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# Investigation of Matrix Converter for Wind Energy Conversion

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***Abstract:*** *The proposed series Z-source matrix converter topology investigates the output voltage, the inrush current and the voltage across the capacitor between the stages. In this paper, that idea is implemented on a three-phase to three phase indirect matrix converter. This z-source matrix converter is connected across the inverter and rectifier circuit for amplifying the voltage gain. The proposed converter is designed on the principle of ultra sparse technology in order to rebate the number of semiconductor switches. The boosting capability of this converter can be enhanced by an optimal PWM technique and by reducing the switching losses. The comparative analysis is performed between series and cascaded Z-source matrix converter topologies can be applied for wind energy conversion system. This comparison manifest that, the series Z-source matrix converter has minimum inrush current and very less capacitor voltage than the previous cascaded z-source matrix converter. Furthermore, the FFT analysis on the output current of converters corroborates the good features of the series Z-source matrix converter over other one.*

***Key Words:*** *series Z-source matrix converter cascaded Z-source matrix converter, PWM technique, FFT analysis.*

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## I. Introduction

The energy efficient power converters are recommended for industrial applications to expound many power quality issues with reduced number of switches. The matrix converter is an AC-AC converter having the most suitable characteristics than that of other power converters like,

1. Generation of output voltage with the required amplitude and frequency.
2. Pure Sinusoidal input and output.
3. Excellent improved power factor.
4. Regeneration capability.

These characteristics of matrix converter can be applied for induction motor drives and replace the needs of conventional voltage source inverter and current source inverter. There is no need of any dc link and any energy storage elements. This is the main advantage of matrix converter, which upgrades the performance of the converter topology. The main types of matrix converters are,

1. Direct matrix converter
2. Indirect matrix converter

In direct matrix converter 9 bi-directional controlled switches are in a 3*3 matrix form to produce variable voltage with variable frequency. In indirect matrix converter [1], a rectifier and an inverter circuit are used for AC-AC conversion. Z-source network concept has been proposed as the dc link for boost voltage source inverter. The Z-source placed in cascaded arrangements has two drawbacks.

First the voltage across Z-source is larger than the input voltage, second the inrush current and resonance in the Z-source network are not suppressed. The novel converter constitutes an improvement over the cascaded Z-source matrix converter by reducing the voltage across the capacitor and limiting the inrush current at startup. Here, experimental results of investigation of those converters are presented to verify the effectiveness of the proposed topologies and control strategies in providing high boosting capability.

## II. Proposed Topology And Operation

In the proposed system to reduce the number of switches an ultra sparse matrix topology is used. In indirect matrix converter, the AC-AC conversion is split into AC-DC and DC-AC stages. The fig 1 shows the series Z–source matrix converter and fig 2 shows the cascaded Z-source matrix converter [3]. In this SZMC, all the inductors have same inductance and all the capacitors have same capacitance. In the rectifier side three switches are used and in the inverter side six numbers of switches are used. The inverter side works on $180^o$ mode operation because it has higher output than the $120^o$ mode operation. In rectifier side two diodes are back to back connected so it acts as a switch and we are providing common gate triggering for the switches in same leg. The 3-D inductive–capacitive topology of that source boosts the voltage by varying the change rate of current in the inductors. The series Z-source network reduces the voltage of the capacitors and limits the inrush current while keeping the same boosting ratio as that of the traditional one.

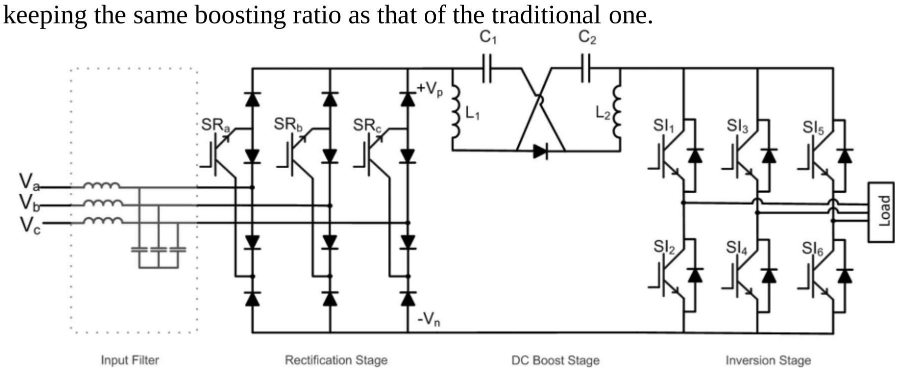


**Fig1. Series Z-source matrix converter**

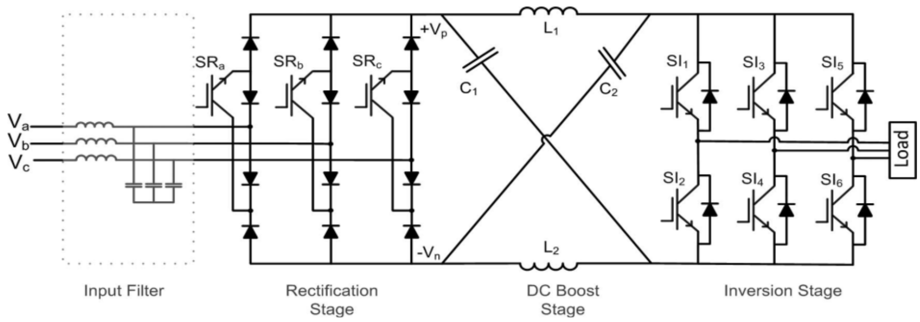


**Fig 2. Cascaded Z-source matrix converter**

As all the inductances have same inductance and all the capacitors have same capacitance, the symmetry of the series Z-source network yields

$\mathbf{V_C = V_{C1} = V_{C2}; V_L = V_{L1} = V_{L2}}$ ---------------------------- **(1)**

In shoot-through states, as the inverter side is shorted; inductor voltages are,

$$\mathbf{V_L = V_C + V_{vir}} \quad \text{------------------------------------------------} \ \mathbf{(2)}$$

$V_{vir}$ is the virtual dc link voltage produced by rectification stage. In the non-shoot-through states of conductor, inductor voltage is

$$\mathbf{V_L = -V_C} \quad \text{------------------------------------------------} \ \mathbf{(3)}$$

An equivalent circuit of the series Z-source is shown in Fig. 3(a) during the non-shoot-through states and in Fig. 3(b) during the shoot-through states.

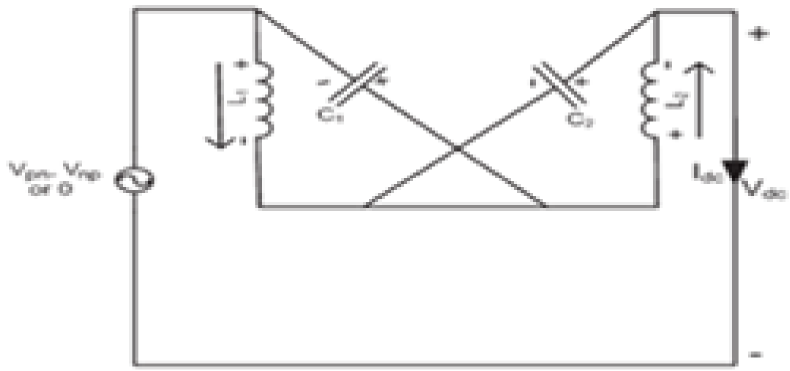

**Fig 3a. Equivalent circuit of the Z-source with Non shoot-through state**

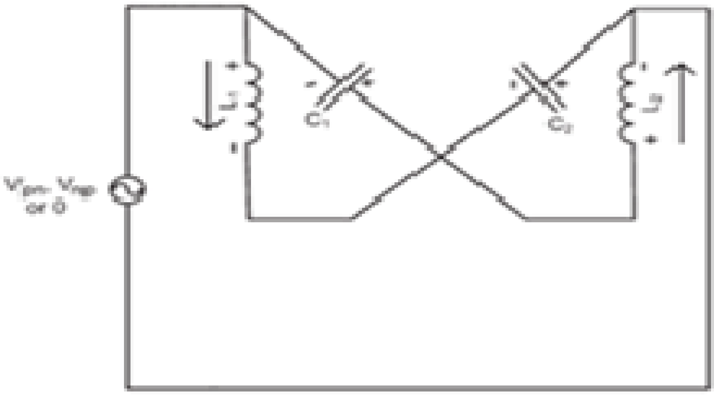

**Fig 3b. Equivalent circuit of the Z-source with shoot-through state**

Applying the KVL balance equation in the above circuit,

$$V_{dc} = 1/(1 - (2 * D_{sh-th} * V_{vir})) \quad \text{------------------------------(4)}$$

From the equation (4) it is clear that, when the shoot-through duty ratio is zero, the Z-source capacitor voltage is zero. So if we control $D_{sh-th}$ to increase gradually from zero, $V_C$ can increases from zero gradually and soft start can be achieved. In the non-shoot-through state, Kirchhoff's voltage law in closed loop can be written as

$$V_{dc} = V_{vir} + V_C - V_L \quad \text{------------------------------------------ (5)}$$

$V_{dc}$ is the voltage at the output of the Z-source network.
The same analysis as that of the SZMC is done in CZMC from that we have found out that,

$$V_{dc} = (1 - D_{sh-th}) / (1 - (2 * D_{sh-th} * V_{vir})) \text{--------------------------(6)}$$

## III. Simulation Results

The simulation of Series and Cascaded matrix converter topology is performed by MATLAB simulation tool with the input of 150V, 50Hz three phase source and supplied by three phase RL load. The boosted output voltage is 490V for series matrix converter and 450V for cascaded matrix converter. From the below simulation result, the current stress in series Z source matrix converter is considerably reduced than that of cascaded Z source matrix converter. The dc link capacitor voltage of cascaded Z source matrix converter is 45V and for series Z source matrix converter is 30V. Thus the voltage stress also improved by series Z source matrix converter.

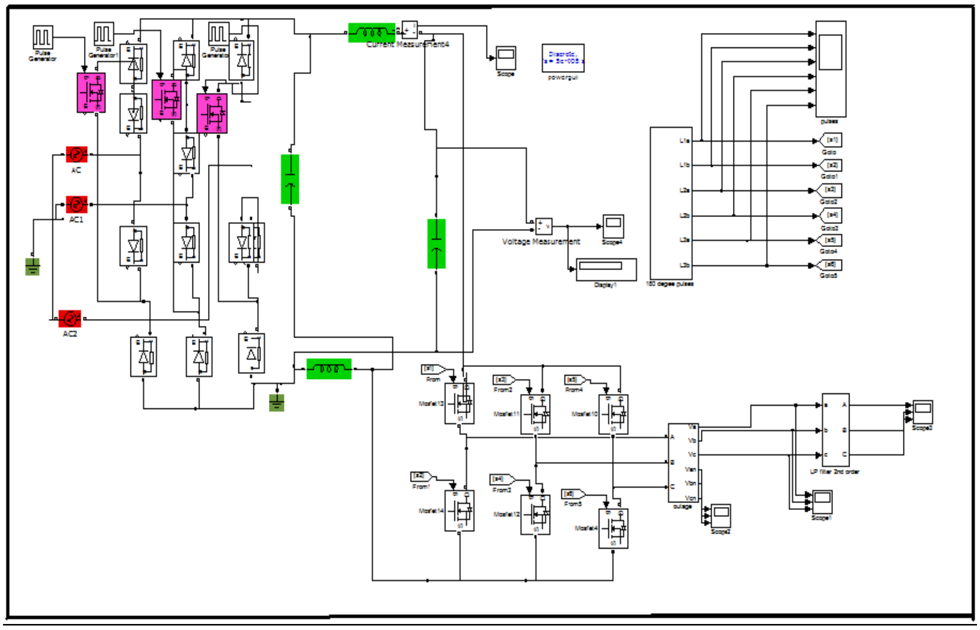

**Fig 4 Simulation model of Cascaded Z-source matrix converter**

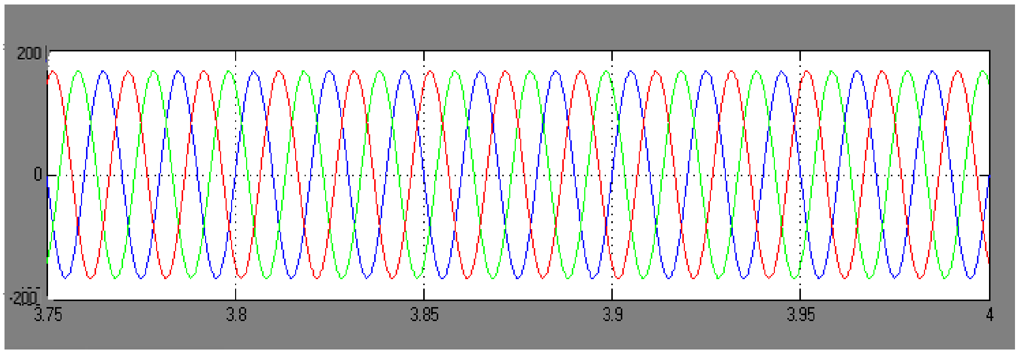


**Fig 4a. Input Voltage wave form**

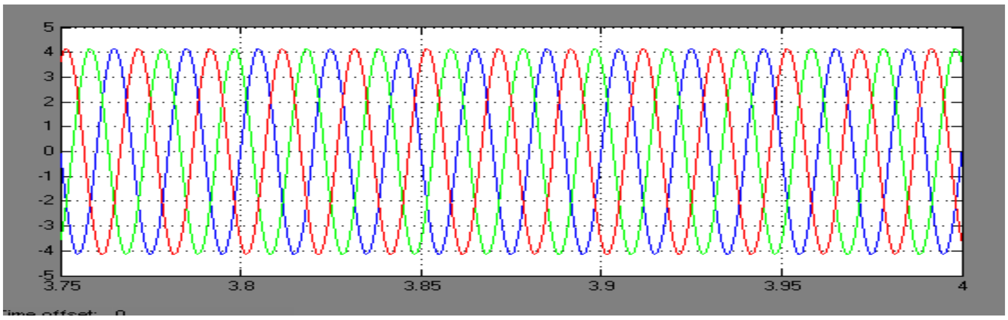


**Fig 4b. Input Current wave form**

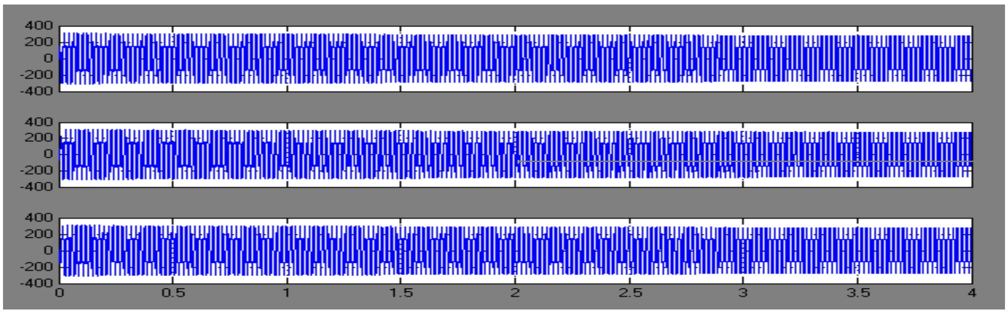


**Fig 4c. Output Voltage wave form without filter**

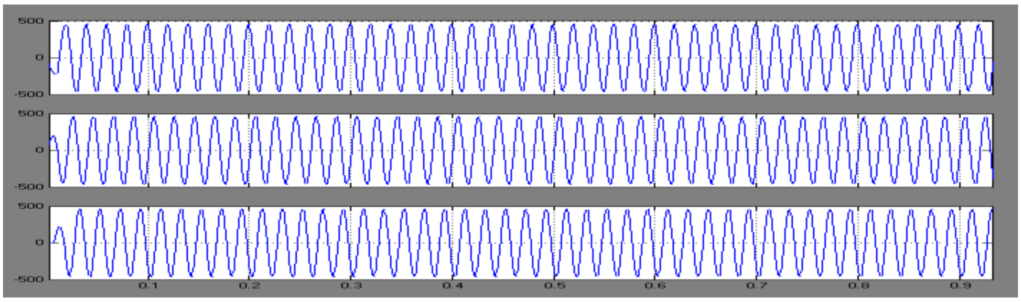


**Fig 4d. Output Voltage wave form with filter**

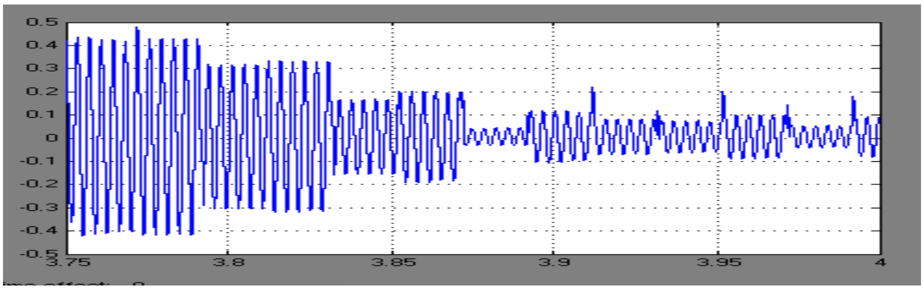


**Fig 4e. Inrush current wave form**

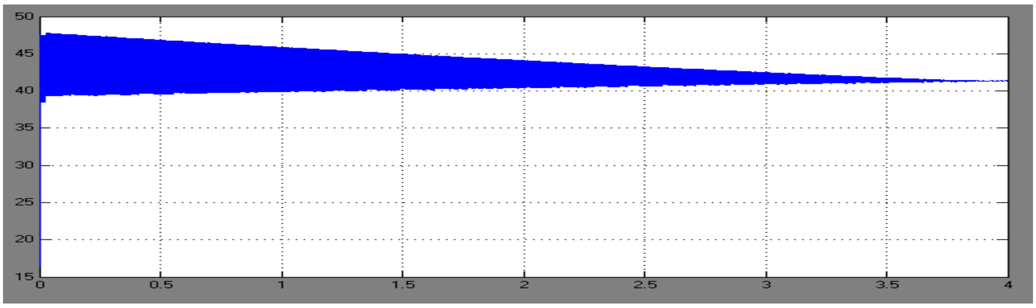

Fig 4f. Capacitor voltage wave form

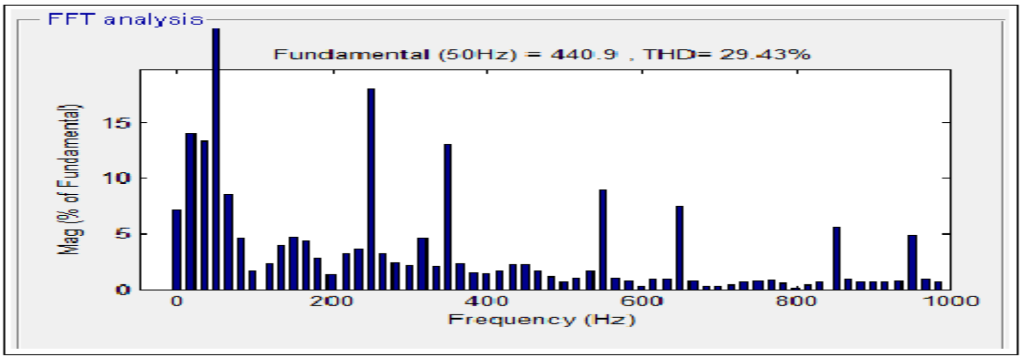


Fig 4g. THD analysis without filter

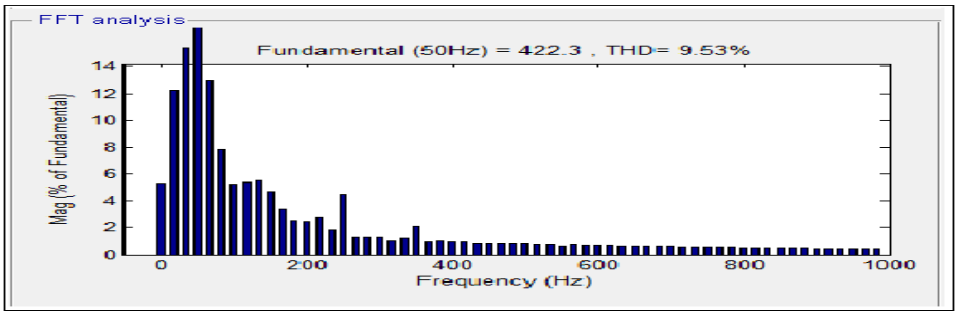


Fig 4h. THD analysis with filter

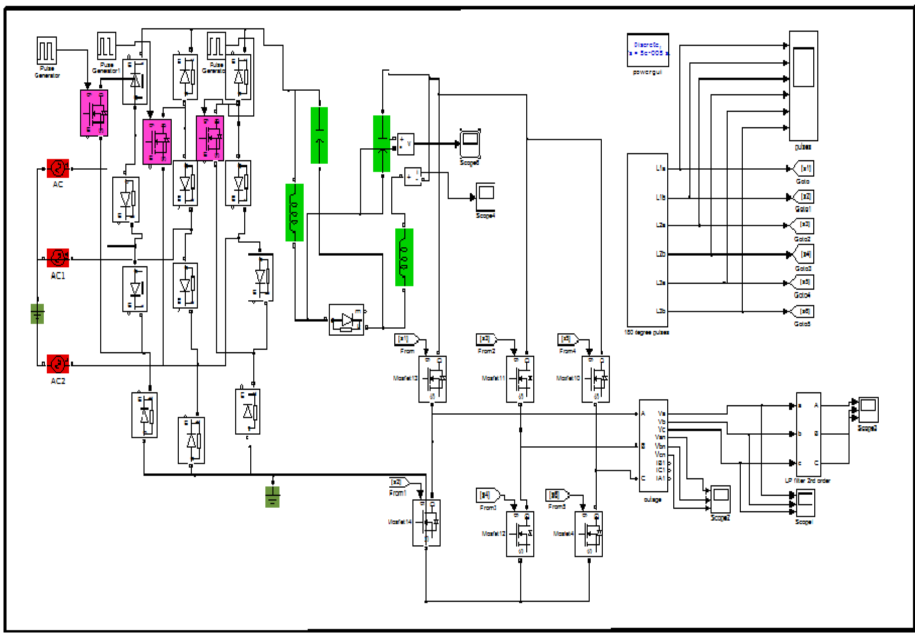

Fig 5. Simulation model of Series Z-source matrix converter

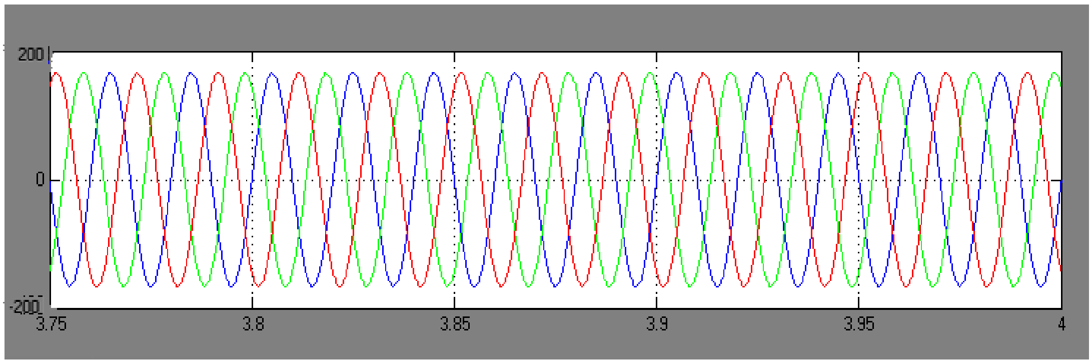


**Fig 5a. Input Voltage wave form**

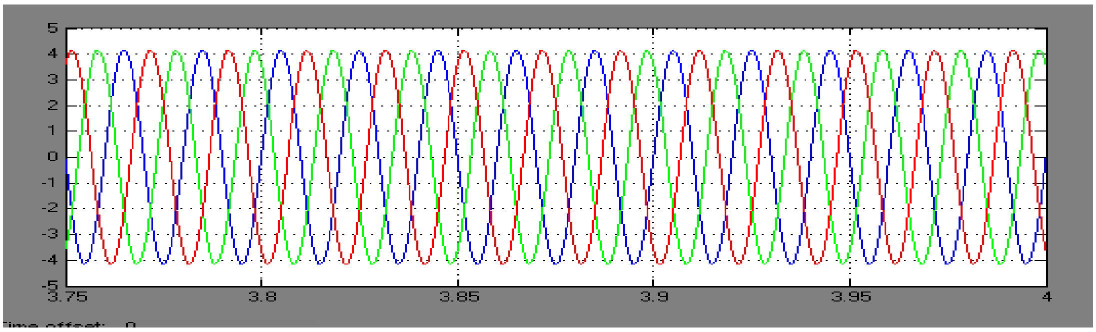


**Fig 5b. Input Current wave form**

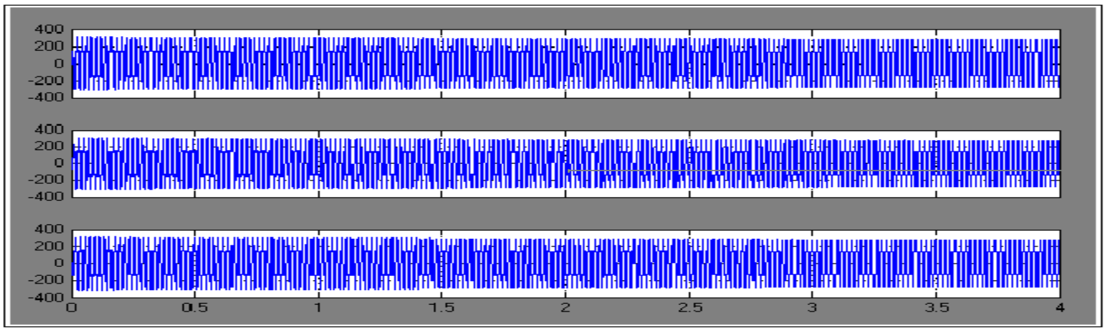


**Fig 5c. Output Voltage wave form without filter**

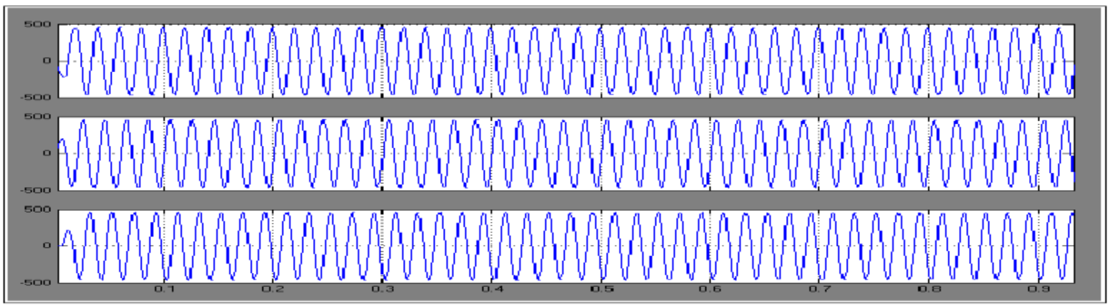


**Fig 5d. Output Voltage wave form with filter**

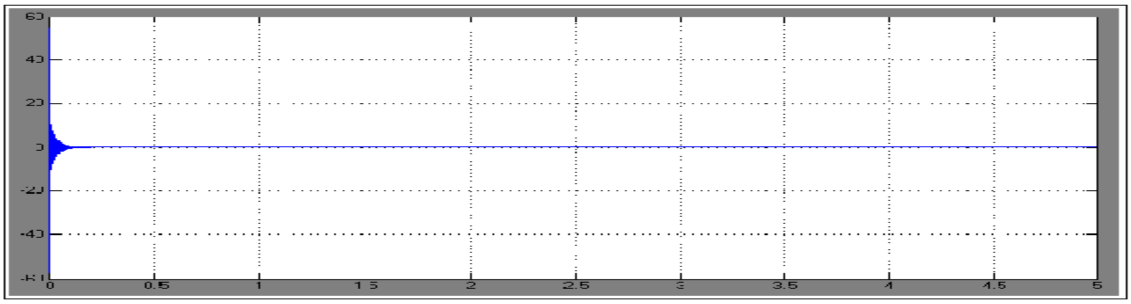

**Fig 5e. Inrush current wave form**

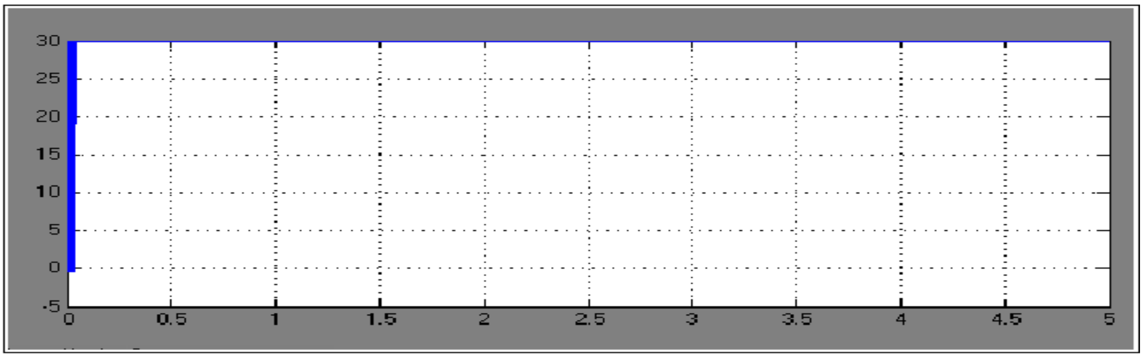


**Fig 5f. Capacitor voltage wave form**

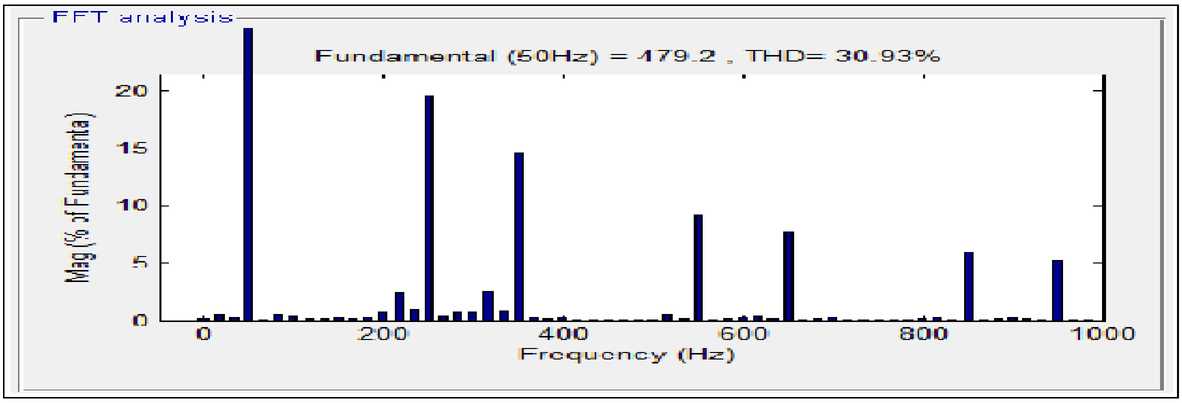


**Fig 5g. THD analysis without filter**

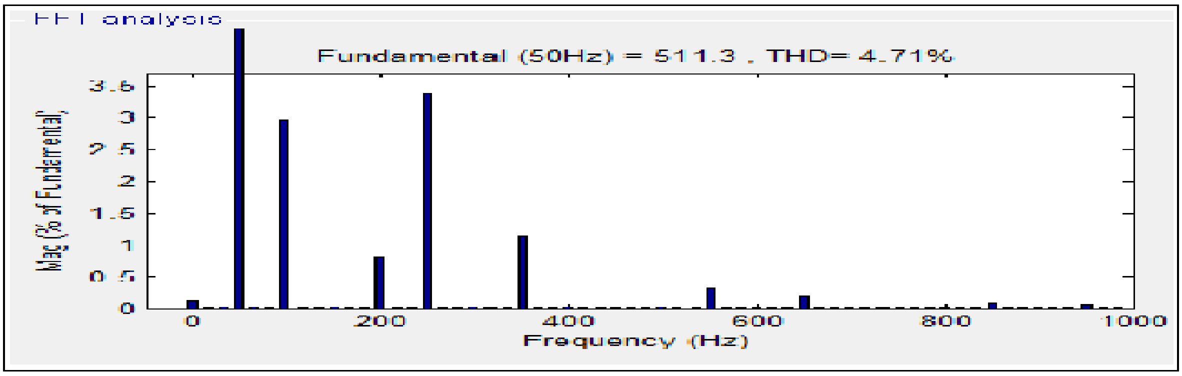


**Fig 5h. THD analysis with filter**

## IV. Comparitive Analysis Of Czmc And Szmc Using Simulation Results

The below table shows the comparison between SZMC and CZMC using simulation results.

**Table 1. Comparison between CZMC and SZMC**

| SI NO | PARAMETER | CZMC | SZMC |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1 | Inrush current | 0.08735 A | 0.0124 A |
| 2 | Capacitor voltage across Z source network | 41.35 V | 30 V |
| 3 | THD analysis before filter | 31.66 % | 30.93 % |
| 4 | THD analysis after filter | 9.53 % | 4.71 % |
| 5 | Input voltage | 150 V | 150 V |
| 6 | Input current | 4.1 A | 4.1 A |
| 7 | Output voltage | 450 V | 490 V |

From the comparison table, the quality of all parameters related to Cascaded and Series Z - source matrix converter are analyzed. The THD of the currents for both Z-source converters are calculated by FFT analysis with respect to fundamental frequency 50Hz.

## V. Hardware Arrangement And Its Output

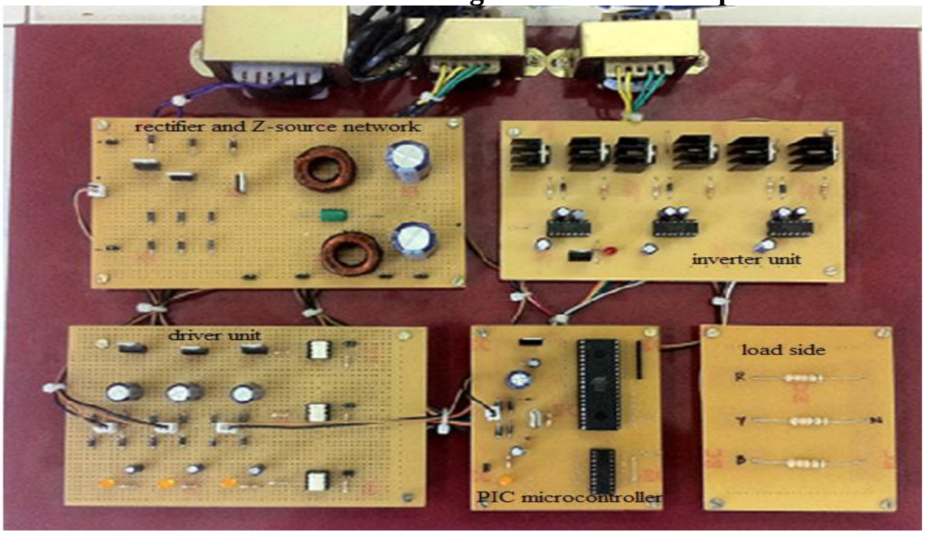


**Fig 6. Hardware arrangement**

The fig 6 shows the overall view of hardware setup. It consists of a rectifier part, Z-source network, inverter part, and PIC microcontroller and driver unit. In this hardware we are providing a single phase supply to the transformer. This transformer converts 230V into 50V which is supplied to the rectifier unit. Rectifier is used to convert the AC into DC. In-between rectifier and inverter units, Z-source network is provided. Z-source network is used to buck or boost the voltage based on our needs. Due to ultra sparse matrix topology less no of switches are used. In inverter side it consists of six MOSFET switches. Inverter mode is operated in 180$^o$ mode. In this 180$^o$ mode each diode conducts for 180$^o$ and in each interval three numbers of devices is turned on. The output of 180$^o$ is high when compared to 120$^o$. The switching sequences are controlled by the PIC microcontroller. The driver circuit is used for triggering of the gate in switches.

The figure 6a, 6b and 6c shows the R-Y phase, Y-B phase and B-R phase voltages respectively. These voltages are measured using CRO. The phase and neutral of the CRO channel probe is connected across the inverter load side.

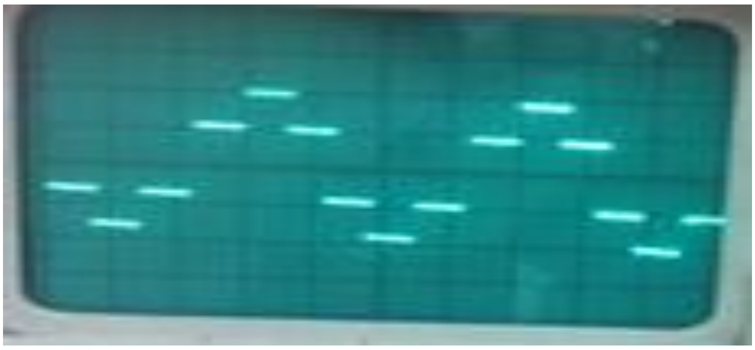

**Fig6a. R-Y phase voltage**

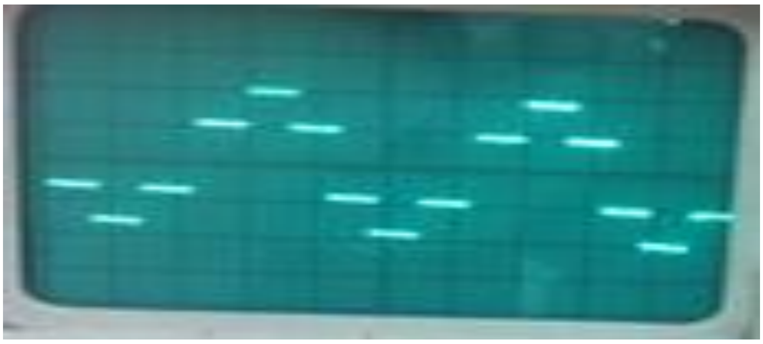

**Fig6b. Y-B phase voltage**

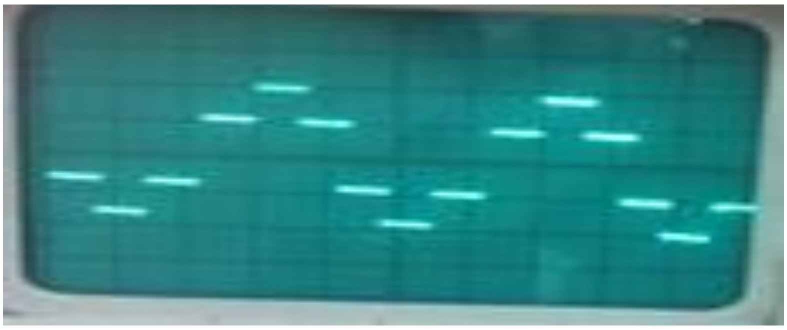

**Fig6a. B-R phase voltage**

## VI. Conclusion

The reliability of the series Z source converter is very high, since we are using less number of switches. The significant hazard of shoot- through problem in the output stage is completely eliminated. Hence, the SZMC are characterized by reduced capacitor voltage in the Z-source network and reduced inrush current during startup. So the SZMC is very suitable converter than CZMC. It is applied to the wide application on wind turbine with low voltage gearless generators. In future, instead of using indirect matrix converter, the advanced topology of direct matrix converter can be used. Moreover, instead of Z-source network an alternate quasi Z-source network can be used.

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