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Implementation of Matrix Converter Using Induction Heater

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Abstract: ***This paper suggests the single-phase matrix converter (SPMC) high-frequency induction heating with improved performance and superior sinusoidal output waveforms are obtained. The converter can buck and boost with step-changed frequency, and both the frequency and the voltage can be stepped up or stepped down. In this paper, we have designed a matrix converter that works on three different frequency levels. Anyone of these frequencies depending upon the load that is used thereby providing us with ease of operation for various loads. With further developments in the single-phase matrix converter, the industries will be capable of using this matrix converter for their high-frequency applications. The simulation results are used to verify the converter can produce an output voltage with three different frequencies 100, 50, and 25 Hz, and that the amplitude of the output voltage can be bucked and boosted. If the output that can be obtained from this matrix converter is improved large power can be saved by the industries. This can reduce the overall consumption of power by the industries and can produce a solution to the huge crisis of power that our nation will be facing in the near future. In future, this technique is used to conserve the electrical power in induction heating for melting the metal in industries and home applications.***

Keywords: ***Single-phase Matrix Converter, Buck-boost Voltage, Step-up and Step-down Frequency, Converter, Induction Heating.***

I. INTRODUCTION

Matrix converter (MC) topology was first introduced by Gyugyi in 1976. The circuit is arranged such that any output lines of the converter can be connected to any input lines [1]. Considerable attention has been given to the study of this topology because MC offers the advantage of a large capacity and compact converter system without the need for an energy storage element due to the absence of DC link [2]. The Matrix Converter is a forced commutated converter which uses an array of controlled bi-directional switches as the main power elements to create a variable output voltage system with unrestricted frequency. It eliminates the need of dc link circuit and does not need any large energy storage elements. The Matrix Converter is an attractive topology of the power converter for power supply applications where factors such as the absence of electrolytic capacitors the potentiality of growing power density, decreasing size and weight and good input power quality are fundamental.

The main feature of this device is to convert the magnitude as well as the frequency of the input into the desired magnitude. Single phase Matrix Converter consists of four bi-directional switches, which are necessary to be commutated in the right way and sequence in order to minimize the losses and produce the desired output with a high-quality input and output waveforms. Recent research on matrix converters has focused mainly on modulation schemes [1]–[6] and on ac drive applications [7], [8]. Clearly, all published studies have allocated with three-phase circuit topologies.

The research in [14] and [15] focused on step-up/step-down frequency operation with a safe-commutation strategy. Applications of single-phase matrix converters have been described for induction motor drives [16], radio-frequency induction heating [17], audio power amplification [18], and compensation voltage sags and swells [19]. It has been reported that the use of safe-commutation switches with pulse width modulation (PWM) control can significantly improve the performance of ac/ac converters [9], [10]. However, in the conventional single-phase matrix converter topology [13]–[17], the ac output voltage cannot exceed the ac input voltage. Likewise, it is not possible to turn both bidirectional switches of a single phase leg on at the same time; then, the current spikes generated by this action will destroy the switches [20].

Among on the most desired structures, the power frequency changes are:

i. Simple and compact power circuit.
ii. Generation of load voltage with arbitrary amplitude and frequency.
iii. Sinusoidal input and output currents.

iv. Operation with unity power factor for any load.
v. Regeneration capability.

These ideal characteristics can be satisfied by Matrix Converters and this is the reason for the incredible interest in the topology. The matrix converter has some advantages over traditional rectifier-inverter type power frequency converters. It delivers sinusoidal input and output waveforms, with minimum higher order harmonics and no sub-harmonics, it has essential bi-directional energy flow capability, and the input power factor can be controlled. Last but not least, it has insignificant energy storage necessities, which allows getting lifetime- limited energy-storing capacitors.

In this project, the modulation strategies are developed for single-phase AC-AC Matrix Converters. The control architecture has to be implemented by using Field Programmable Gate Array (FPGA). The modular power electronics hardware provides a fast method to reconfigure the power converter topology. The purpose of this work is to give a review of key aspects concerning Matrix Converter operation and to establish the state of the art of this skill. It originates by studying the topology of the Matrix Converter, the main control techniques, the real implementation of bi-directional switches and commutation strategies.

II. PROPOSED TOPOLOGY

Fig.1 shows a block diagram of the proposed topology. The AC voltage across the single-phase matrix converter *VA* is boosted by the ac-ac converter with ac input voltage v_i. The output voltage v_o is obtained with a step-changed frequency and a variable amplitude.

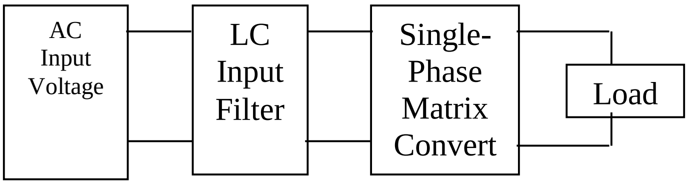

Fig. 1 General block diagram of proposed topology.

Fig. 2 shows the proposed single phase buck–boost matrix converter. It employs an *LC* input filter, bidirectional switches, and an *RL* load. The *LC* input filter is essential to reduce switching ripple included in input current. All the capacitors and inductors are small and are used to filter switching ripples. Since the switching frequency is much higher than the ac source (or line) frequency, the requirements for the inductors and capacitors should be low [17]. As shown in Fig. 2, the proposed single phase buck–boost matrix converter requires four bidirectional switches S_{1j}, S_{2j}, S_{3j}, and S_{4j} (j = a, b) to serve as a single-phase matrix converter and one source bidirectional switch S_{sj} (j = a, b), where a and b refer to drivers 1 and 2, respectively. All bidirectional switches are common emitter back-to-back switch cells. The five switches S_{sj}, S_{1j}, S_{2j}, S_{3j}, S_{4j} (j=a,b) used in the single phase buck–boost matrix converter are bidirectional switches, as shown in Fig. 2. The bidirectional switches are able to block voltage and conduct current in both directions. Because these bidirectional switches are not available at present, they can be exchanged for by combinations of two diodes and two insulated gate bipolar transistors (IGBTs) connected in antiparallel (common emitter back to back), as shown in Fig. 2 [10], [20]. The diodes are included to provide the reverse blocking capability. The IGBTs are used because of their high switching capabilities and their high current carrying capacities, which are desirable for high-power applications. As indicated in the figure, *D* refers to the equivalent duty ratio and *T* is the switching period. Implementing the single-phase buck–boost matrix converter requires different bidirectional switching arrangements depending on the desired amplitude and frequency of the output voltage. The amplitude of the output voltage is organized by the duty ratio *D*, while the frequency of the output voltage hangs on on the switching strategy.

In this paper, the frequency of input voltage f_i is assumed to be 50 Hz, and the desired output frequency f_o is synthesized to be 100 Hz (step-up frequency), 50 Hz (same frequency), or 25 Hz (step-down frequency). For example, Fig. 3 illustrates the converter's switching strategy over one cycle of input voltage for a 100-Hz output frequency in boost mode. To double output frequency of the input voltage, the operation of the converter is divided into four stages, as shown in the figure.

In the absence of a discrete semiconductor device that could fulfill the needs, the use of common anti-parallel IGBT, diode pair as shown in Fig.3 is implemented. Diodes are in place to provide reverse blocking capability to the switch module. IGBTs are preferable because of its high switching capabilities and high current carrying capacities which are desirable among researchers for high-power applications [6].

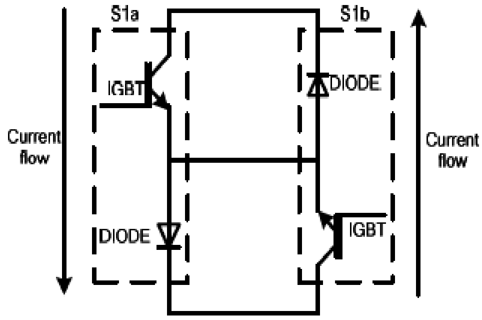

Fig.3 Bidirectional switch realization

III. CIRCUIT EQUATION

The voltage gain K can be defined as

$$K = \frac{V_o}{V_i} = \frac{1-D}{1-2D}$$

Where V_i and V_o are, respectively, the rms value of input voltage and output voltage. The rms value of the fundamental voltage across the load is calculated according to the amplitude of the voltage across the single-phase matrix converter, i.e.,

$$V_o = \frac{V_{am}}{\sqrt{2}}$$

In this paper, the frequency of input voltage is assumed to be 50 HZ and the desired output frequency is synthesized to be 100 HZ (step-up frequency), 50 HZ (same frequency) and 25 HZ (step-down frequency). Fig. 4 illustrates the converter's switching strategy over one cycle of input voltage for a 100 Hz output frequency in boost mode.

Fig.5 plots the voltage gain versus the duty cycle. As shown in Fig.4, the proposed single phase buck–boost matrix converter

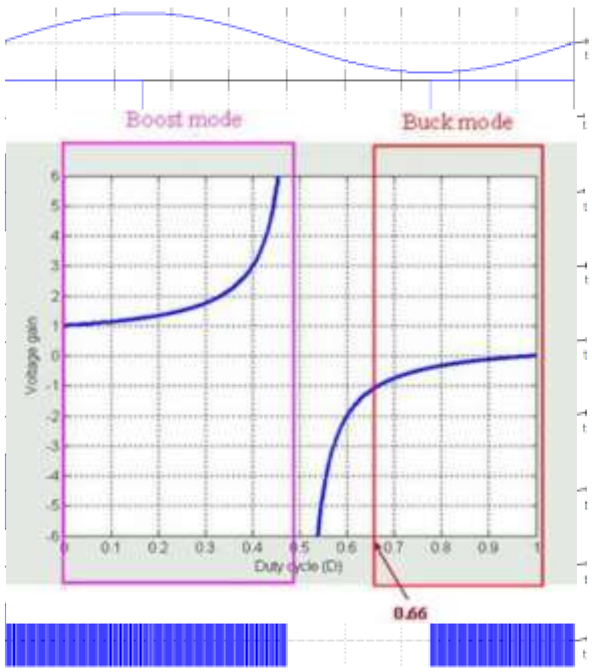

Fig.4 .Switching pattern for the proposed matrix converter

has two operation regions. When $D < 0.5$, the single-phase buck–boost matrix converter operates in boost mode, and when $D > 0.66$, the single-phase buck–boost matrix converter operates in buck mode.

Fig.5 .The relationship between output voltage gain (K) and duty cycle (D).

IV. SIMULATION MODEL

We provide the PSIM simulation results in order to verify the properties described before for the proposed single phase buck–boost matrix converter. We selected the simulation parameters of the LC input filter and load to be $L_i = 0.1$ mH, $C_i = 6.8$ μF. $C_1 =$

$C_2 = 1\ \mu F$, $R = 100\ \Omega$, and $L_f = 3$ mH. The switching frequency was set to 20 kHz, and the dead time for commutation at 0.5 μs. The input voltage was 40 V_{rms}/50 Hz, and the output voltage was 200 V_{rms} with $D = 0.3$ in boost mode.

TABLE-I BLOCK PARAMETERS OF MATRIX CONVERTER

Component	Value
Input source (AC)	40 V
Frequency of carrier signal, fc	20 KHz
Frequency of reference signal, fr	50 Hz
Duty cycle (D)	0.3,0.7
Output resistor, R Output Inductor, L	100 Ω 3 mH
LC filter	L= 0.1 mH C= 6.8 µF

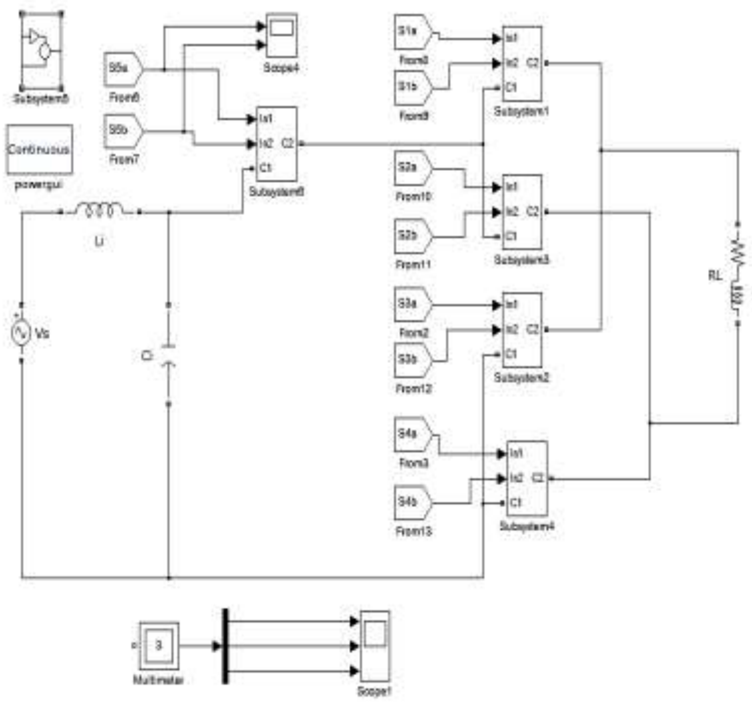

Fig.6 Simulation Model of Matrix Converter

The top-level main model of a single-phase matrix converter fed induction heater and power circuit of SPMC in MLS are shown in Fig.6

In SPWM model as shown in Fig.6, the reference signal is compared with the carrier signal to produce the required respective SPWM output. The comparison is made using "Relational Operator" block in PSB. The carrier signal is generated by using "Repeating Sequence" block that produces triangular wave signal.

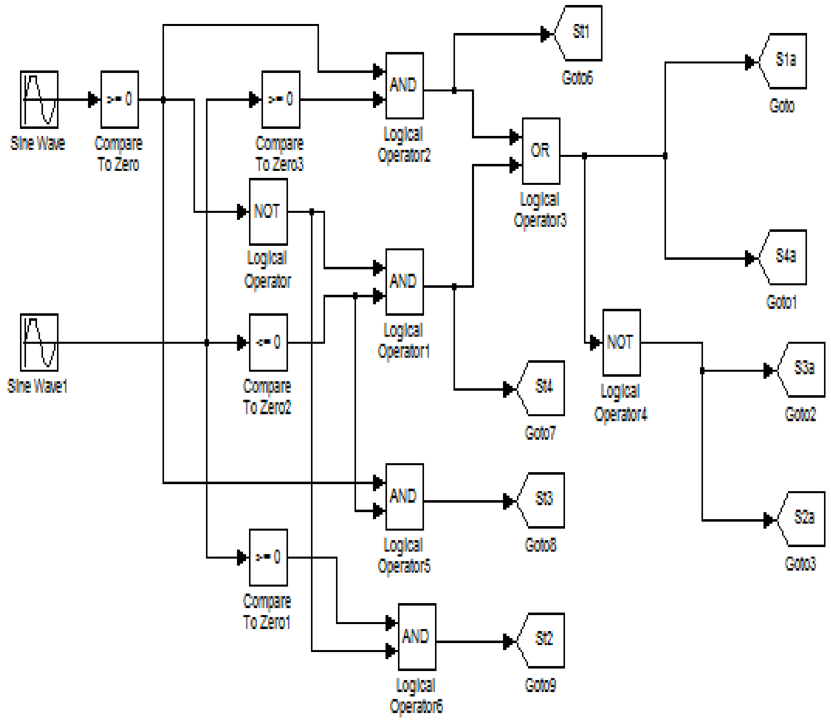

Fig.7 Reference Signal Model of Matrix Converter

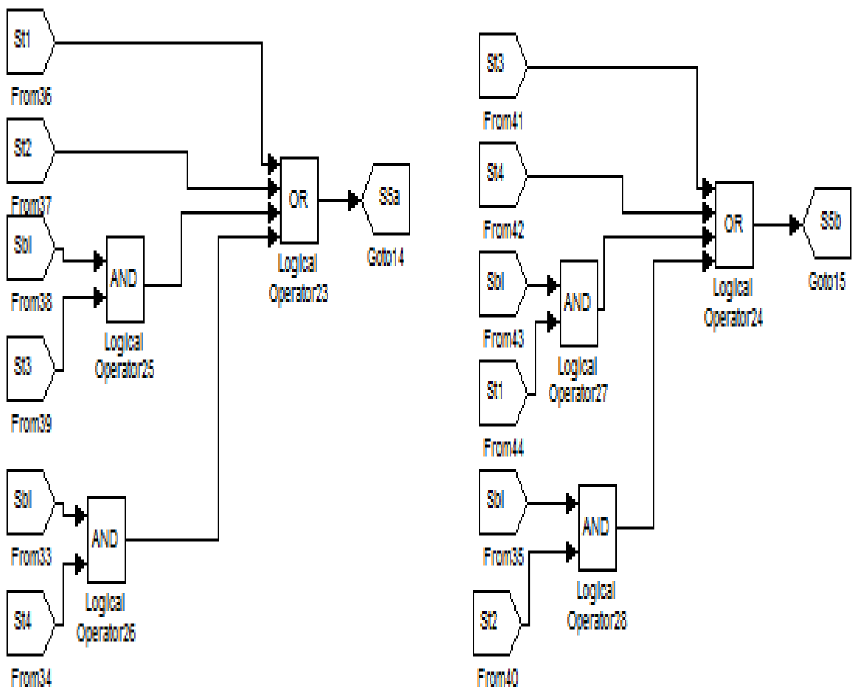

Fig.8 Switching pattern for Matrix Converter

V. RESULT AND DISCUSSION

Fig.9 shows the simulation results for the proposed system with D = 0.3 at output frequencies of 100Hz. The output voltage is boosted to about Vo = 200 V from an input voltage of 40 V.

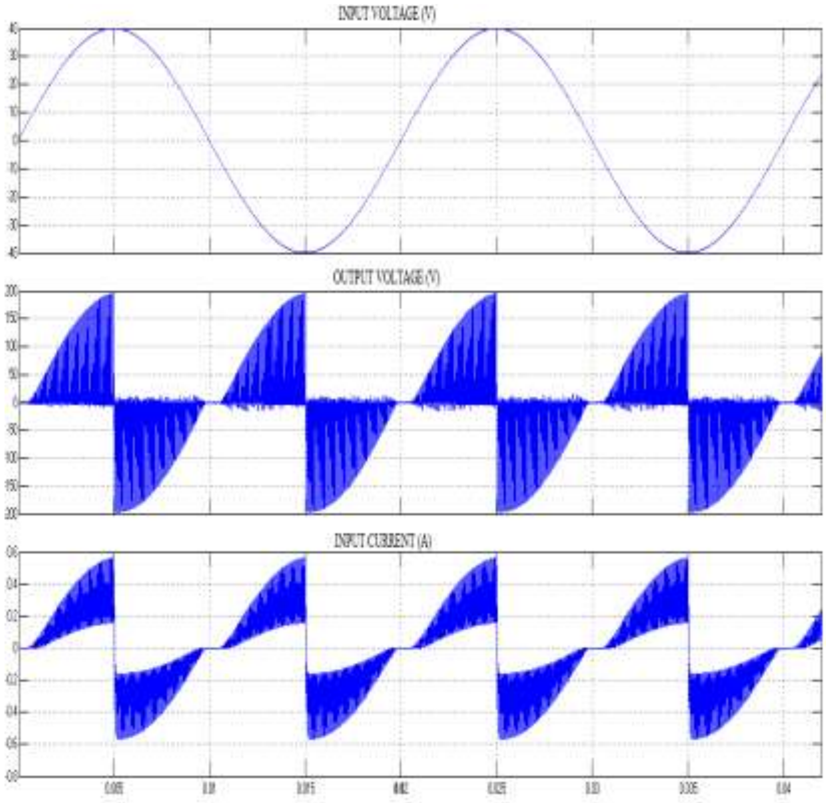

Fig.9 Simulation Result of Proposed System at 100 HZ.

Fig.10 shows the simulation results for the proposed system with D = 0.3 at output frequencies of 25 Hz. The output voltage is boosted to about Vo = 200 V from an input voltage of 40 V.

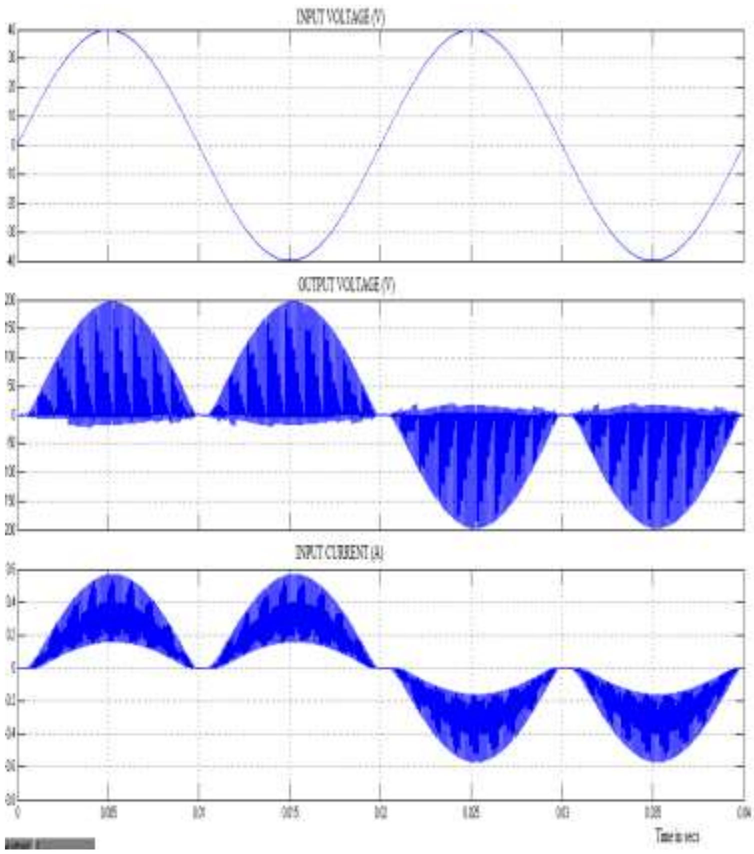

Fig.10 Simulation Result of Proposed System at 25 HZ.

VI. CONCLUSIONS

In this work, we have proposed a new single-phase buck–boost matrix converter fed induction heaters that can buck and boost to the desired output voltage with step changed frequency. The output of this single phase buck–boost matrix converter produces the voltage in buck–boost mode with a step-changed frequency, in which the output frequency is either an integer multiple or an integer fraction of the input frequency. It also provides a continuous current path by using a commutation strategy. The simulation results with a passive *RL* load showed that the output voltage can be produced at two different frequencies, 100 and 25 Hz, and in the buck–boost amplitude mode.

We expect that this proposed strategy can be used in various industrial applications that require step-changed frequencies and variable voltage amplitudes. The proposed converter is particularly suitable for controlling the speed of a fan or a pump without the use of an inverter because, for these applications, the input voltage frequency must be changed to control their speed by stages.

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