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HERIC Configuration Based Back To Back Converter With Reduced Losses For Regenerative Load Applications

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Back to back converters are used in many applications including machine drives and HVDC links. It is a combination of AC to DC and DC to AC converters with topologies suitable for the application. Here a single phase converter topology is developed by combining a Z source network and HERIC inverter which operates with lesser losses and more controllability. Compared to conventional inverter model, the conduction losses are much less in HERIC configuration. The Z source network help in boosting the DC voltage level so as to obtain the required level of AC output. This back to back converter is mainly meant for regenerative load application which can be utilized in equipment testing. The power drawn by the converter can be regenerated to supply back to the utility grid there by it is possible to conduct equipment testing without wasting energy. The details of the proposed configuration and the output waveforms are explained. Also a comparative study of the losses in conventional converter and proposed converter is presented.

Key words *Back to back converter, HERIC inverter, Z source nettwork, regenerative load*

1.0 INTRODUCTION

Many electrical applications demand the conversion of AC to DC and back to AC or vice versa, for controlling the power flow, current profile etc. So, back to back converters appear with various configurations according to the application. Modification of the rectifier part or the inverter part in the back to back converter will give better performance for the converter. Here a converter with HERIC configuration and Z source network is developed suitable for regenerative load emulator application for operation with reduced losses. The back to back converter is to be controlled so as to control the current profile drawn by the converter according to the standards [5]. The output AC is to be fed back to the grid so that energy is not wasted during the testing.

Various types of load emulators have been developed for testing and research purpose including the recent developments in renewable energy sector [1]. Emulators using pure power electronic circuit is of the main interest here, for which the converter has been developed [2-4]. New configurations of back to back converters are developed based on their applications by incorporating new control techniques and operating logic [6-8]. A comparative study of various configuration is also done in [7]. The advantages of using Z- Source inverter is well known especially in renewable energy applications. The use of Z source network is extended to various converter models to obtain the required output as can be seen in [12- 14].

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2.0 BACK TO BACK CONVERTERS

Back to back converters are used in many AC and DC applications [1-4]. A general topology is shown in Figure 1. The main features are:

- It consists of a force-commutated rectifier and a force-commutated inverter connected together.
- The operation of the converter can be regulated in such a way as to obtain the required characteristics by controlling the rectifier and inverter combined or individually.
- The output converter can be operated to get sinusoidal currents, for which the dc-link voltage must be higher than the peak main voltage.
- The dc-link voltage is regulated by controlling the power flow to the ac grid.

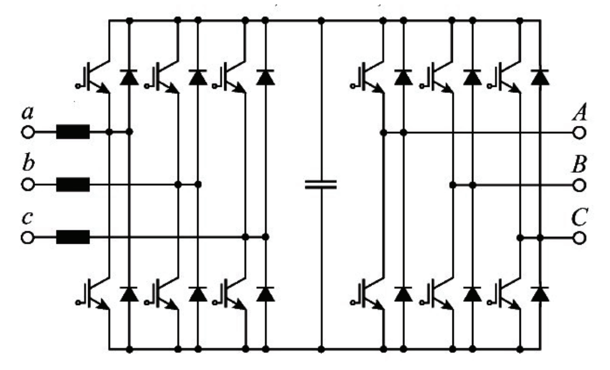

FIG. 1 GENERAL TOPOLOGY OF THREE PHASE BACK TO BACK CONVERTER

One of the common applications is that braking energy can be fed back to the power grid instead of wasting it in a braking resistor. The same principle is utilized in regenerative load emulators. Another important property of the back-to-back converter is the possibility of fast control of the power flow. The current drawn by the rectifier can be regulated without affecting inverter performance [8-9].

For testing of power equipments, resistive inductive and capacitive load are evaluated by using an electronic load. The power drawn by the load is dissipated in the load which causes energy wastage. This can be overcome by using a regenerative load emulator. A suitable back to back converter configuration is designed so as to draw the required load profile from the equipment and to regenerate it as sinusoidal ac. The block diagram of the proposed scheme is shown in Figure 2.

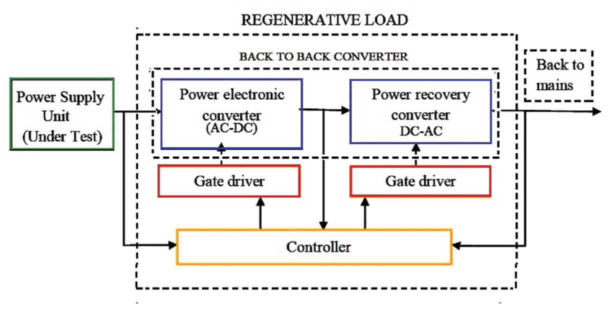

FIG. 2 BLOCK DIAGRAM OF REGENERATIVE LOAD EMULATOR USING BACK TO BACK CONVERTER

3.0 HERIC CONFIGURATION

Large number of inverter topologies and control techniques has been developed by researchers throughout years. The inverter topology and controller logic are chosen based on the type of application. Multi level inverters were developed in order obtain better sinusoidal waveform with lower harmonic contents like diode-clamped, cascaded H-bridge, multi cell, modified H-bridge etc. These configurations have more number of switches and consequently more switching losses and leakage currents.

Here a combination of HERIC converter and Z source inverter is utilized in the back to back converter for regenerative load application. The basic topology of a single phase HERIC converter is shown in Figure 3. This can be utilized in 3 phases to obtain 3 phase voltage output for three phase loads.

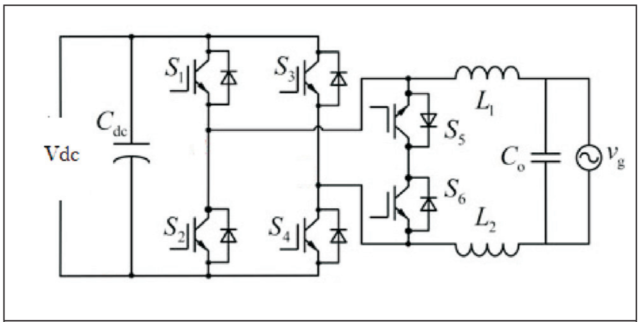

FIG. 3 HERIC INVERTER TOPOLOGY

The main features of this converter are:

- It has two extra switches on the ac side of the inverter so that leakage current is cut off.
- During all modes of operation, the inductor current is flowing through two devices; both during active mode and freewheeling mode.
- The conducting devices in each mode is shown in the Table 1 below [10-11].
- The total losses in the switching devices is lesser compared to conventional single phase inverter topology.

TABLE 1

SWITCHING PATTERN FOR HERIC INVERTER

Mode	**Half period**	**Conducting devices**
Active	Positive	S_1, S_4, S_5
Free wheeling	Positive	S_5, D_6
Active	Negative	S_2, S_3, S_6
Free wheeling	Negative	D_5, S_6

4.0 Z SOURCE NETWORK

Z-source inverters (ZSI) are used in many industrial applications which increase the reliability by allowing lower inrush current, lower harmonic injection and high immunity to EMI noises. The condition called shoot through state occurs in conventional voltage-source inverter when the switching of the same-phase leg switches at the same time will cause a short circuit. This will cause damage and malfunctioning of the device. Z- source inverter uses an impedance source network where there is no shoot through problem. Voltage level higher than input voltage can be obtained which requires a boost converter in conventional VSI. Figures 4 and 5 show the equivalent circuit of Z source inverter in two states [12-14].

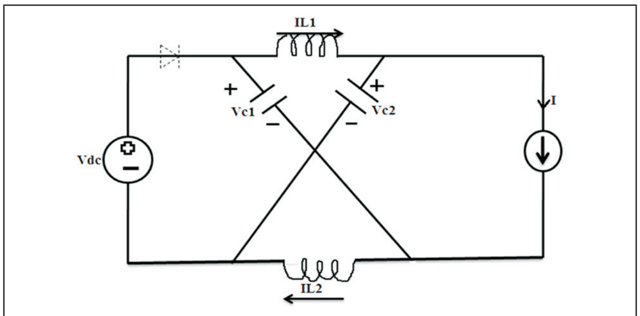

FIG. 4. EQUIVALENT CIRCUIT OF Z SOURCE INVERTER DURING NON- SHOOT THROUGH STATE

V_L - inductor voltage

V_C - capacitor voltage

V_{dc} - DC voltage

T_1 - Non-shoot through period

T_0 - shoot through period

T - total switching period = T_0+T_1

In non-shoot through mode, assuming that the average inductor voltage over one switching period is zero, we have

$$V_L = \frac{T_0.V_C + T_1(V_{dc} - V_C)}{T} = 0 \quad ....(1)$$

That is,

$$\frac{V_C}{V_{dc}} = \frac{T_1}{T_1 - T_0} \quad ....(2)$$

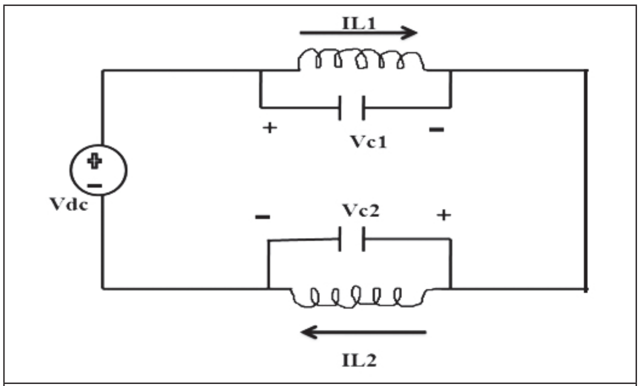

FIG. 5 EQUIVALENT CIRCUIT OF Z SOURCE INVERTER DURING SHOOT THROUGH STATE

In shoot through mode , the diode placed at the input side is reverse biased and the capacitors charge the inductors as shown in Figure 5.
The inductor voltages,

$$V_L=V_C \quad ....(3)$$

$$V_{L1}=V_{C1};\ V_{L2}=V_{C2} \quad ....(4)$$

It is assumed that the impedance network is a symmetric network ($C_1=C_2=C$ and $L_1=L_2=L$), it can be observed that $V_{L1}=V_{L2}=V_L$ and $I_{L1}=I_{L2}=I_L$ and the DC link voltage across the inverter bridge during shoot through interval is

$$V_i=0 \quad ....(5)$$

5.0 COMPLETE CONVERTER MODEL

The operation of the proposed converter configuration is verified using MATLAB simulation. The complete simulation diagram is shown in Figure 6 The design is done for 1 kW prototype and the outputs are verified at the input, DC link and output sides.

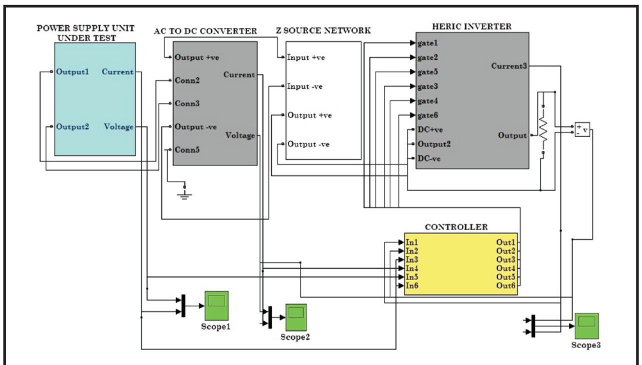

FIG 6 COMPLETE SIMULATION MODEL OF THE PROPOSED CONVERTER CONFIGURATION

The subsystem of inverter portion along with the Z source network is shown in Figure 7. The same configuration can be utilized for three phase and can be cascaded for multi level logic. Two different signal generator circuit are used for the rectifier part and inverter part. The switching of HERIC converter is done as per the explanation in section 3.0.

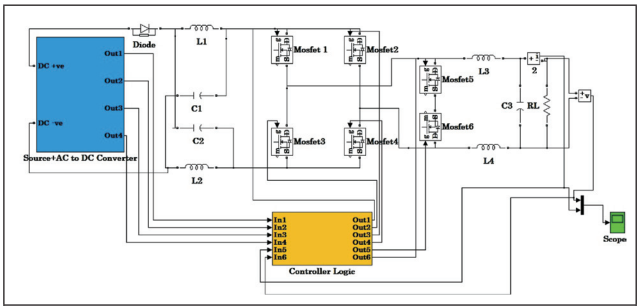

FIG. 7 INVERTER SUBSYSTEM WITH Z SOURCE NETWORK.

6.0 RESULTS AND DISCUSSIONS

The operation of the proposed converter is verified using simulation and the results are shown below. The DC link and output AC voltage and current waveforms are shown in Figure 8 and 9. The output is verified for various power ratings.

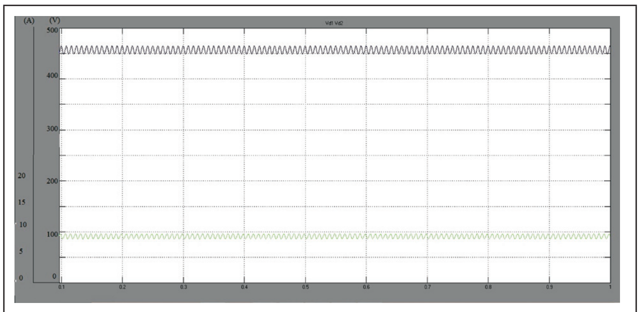

FIG. 8 VOLTAGE AND CURRENT WAVEFORMS FOR DC LINK

A comparative study of the power loss during the operation of Back to back converter with conventional topology and the proposed topology was done. A comparison chart is shown in Figure 10. The proposed converter works with about 5% lesser losses

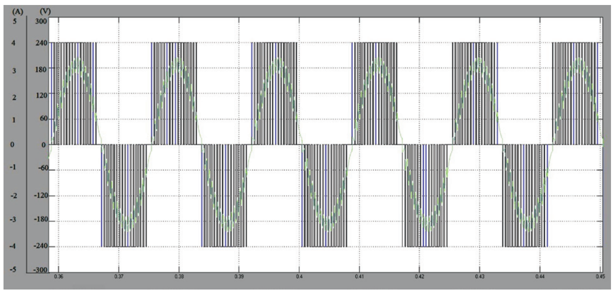

FIG. 9 VOLTAGE AND CURRENT WAVEFORMS FOR OUTPUT AC SIDE

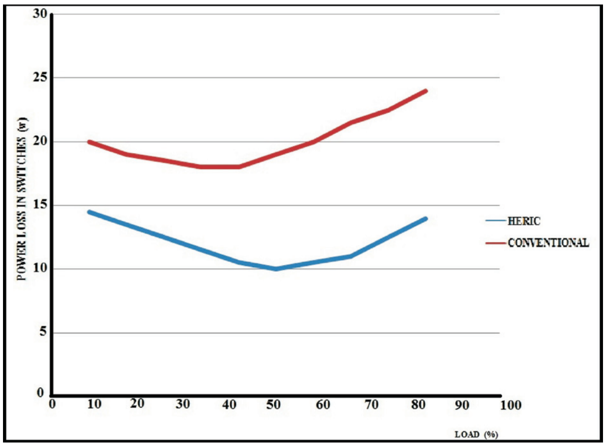

FIG. 10 COMPARISON OF LOSSES DUE TO SWITCHING IN CONVENTIONAL AND PROPOSED BACK TO BACK CONVERTER.

The output is shown only for single phase unity power factor operation. The converter can be made three phase and for variable power factor application for obtaining various types on leading lagging and harmonic characteristics.

7.0 CONCLUSIONS

A back to back converter configuration with HERIC Converter and Z source network is proposed. The operation is explained and output is verified using simulation. The conclusions from the work are,

- The proposed converter operates with lesser losses compared to conventional back to back converter.
- The current profile drawn can be controlled according to requirement.
- So the converter is suitable for regenerative load application for testing of power supplies and electrical equipments.
- Use of regenerative load emulators for electrical equipment testing will provide a more flexible platform for obtaining variety of load conditions. The losses during testing can be minimized to a great extent.
- The converter can be utilized for electrical drives applications also to operate with reduced losses.

8.0 ACKNOWLEDGEMENT

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9.0 REFERENCES

[1] Davies R., Fazeli A., Sung Pil O., Sumner M., Johnson M. and Christopher E., "Energy management research using emulators of renewable generation and loads," Innovative Smart Grid Technologies (ISGT), 2013 IEEE PES, 24-27 February 2013, pp. 1-6.

[2] Klein R. L., De Paiva A. F. and Mezaroba M., "Emulation of nonlinear loads with energy regeneration," Power Electronics Conference (COBEP), 2011 Brazilian, 11-15 September 2011, pp. 884-890.

[3] Rao Y. S. and Chandorkar M. C., "Real-Time Electrical Load Emulator Using Optimal Feedback Control Technique," Industrial Electronics, IEEE Transactions on Industrial Electronics, vol. 57, no. 4, April 2010, pp. 1217-1225.

[4] Han B. M., Bae B. Y. and Jeong Y. S., "Load simulator with power recovery capability based on voltage source converter–inverter set," IEE Proceedings on Electrical Power Application, vol. 153, no. 6, November 2006, pp. 1-7.

[5] International Electro technical Commission, Standard IEC 61683-1-1, , ed.1, 1999.

[6] Mahmoud S., Philippe P., Shahrokh S, and Mohammad R. Z., "FPGA-Based Reconfigurable Control for Fault-Tolerant Back-to-Back Converter Without Redundancy" IEEE Transactions On Industrial Electronics, Vol. 60, No. 8, August 2013, pp. 3360-3371.

[7] Thomas F., Johann W., Kolar J.R., and Patrick W. Wheeler, "Comparative Evaluation of Three-Phase AC–AC Matrix Converter and Voltage DC-Link Back-to-Back Converter Systems," IEEE Transactions On Industrial Electronics, Vol. 59, No. 12, December 2012, pp. 4487-4510

[8] Minshull S.R., Bingham C.M., Stone D.A. and Foster M.P., "Frequency reduction schemes for back-to-back connected, diode-clamped multilevel converters," *IET Power Electronics,* Vol. 3, Issue 1, December 2010, pp. 65–74.

[9] Dongsen Sun Baoming Ge, Fang Zheng Peng, Haitham A.R., "A new grid-connected PV system based on cascaded H-bridge quasi-Z source inverter" *IEEE International Symposium on Industrial Electronics (ISIE),* 2012, pp. 951 – 956.

[10] Araujo S.V., Zacharias P., Mallwitz R. ,"Highly Efficient Single-Phase Transformerless Inverters for Grid-Connected Photovoltaic Systems" *IEEE Transactions on Industrial Electronics,* Vol. 57 , Issue 9, September 2010, pp. 3118-3128.

[11] Ming Xu, Li Zhang, Yan Xing , Lanlan Feng, "A novel H6-type transformerless inverter for grid-connected photovoltaic application" *7th IEEE Conference on Industrial Electronics and Applications (ICIEA),* July 2012 pp. 58 – 63.

[12] Peng F.Z., Joseph A. and Wang J. "Z-source inverter for motor drives", *IEEE Trans. Power Electron.*, Vol. 20, No. 4, , 2005 pp. 857–863.

[13] Huang Y., Shen M., Peng F.Z. and Wang J., "Z-source inverter for residential photovoltaic systems", *IEEE Trans. Power Electron*., Vol. 21, No. 6, 2006, pp. 1776–1782.

[14] Rosas Caro J.C., Peng F.Z., Cha H. and Rogers C., "Z-source converter-based energy-recycling zero-voltage electronic loads", *IEEE Trans. Ind. Electron.,* Vol. 56, No. 12, 2009, pp. 4894–4902.