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Hardware Implementation of Single Phase AC to DC matrix Converter as a DC Motor Drive

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Abstract: *A novel AC to DC converter using single phase matrix topology is discussed with the hardware implementation of the same. Using this converter a DC motor is driven with closed loop PID control. Simulation results showed improvement in power factor at the supply side than conventional diode rectifiers, thereby making input current continuous, sinusoidal and in phase with the input voltage. Quasi Z source network is provided at the supply side for reducing high inrush current and isolation for the whole circuit during various modes of operation of the converter. MOSFETs are used as the main switching device. Hardware implementation is done using ATMEL microcontroller.*

Keywords: *DC motor, Power Factor, Quasi Z-Source network (qZS), Single Phase Matrix Converter (SPMC).*

1. INTRODUCTION

Power electronics is used for the control and conversion of electric power from AC to AC, AC to DC, DC to AC and DC to DC and is mainly an interface between load and supply. The most typical power electronics device found in many consumer electronic devices like television sets, personal computers, battery chargers etc. is AC to DC converters. Diode bridge rectifiers or controlled rectifiers are commonly used for converting AC supply to unidirectional rectified output. In most cases the input supply current will be discontinuous and non-sinusoidal leading to poor power factor and increased harmonics. Moreover dual converter operation is not possible with conventional diode bridge rectifier.

Matrix converter is mainly used for AC to AC conversion, but it is proved that it can act as universal converter for all types of conversions: AC to AC, AC to DC, DC to AC, DC to DC. Matrix Converter is basically an AC – AC conversion in which both amplitude and frequency of output voltage can be varied. Also in this topology reactive energy storage components used in conventional rectifier-inverter based system is not required [1], [2]. This was first presented by Gyugyi in 1976. The SPMC was first recognized and realized by Zuckerberger. The vast operation of SPMC was further elaborated by Hosseini, Abdullah Khoei, Firdaus et al. [1], [3].

Single Phase Matrix Converter (SPMC) topology is used here for AC to DC conversion incorporating dual converter operation [4], [5], [6] and for the improvement of power factor which are the drawbacks of diode rectifier. MOSFET switches are used as matrix switch. In order to reduce the high inrush current during staring, a quasi Z source (qZS) network [7] is provided at the supply side. This also provides isolation to supply side during the various operations of matrix converter [1]. Hardware implementation of single-phase AC - DC converter is done using SPMC topology which is fed from a quasi Z-source network for DC Motor. The input current is made continuous and in phase with input voltage so that power factor is improved. A closed loop PID control is given to the motor for speed control. Simulation results are presented to verify proposed operation [1]. ATMEL microcontroller is used for hardware implementation of the same.

2. SINGLE PHASE MATRIX CONVERTER (SPMC)

The SPMC topology has four bidirectional matrix switches which conducts current in either direction. Metal Oxide Semiconductor Field Effect Transistor (MOSFET) with antiparallel diode is used as the matrix switch (Figure 1). The DC output of converter is generated by switching matrix switches in a suitable manner [1].

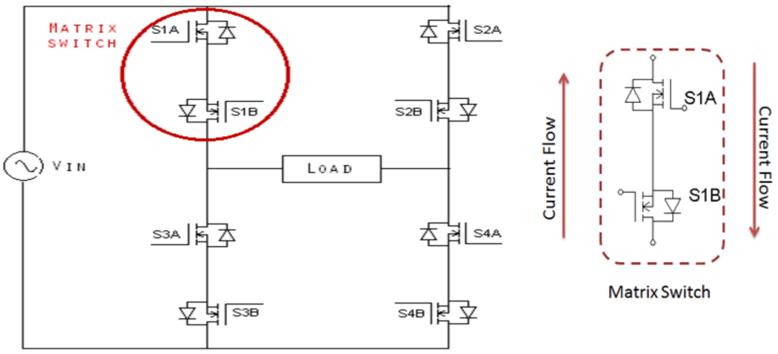

Figure1. *Single Phase Matrix Topology with Matrix Switch*

As shown in Figure 1, load is connected in between the two legs. Each matrix switch has two MOSFET switches `A' and `B'. For AC to DC conversion, during positive half cycle of AC input voltage, switches S1A and S4A are turned ON. And in negative half cycle, switches S2B and S3B are turned ON. Thus a rectified output will be obtained using SPMC. The modes of operation of SPMC is as shown in Table 1.

Table1. *Modes of Operation of SPMC*

Mode	S1A	S1B	S2A	S2B	S3A	S3B	S4A	S4B
I	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF
II	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF
III	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF
IV	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON

3. Block Diagram - DC Motor Drive Using SPMC

DC Motor drive using SPMC fed by a qZS network with closed loop speed control is illustrated using the block diagram in Figure 2.

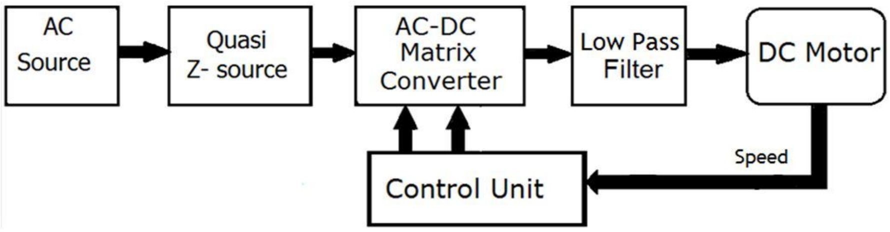

Figure2. *Block Diagram*

Switching pulses for the matrix switches in the converter is provided by the control unit. Both clockwise and counter clockwise rotation of motor is made possible with the same converter by proper switching of the matrix switch. The supply current is made continuous and in phase with the supply voltage thereby improving the power factor at the input side. Speed control of the motor is also made possible [1].

1.1 Quasi Z-Source Network (qZS)

Quasi Z- Source (qZS) network topology is also a combination of two inductors and two capacitors with a switch connected as shown in Figure 3.

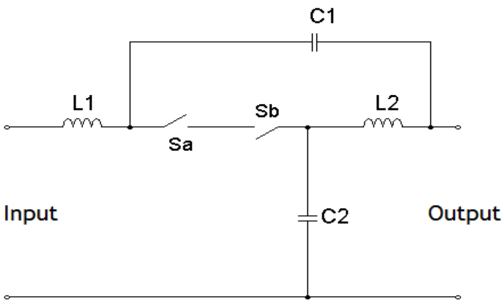

Figure3. *Quasi Z Source Network*

This network provides isolation for the supply side during the shoot through period of the matrix converter. There is a matrix switch in this network for bidirectional power flow or dual converter operation of DC motor. The matrix switch is formed by two MOSFET switches marked as Sa and Sb.

1.2 Control Unit

In the control unit, speed is controlled through a PID controller as demonstrated in Figure 4.This pulses is given to switches in the matrix converter and the qZS network.

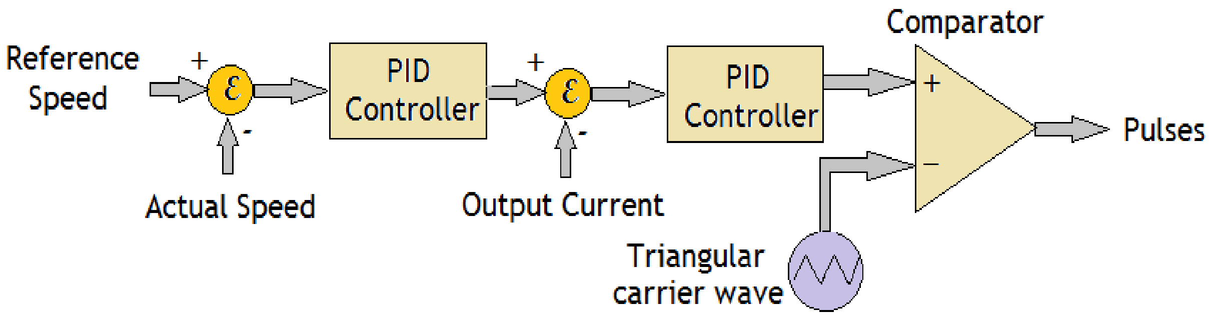

Figure4. *Block Diagram of Control Unit*

4. HARDWARE IMPLEMENTATION OF THE SYSTEM

Simulation of the system was done in Power Sim (PSIM) software. The output speed and voltage in both clockwise and counter clockwise operation is obtained as shown in Figure 5 and 6. The input current is made more sinusoidal and in phase with voltage thereby improving the power factor to 0.91 as in Figure 7 which is far better than that with diode bridge rectifier.

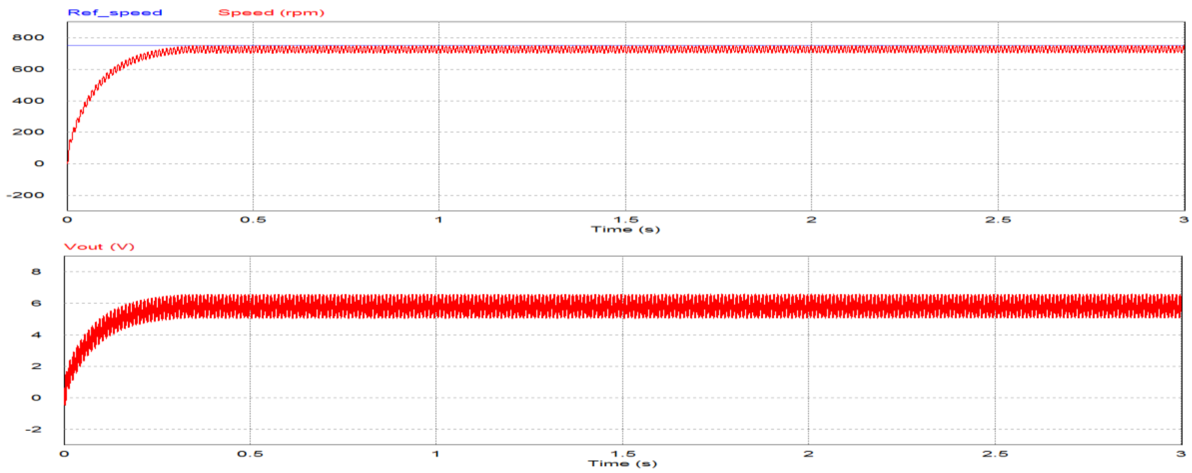

Figure 5. *Speed and Output Voltage – Clockwise Operation*

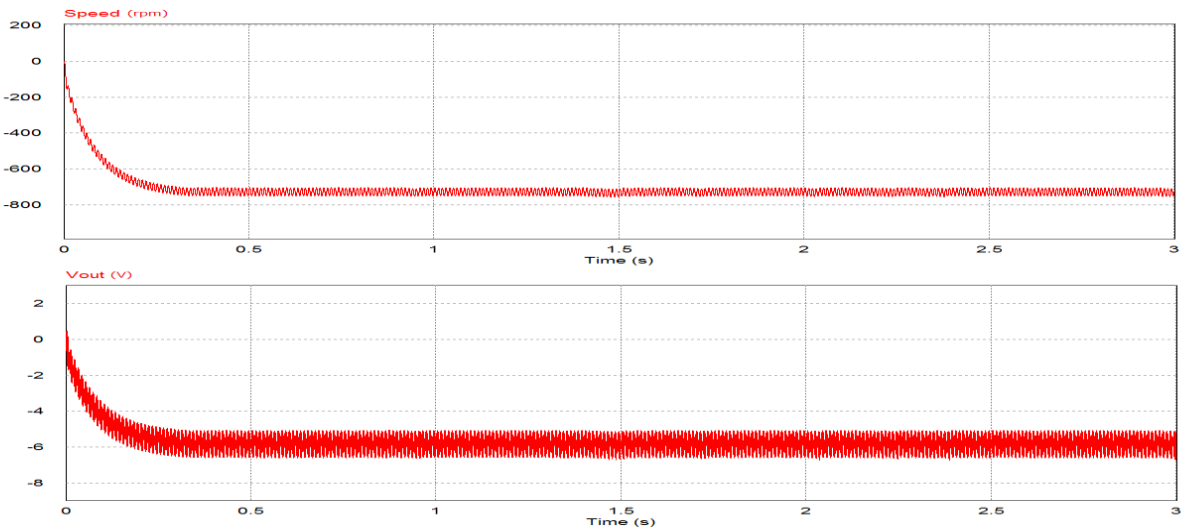

Figure 5. *Speed and Output Voltage – Counter Clockwise Operation*

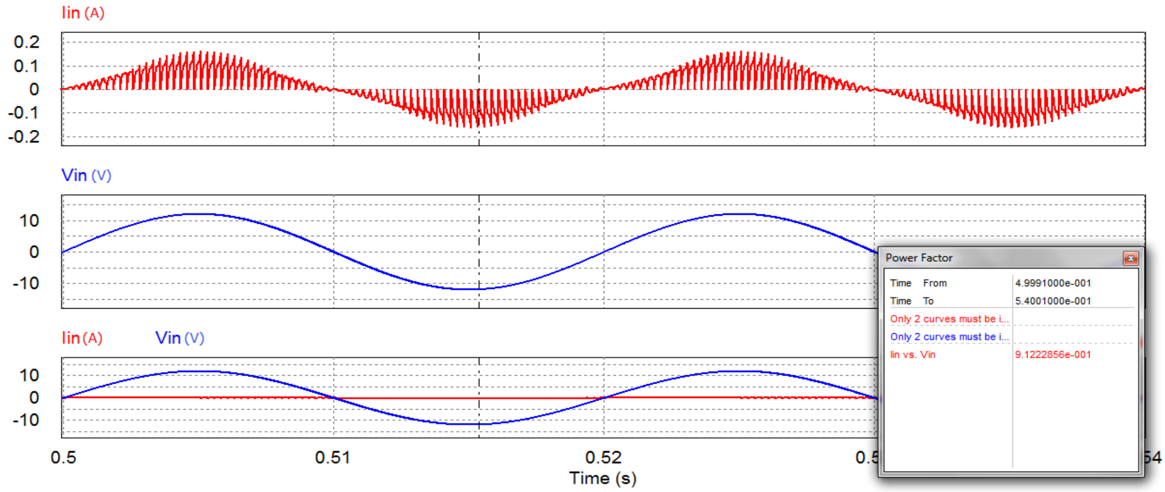

Figure 7. *Input Current and Power Factor*

Hardware of the whole system was implemented in PCB using AT89S8253 microcontroller. The entire hardware setup of the system is shown in Figure 8.

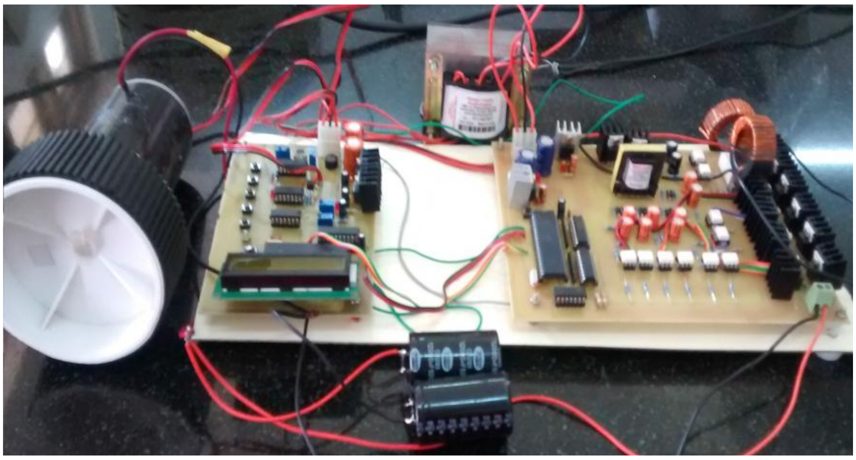

Figure 8. *Hardware Setup*

Closed loop speed control of the DC motor is obtained which is shown in Figure 9. Set speed is given as 15 rps and the actual speed follows the set speed and is controlled to be 15 rps itself. Speed control up to 24rps is made possible in both CW and CCW rotation of DC motor using this single phase matrix converter.

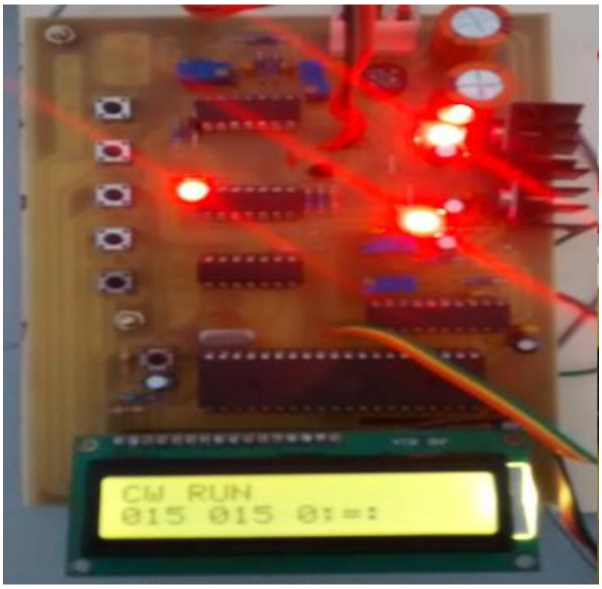

Figure9. *Speed Control– LCD Display*

The motor is operated in dual converter mode using SPMC. The output DC voltage in CW mode and CW mode is obtained and is as shown in Figure 10 and 11.

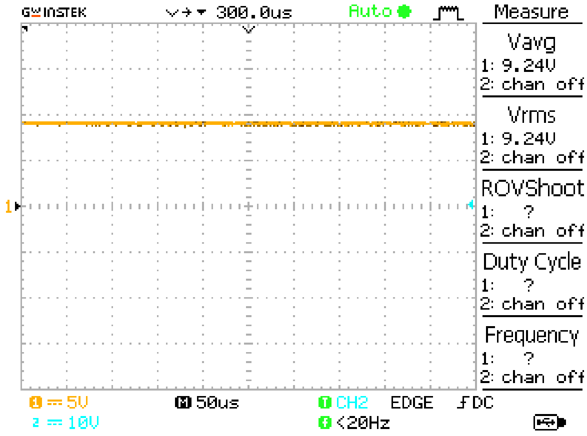

Figure10. *Output Voltage-Clockwise Operation*

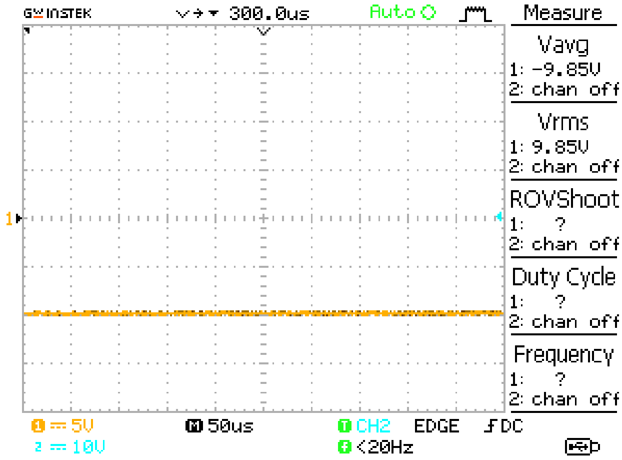

Figure11. *Output Voltage- Counter Clockwise Operation*

From the above hardware results it is clear that the matrix converter can be used as a novel DC motor drive with dual converter operation. It also provides closed loop speed control in both CW and CCW modes.

5. CONCLUSION

A study on single phase matrix converter topology is done and its operation as AC to DC converter is found to be used as a drive for DC motor. The simulation results showed that input supply current is sinusoidal, continuous and in phase with the supply voltage. Dual converter operation is done and output voltage in both CW and CCW operation is obtained. Power factor is obtained as 0.91. When comparing with conventional diode bridge rectifier, the matrix converter is found to be more advantageous. The hardware implementation of the same system is done in PCB using AT89S8253 micro controller. Hardware implementation showed that dual converter operation is possible and closed loop speed control can be achieved using single phase matrix converter.

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