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Six Switch Single Phase Matrix Converter

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ABSTRACT

This project proposes a six switch single phase buck-boost matrix converter without snubber circuit. The safe commutation technique eliminates the use of snubber circuit to provide path for inductor current. The buck-boost MC produces output voltage greater or lesser than the input voltage. Micro-controller and driver circuits are used to obtain output frequency with variable voltage suitable to drive variable frequency loads. In the earlier work, the operation is limited to fixed frequency. In the proposed work, the output voltage can be obtained for variable frequency by using PWM switching control strategies. Reduced number of switches helps to minimize the switching losses. The proposed MC features the advantages of sinusoidal output current, controllable input power factor and simple commutation. Simulation results are obtained by using MATLAB software.

Keywords: Matrix converter, Sinusoidal PWM, Microcontroller and Variable frequency.

1. INTRODUCTION

Traditional direct and indirect method of AC-AC conversion needs a large dc-link capacitor and involves multiple leg of conversion process. It can only provide variable output voltage at constant frequency. In Z-Source converter, the input voltage can be bucked and boosted using passive components. But the converter produces output voltage in same polarity to that of input voltage within the duty cycle of 0 to 0.5. As the reversal output voltage is not possible to obtain, it cannot be suitable for four quadrant operation. For duty cycle greater than 0.5, it produces incongruous results due to the shoot-through state [1]. Matrix converter converts AC input supply to the required variable AC supply as output without any transitional conversion process whereas in case of inverter which converts AC-DC-AC which takes more extra components as diode, rectifiers, filters etc. Lack of dc-link ensures its compact design. It utilizes bidirectional controlled switch to conduct in both the directions. It operates at unity power factor and has the restoration proficiency. In this paper sinusoidal pulse width modulation technique has been used to vary the gate signals. PWM technique is widely used to obtain efficient output when compared to other techniques [2]. In addition to bidirectional operation with the same set of switches, an optimized power factor, reduced harmonic content of input currents and voltage stress are also achieved. In this paper, venturini modulation algorithm has been used.

This algorithm is used to obtain unity fundamental displacement factor at the input regardless of the load displacement factor. The output voltage of 115V at 100Hz frequency has been obtained for the input voltage of 300V 50Hz frequency. The efficiency obtained is about 50% and the Total Harmonic distortion (THD) was found to be 50Hz. This technique has reduced harmonic content and less heat dissipation [3]. Matrix converter results in single leg conversion without the need of huge energy storing elements as in conventional system and it provides variable output voltage at step-changed frequency. Space vector modulation technique is another control strategy used. It represents input and output voltage in vector form. SPWM technique produces maximum output, optimized efficiency and high reliability. It produces reduced harmonic content of output voltage for 50Hz 110V input frequency [4]. Carrier frequency determines the number of pulses per half cycle. By varying modulation index, output voltage can be controlled. The proposed single phase matrix converter uses reduced number of switches when compared to Z-source single phase MC which increases power density and reduces the number of switches. The main advantage of matrix converter is, it has the ability to regenerate energy back to the utility [5].

Matrix converter perform both inverting and non-inverting operation for specific intervals. It can be performed by altering the gate pulses given to the MOSFET switches. The proposed work deals with a design, simulation and implementation of single-phase Matrix converter producing variable output voltage at different frequency Sinusoidal PWM (SPWM) based matrix converter used in variable frequency applications.

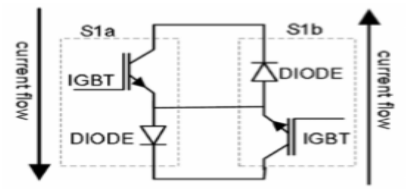

Fig.1. Bidirectional switch

2. SINGLE PHASE MATRIX CONVERTER

This topology consists of a matrix of input and out lines with bidirectional switches connecting supply to the load to achieve automatic conversion of fixed AC to variable AC. The bilateral switches of the matrix converter are fully controlled and are able to operate at high frequencies. Compared to conventional direct and indirect converters, it has the following advantages are no large energy storage components like DC capacitors and inductors which results in compact design and four quadrant operation is straightforward, by controlling switching devices, both output voltage and current are sinusoidal.

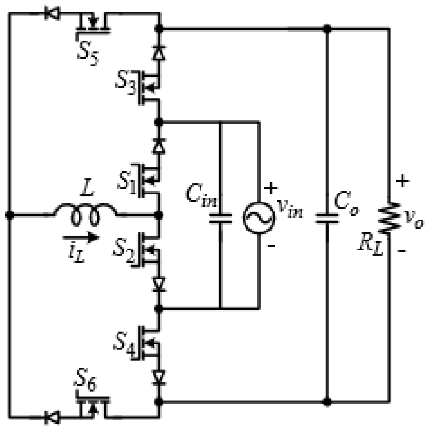

Fig.2. Six Switch Single Phase Matrix Converter

Matrix converter is classified into two types: Direct matrix converter (DMC) and Indirect matrix converter (IMC). DMC involves single stage of conversion process in which the input voltage is directly given to the load through six bidirectional switches. In contrast, IMC involves two stages of conversion such as rectifier and inverter stage. Matrix converter is a forced commutated converter which uses an array of bidirectional switches to produce variable output voltage with unrestricted frequency.

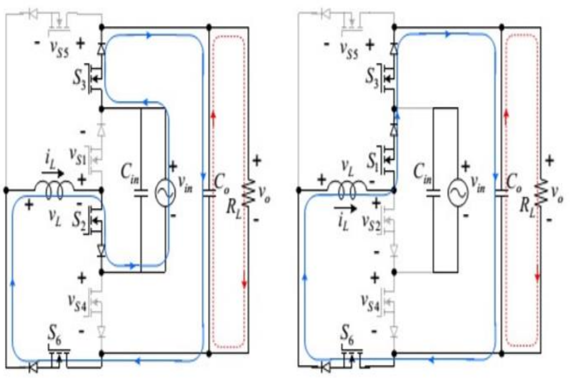

Fig.3. Modes of Operation

3. MODES OF OPERATION

During positive half cycle, for Vin > 0 , switches S2,S3,S6 are always turn on and S1 S4 are always turn off, while switch S5 is switched at high frequency. Fig.8 shows the equivalent circuits of the proposed converter for Vin 0. During DT interval in which switch S5 is turned on and the input energy is stored in inductor L. The switchS6 is also turned on, however, its external series diode becomes reverse biased because of current flows through switch S6during this interval,) Applying KVL, we get $V_L = V_{in}$ .During (1-D)T interval switch S5 is turned off while S6conducts in this interval as its series diode becomes forward biased due to freewheeling action of inductor L current. Energy stored in inductor is released to load in this interval. Applying KVL yields,

$$V_L = V_{in} - V_O \quad \text{………..(1)}$$

By applying voltage balance equation, the gain in this mode is given by,

$$\frac{vo}{vi} = 1/(1-D) \quad \text{………(2)}$$

During negative half cycle, Vin < 0 , switches S1,S4,S6 are always turn on while switches S2 S3 , are always S6 becomes high frequency switch. The operation for Vin < 0 is same as explained for only difference is that now the operation of switch S6 is same as that of S5 (for Vin > 0), and vice versa. It can be concluded that the voltage gain of the proposed ac-ac converter in this operation mode is same as that of non-inverting boost converter.

To obtain an output voltage of desired magnitude and frequency, the matrix converter chops the high frequency input AC voltage. SPWM technique is used to generate switching signals for the switches S2 and S4 while switches S1 and S3 are operated at modulation frequency. The fundamental component of the output frequency is given by,

$$fo = fm - fi$$

Where fm is the modulation frequency and fi is the input frequency

The input voltage is given by,

$$Vi(t) = Vim\ cos\omega t \quad \text{………………(3)}$$

The output voltage is given by,

$$Vo(t) = Vom\ cos\omega t \quad \text{……………….(4)}$$

4. SYSTEM DESCRIPTION

The proposed matrix converter provides variable output voltage at variable frequency. The output obtained from the converter can be used for variable frequency applications. The output frequency of the converter can be varied by altering the ON and OFF time of the bidirectional switches. Microcontroller is used to convert analog signals into digital signals. The driver circuit generates PWM signals by comparing sine wave and the carrier wave. The PWM signals generated are given to the matrix converter. The switching pattern of PWM signals can be varied by changing the modulation index. These PWM signals are provided as gate signals to the switches to turn ON and OFF for definite intervals.

5 BLOCK DIAGRAM DESCRIPTION

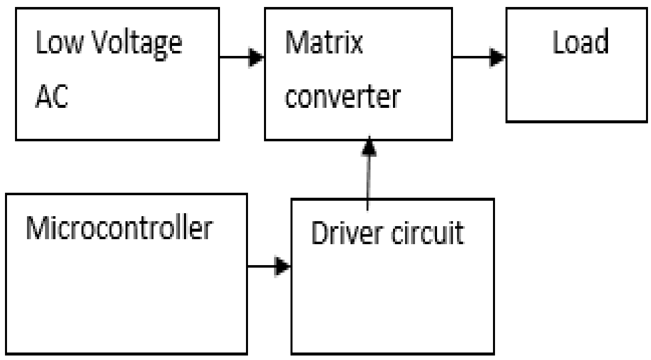

Fig.4. Block diagram of proposed system

5.1. Input supply

Transformers are used for providing input supply to the matrix converter and the driver circuit. From PC, the programs are loaded inside the microcontroller. The microcontroller is used to convert analog signals into digital signals.

5.2. Microcontroller

The microcontroller used here is Arduino UNO ATMEGA328p. It has 28 pins and it is an 8 bit microcontroller with 32KB flash memory, 1KB EEPROM, 2KB internal SRAM. It has 14 digital I/O pins. The output of the microcontroller is given to the driver circuit.

5.3. Driver circuit

Driver circuits are designed to generate PWM signals. Sine block and the carrier blocks are compared using relational operator. The switching time can be varied by using constant block to provide constant delay for the switches. The constant block indicates the modulation index. Thus the magnitude of the voltage can be changed by varying this constant value.

5.4. Matrix converter

The proposed matrix converter consist of six bidirectional switches with the diodes connected in antiparallel. It consist of input LC filter to eliminate the supply side harmonics. The bidirectional switches has the capability of allowing unidirectional current flow and bidirectional voltage blocking competence. It has the restoration proficiency.

6. SIMULATION

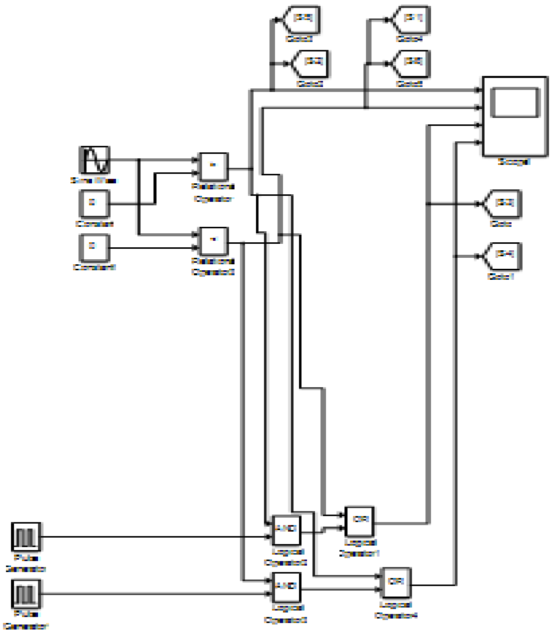

Fig.5. Subsystem Model

Here sine wave and carrier wave are compared using relational operator. Constant block is used to provide constant time delay to the switches. First the sine block and the constant block are connected with the relational operator. The outputs from these blocks and the pulse generator are given to the AND operator. The output from the operators are given to the switches.

Thus each switches has different timing for switching operation. Thus variation in switching time may vary the output frequency. So that the output obtained from the matrix converter provides variable output voltage with variable frequency. Thus the obtained output can be used as the driver circuits for operating the machines.

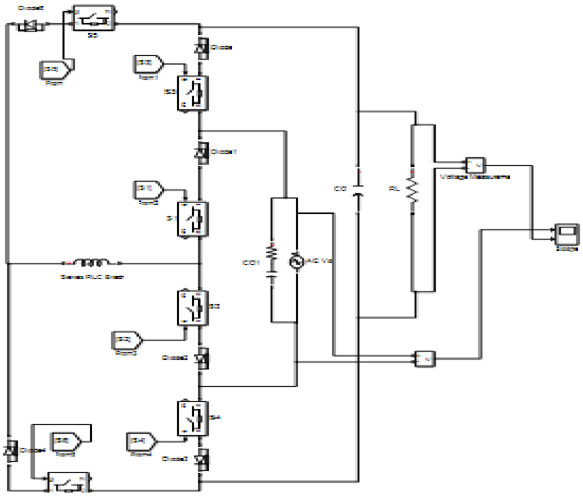

Fig.6. Main Model

7. SIMULATION OUTPUT

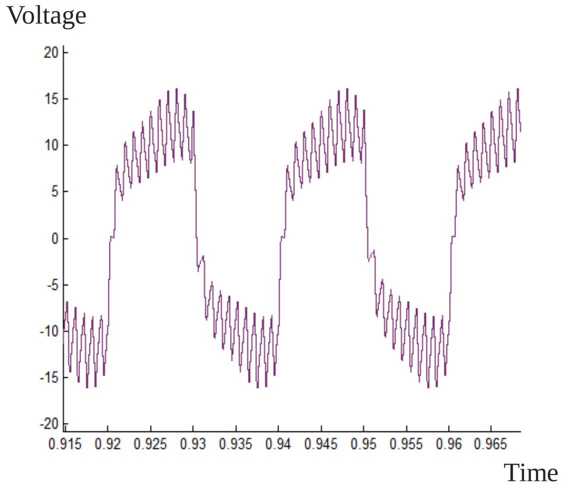

Fig.7. Output for the frequency of 200Hz

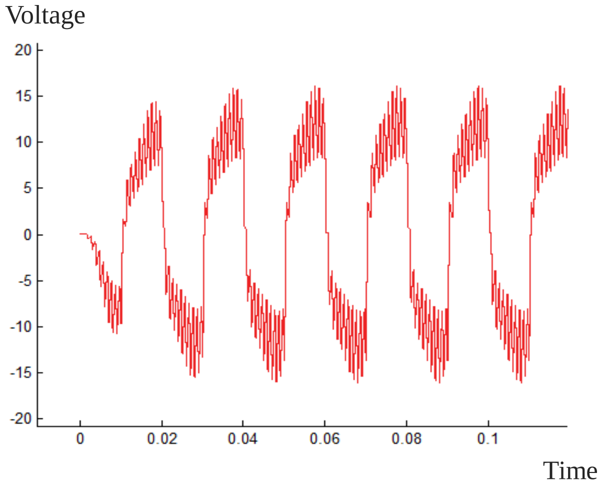

Fig.8. Simulation output for the frequency of 50Hz

8. HARDWARE

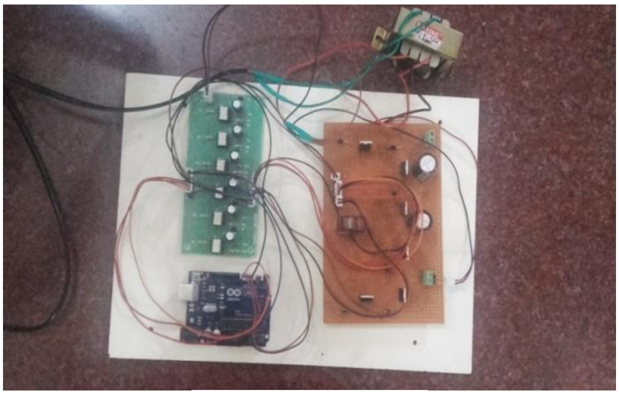

Fig.9. Hardware setup

The hardware setup consists of six switches controlled by microcontroller and a driver circuit. Low voltage AC signal is given as the input to the converter and the gating pulses are generated using PWM technique by the microcontroller. The gating pulses are applied to the converter through the driver circuit. By changing the duty cycle of the PWM generator, the output voltage magnitude and frequency are varied.

9. CONCLUSION

The proposed work illustrates that the supply frequency can be changed in single phase matrix converter having bidirectional switches. It is further revealed that the results obtained from simulation is similar with the experimental results. Reduced number of switches minimizes the switching losses. Theoretical analysis along with simulation results shows the variable output voltage at variable frequency. A laboratory prototype of the proposed matrix converter setup consist of microcontroller and driver circuits to generate control signals. The proposed matrix converter output could be used to control the speed of a fan or a pump.

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