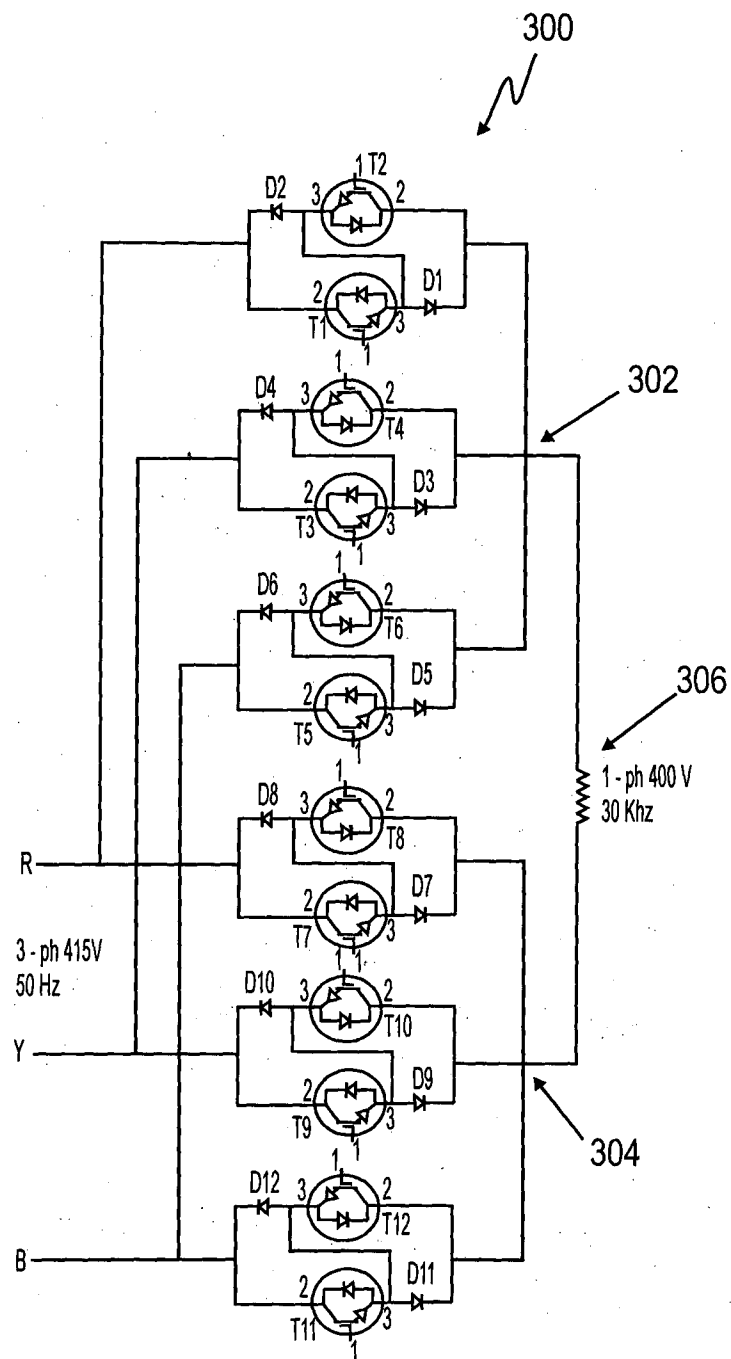


FIGURE 3

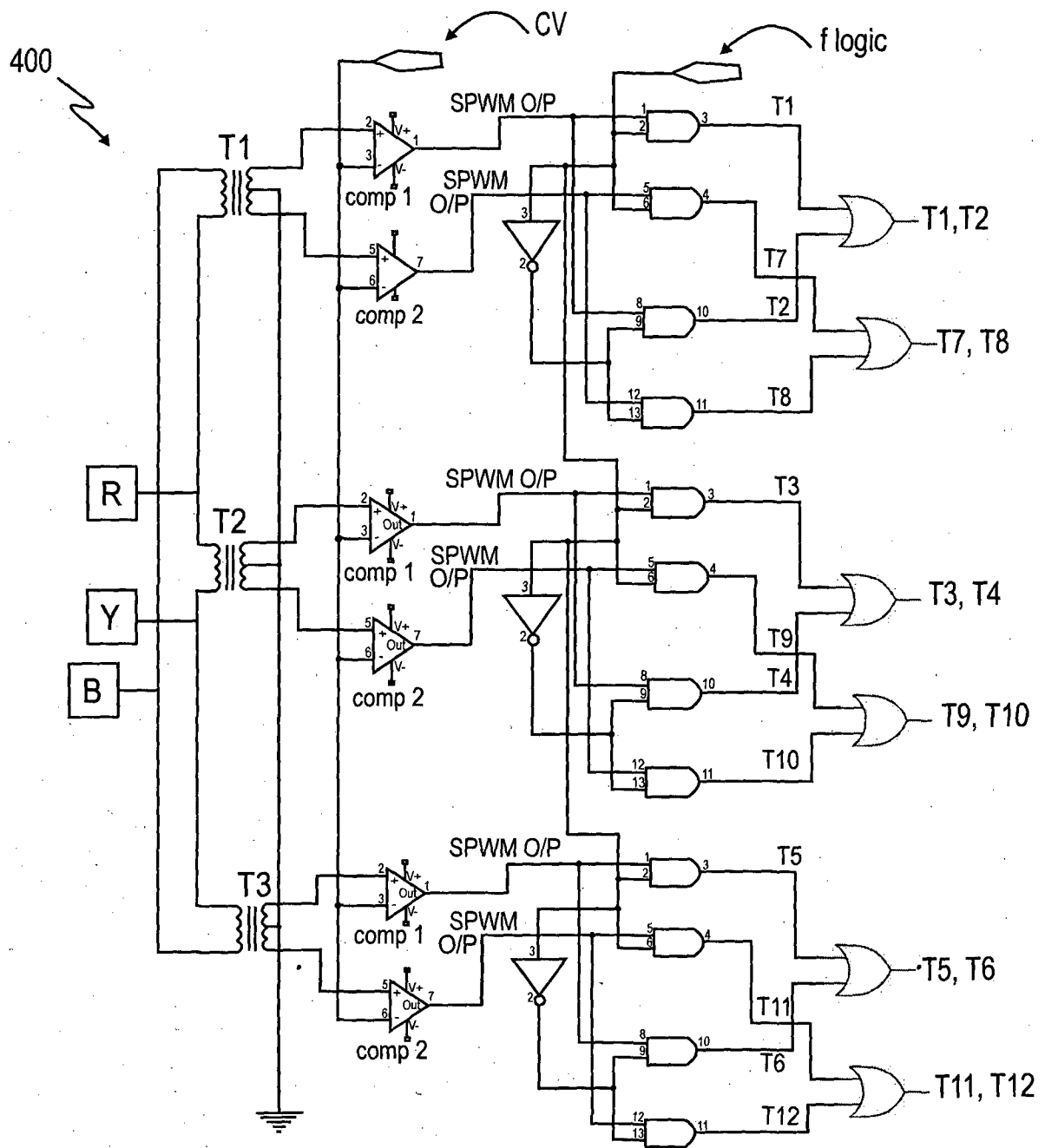


FIGURE 4

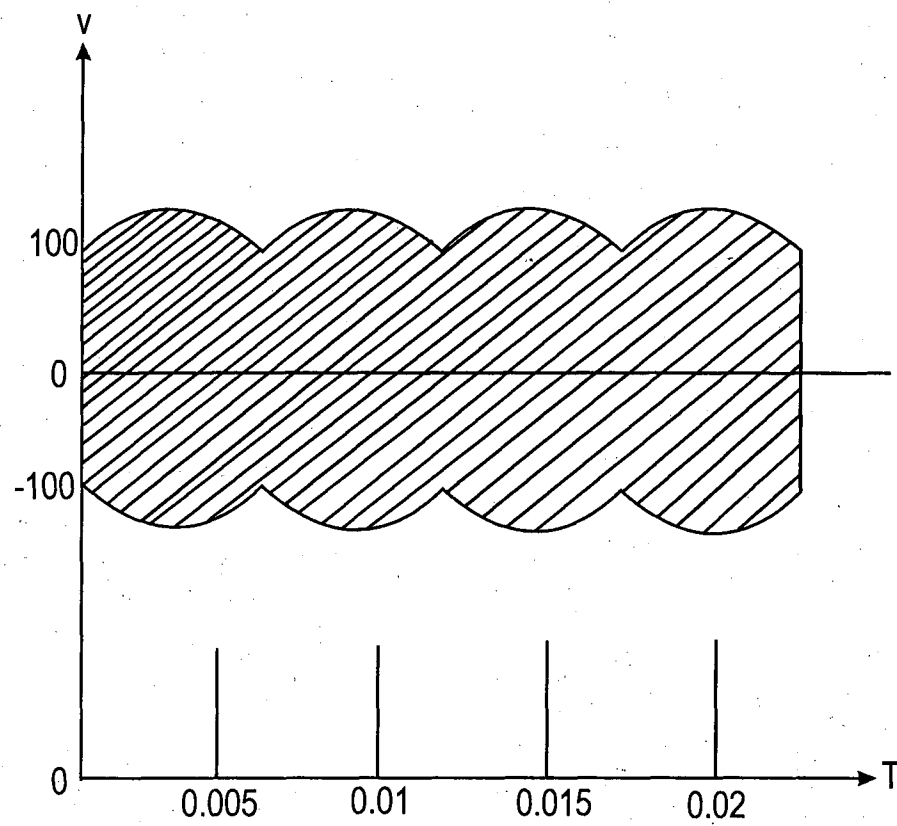


FIGURE 5

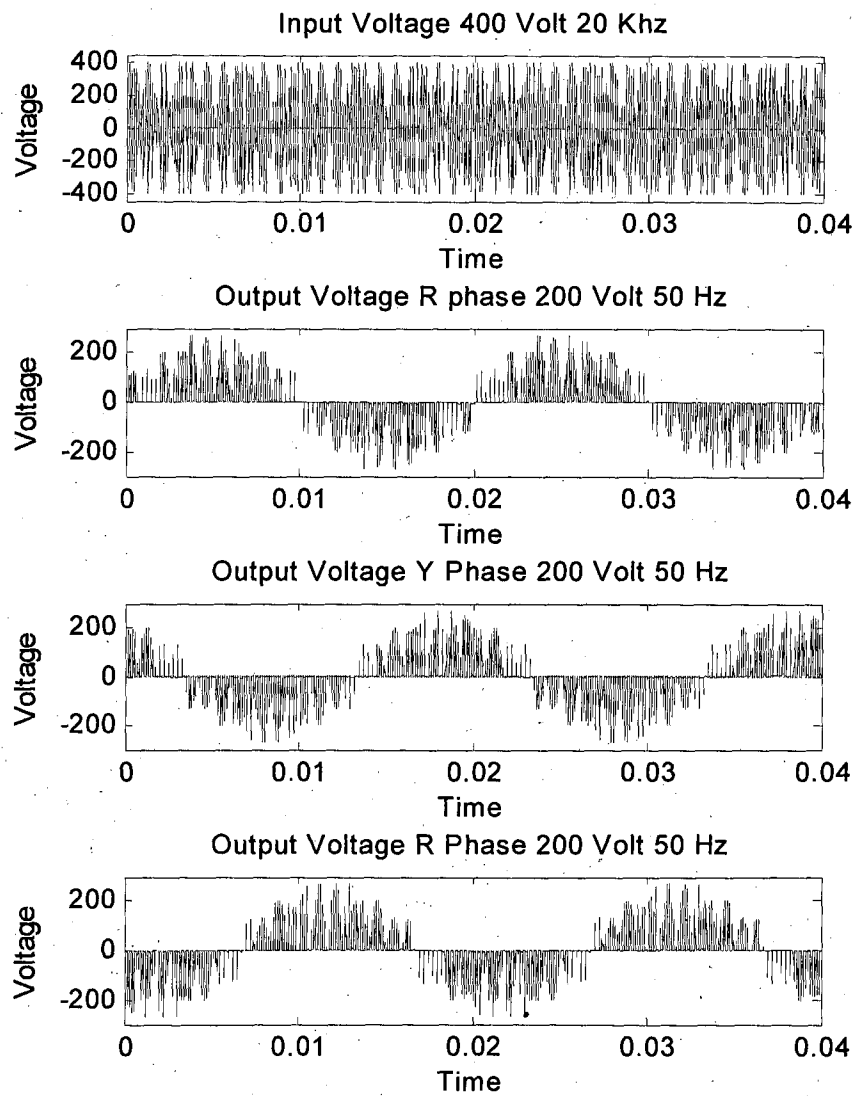


FIGURE 6

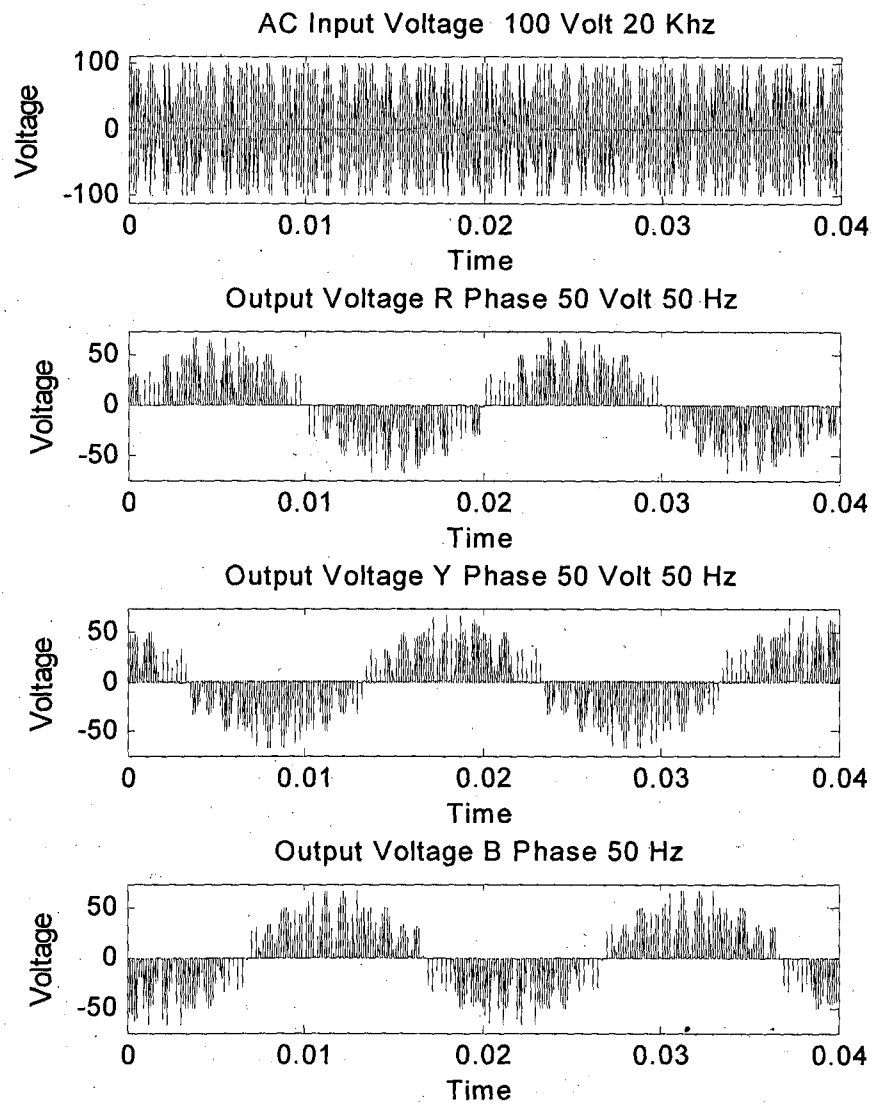


FIGURE 7