International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

Performance Analysis of Z-Network Plus Switched-Capacitor Boost DC-DC Converter

[1]G.Bhaskar Rao , [2]U.ViswaVarshini [3]D.Shakeela Bee [4]P.Rohith Pavan [5]G.Pushyavardhan

[1]Assistant Professor at Srinivasa Ramanujan Institute of Technology, Anantapur

[2,3,4,5] B.Tech Students at Srinivasa Ramanujan Institute of Technology, Anantapur

Abstract:

A multi-stage conversion is necessary when a basic DC-DC boost converter (BBC) raises the low voltage of PV panels to a high voltage, which is then used as the dc-link voltage of the inverter. The aim can be achieved with this multi-stage power electronic conversion, but more intermediate converters are needed. Additional converters increase the number of components while also lowering overall efficiency, which lowers reliability. The Z-Source Inverter (ZSI) is a practical alternative that not only carries out single-stage power conversion (boosting plus DC-AC conversion), but also successfully gets rid of the drawbacks of the traditional voltage-source and current-source inverters. Switching Inductor (SL) cells are used in place of the Z-Source Inverter (ZSI) inductors to maximize voltage gain. This device replaces one of the inductors of the QZSI with an SL cell (QZSI). The Z-network combined with Switched-Capacitor Boost DC-DC Converter (ZSCBC) with ANFIS Controller is suggested in this project to achieve high gain for a range of duty ratios. The Z-network plus Switched-Capacitor DC-DC Boost Converters with ANFIS controller developed in MATLAB Simulink and also with PI controller. The dynamic performance of the Z-network plus Switched-Capacitor DC-DC Boost Converters with ANFIS controller is compared with that of PI controller.

Keywords: Boost converter, Switched-Capacitor, Quasi-Z Source DC-DC Converter, Z-source Inverter.

I. Introduction:

In the past few years, scientists focused on single-stage power inverters (SSIs) that convert DC input voltage into AC output voltage. SSIs have low weight, low cost, high reliability, and high performance. The Z source inverter (ZSI) is introduced. In ZSI ,DC-line is connected to the H-bridge via two capacitors and two inductors. Despite the advantages, such as operating in buck or boost and ST modes, there exist plenty of elements. The quasi-Z-source inverter (QZSI) is a reasonable option in renewable energy applications , due to having continuous input current, boosting capability, and capacitor voltage stress. The QZSI has Shoot Through state (ST). In the ST state, both switches in one leg are on. This feature can increase the voltage gain. Also, the reliability is enhanced because dead-time is not required. The voltage-fed (DC-link) Quasi Z-source converter (QZSI) has been mainly suitable for different renewable wide varying source (DC-link) applications (Fuel Cells (FC), Solar panels, wind power generators, etc.) because of its unique capability of voltage boost and buck functions in a single stage. A family of Z-network and quasi-Z-network-based solutions to achieve high voltage boosting is reported.

Their voltage gain is many times higher than the conventional boost topology-based solutions. DC-DC converters based on quasi-Z-network reported and do not provide much higher gain than boost converters and they also have a higher number of passive components. Replacing inductors with switched inductor (SL) cells in Z-source inverters (ZSI) increases voltage gain but reduces duty cycle range and increases voltage stress on devices, while SL-based quasi-ZSI (SLQZSI) achieves higher voltage gain than ZSI and quasi-ZSI (QZSI) but still has limitations of SLZSI. The "Analysis of Performance of Z-network plus Switched-Capacitor Boost DC-DC Converters" have the primary objective of increasing high voltage gain while simultaneously maintaining low duty ratios. Z Network Switched Capacitor Boost Converters (ZSCBCs) have a high voltage gain, but their output voltage is inaccurate, and they can only be used with specific loads when utilizing a PI controller. A more complex controller known as the ANFIS Controller was implemented in order to achieve improved performance in output voltage as well as a reduction in voltage and current ripples.

II. Description of Z-Network Plus Switched Capacitor Boost DC-DC Converter:

Z-Networks are merged with switching capacitors to provide DC-DC converters with larger voltage gains. By adding a switched capacitor (SC) cell in cascade, the voltage gain of the ZSC is further improved. Although it lacks a common ground between its input and output terminals, it is limited by discontinuous input current, limited voltage gain, and limited voltage gain. When the duty ratio range and higher voltage stress across the devices are compromised, a QZSC with a voltage-lift cell has enhanced voltage gain. Two brand-new QZSC designs with single-switched capacitor branches, although none of them share a common ground and have a very low voltage gain. Although a QZSC with switching capacitor has a voltage gain that is almost twice as high as the converter this gain is insufficient. A QZSC with a hybrid SC/SL design is provided. Although it has more passive components and no common ground, it has a high voltage gain. A QZSC with a hybrid SL configuration is configured. This device has a very high voltage gain, but a smaller duty ratio range and greater voltage stress across devices. Most converters discussed above have several major drawbacks that must be addressed, including: 1) limited voltage gain, 2) high voltage stress between devices, 3) low duty ratio range, and 4) no common ground between input and output terminals. The limitations mentioned above generated an idea to address them by merging the Z-network with switched capacitors in a novel method, resulting in the proposed converters and motivating the evolution of Z network plus switched capacitor based DC-DC boost converters (ZSCBC).

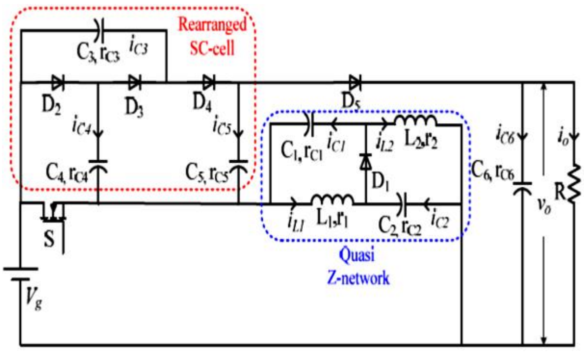

Fig 2.1: ZSCBC

On analysing the circuits of ZSCBC it ideal voltage gain is obtained as

$$M = \frac{V_0}{V_g} = \frac{3-2D}{1-2D} \dots (1)$$

The proposed converter has two inductors and six capacitors, and each component exhibits non-ideal resistance. The ZSCBC consists of a modified Z-network (inductors L1, L2 and capacitors C1 and C2 and a diode D1), a switched capacitor arrangement (C3, C4, C5, D2, D3, and D4), filter capacitor C6, switch S and diode D5. The converter is assumed to be operated in Continuous Conduction Mode (CCM).

This converter operates in two different modes. Though all these non-ideal resistances may not be coming in series but depending on the mode of operation, few of them will be in series with the load. In view of this, the non-ideal voltage gain is slightly different from the ideal gain. If the power drawn from the source is equal to the power supplied to the load, i.e., Vg Ig = $V_0 I_0$ the average current drawn from the source as

$$Ig = M\ I_0 \quad \dots(2)$$

By using above equations, we get the inductor current as

$$I_{L1} = I_{L2} = \frac{2I_0}{1-2D} \dots (3)$$

In this work PI controller is used to control load voltage. Since the proposed ZSCBC is higher order, a simple PI is inadequate to ensure desired degree of relative stability. Here we are using ANFIS controller to overcome the drawbacks of PI controller and to maintain the stability.

III. Control Strategies:

There are two types of Control Strategies:

They are: (1) PI Controller

(2) ANFIS Controller

(1) PI Controller:

Proportional Integral controller sometimes also known as **proportional plus integral (PI) controllers**. It is a type of controller formed by combining proportional and integral control action. Thus it is named as PI controller. In the proportional-integral controller, the control action of both proportional, as well as the integral controller, is utilized. This combination of two different controllers produces a more efficient controller which eliminates the disadvantages associated with each one of them.

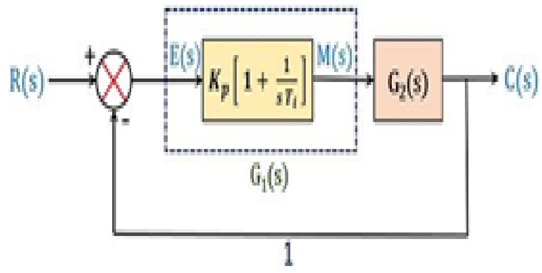

Fig 3.1: Block diagram of PI Controller

(2) ANFIS Controller:

When it comes to AI algorithms, the ANFIS algorithm has been increasingly popular in recent years. With this approach, the benefits of both neural networks and fuzzy logic are leveraged. This program uses neural networks as a form of rule compensation.

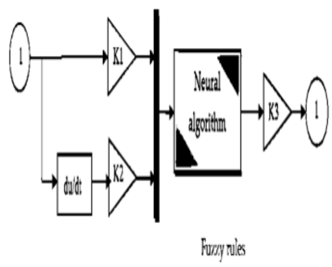

Fig 3.2: The internal structure of ANFIS algorithm

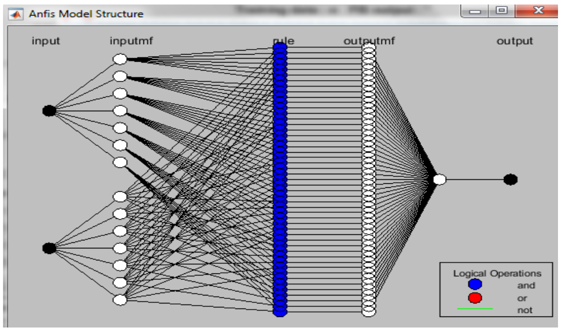

Fig 3.3 ANFIS model structure

This algorithm's benefits are its simplicity, independence from the system, and ease of application and implementation. It has a number of drawbacks, including the lack of a formal theory explaining how the rules pick the amount of neurons in the neural network's hidden layer. So, the effectiveness of this algorithm in automated systems is tied to the skill level of the user. But the ANFIS controller is straightforward and simple to use. It is independent of the system under study, hence it can be applied to any system of any complexity. When faced with a difficult problem, the ANFIS controller can offer the best possible answer. It's simple to make changes to the system in order to tweak its performance. The ANFIS controller also aids in accommodating engineering ambiguities. The ANFIS algorithm was implemented using the criteria presented in Fig. 3.2. In Fig 3.3, we can see the membership functions (MFs) required to implement the ANFIS algorithm, which are the identical for both inputs (error and change in error). 36 rules were applied for higher precision and better outcomes. Aside from the fact that the higher the number of these rules is, the slower that the system is, they were selected based on experience, expert knowledge, and the dynamics of the process. The ANFIS algorithm was implemented according to the 36 rules.

IV Simulation Model:

PI CONTROLLER MODEL

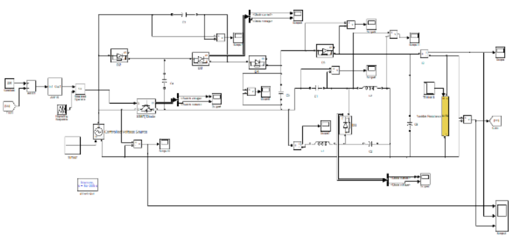

Fig. 4.1 - Simulation model of ZSCBC with PI Controller

ANFIS CONTROLLER MODEL

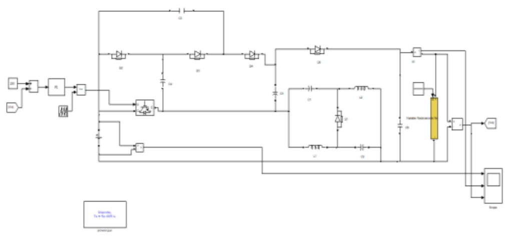

Fig. 4.2 - Simulation model of ZSCBC with ANFIS Controller

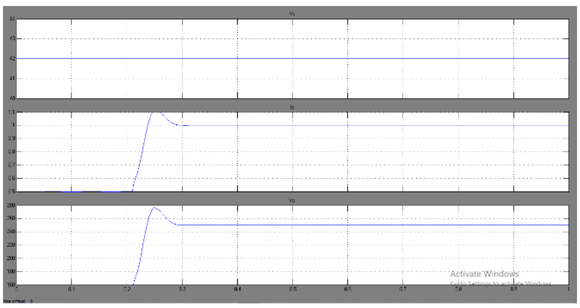

Fig.4.3 - Dynamic response of the load voltage against reference variation with PI Controller

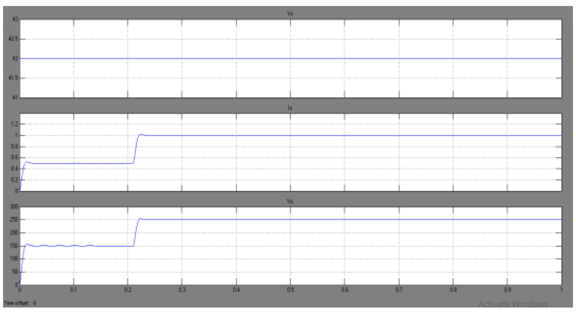

Fig.4.4 - Dynamic response of the load voltage against reference variation with ANFIS Controller

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

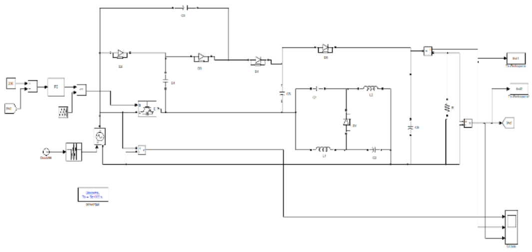

Fig. 4.5 - Simulation model of ZSCBC with PI Controller

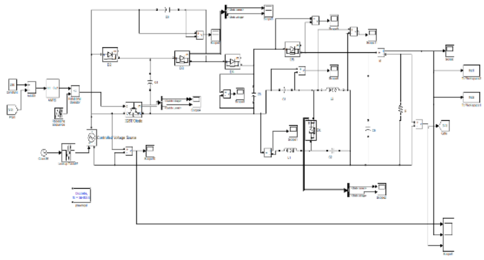

Fig. 4.6 - Simulation model of ZSCBC with ANFIS Controller

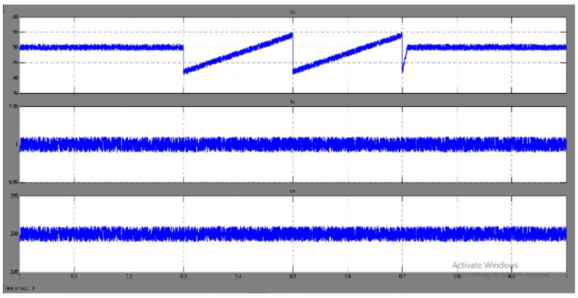

Fig. 4.7 - Measured Dynamic response of the load voltage against Ramp variation in source voltage with PI Controller

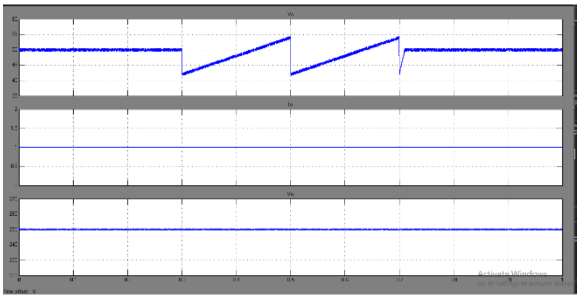

Fig. 4.8 - Measured Dynamic response of the load voltage against Ramp variation in source voltage with ANFIS Controller

PI CONTROLLER MODEL

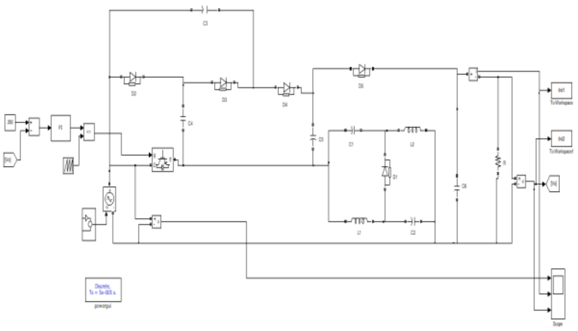

Fig. 4.9 - Simulation model of ZSCBC with PI Controller

ANFIS CONTROLLER MODEL

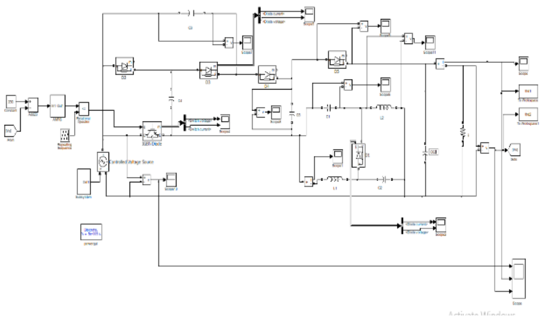

Fig. 4.10 - Simulation model of ZSCBC with ANFIS Controller

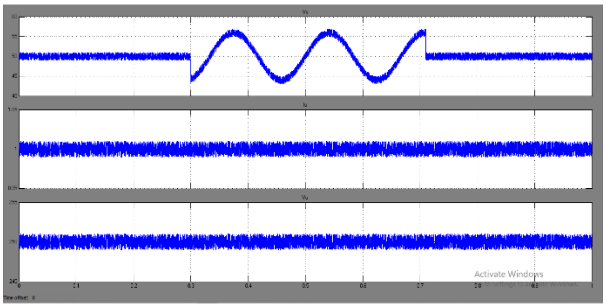

Fig 4.11 - Measured Dynamic response of the load voltage against Sinusoidal variation in source voltage with PI Controller

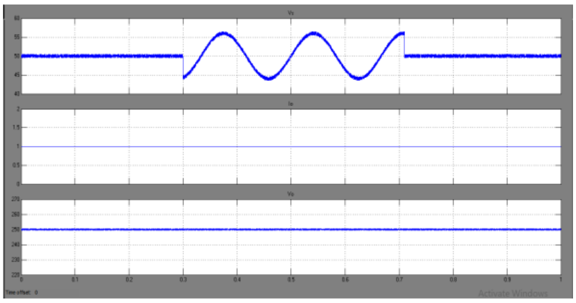

Fig 4.12 - Measured Dynamic response of the load voltage against Sinusoidal variation in source voltage with ANFIS Controller.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

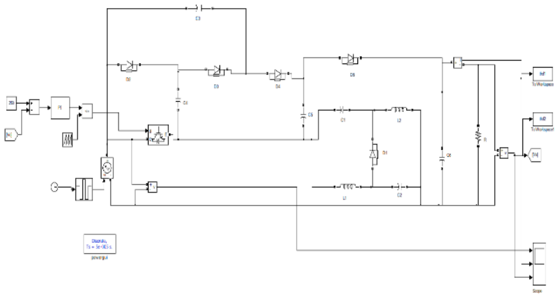

Fig. 4.13 - Simulation model of ZSCBC with PI Controller

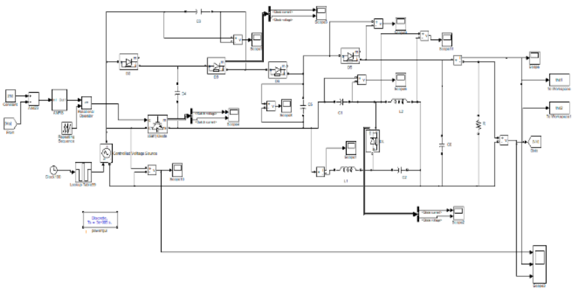

Fig. 4.14 - Simulation model of ZSCBC with ANFIS Controller

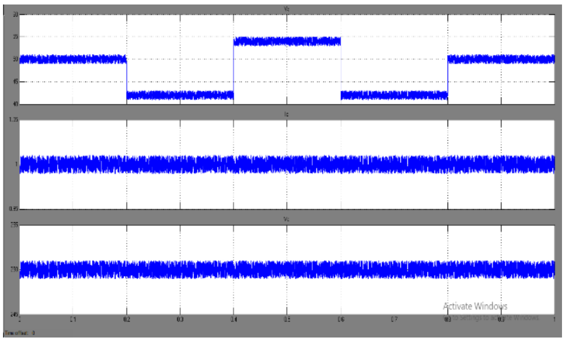

Fig 4.15 - Measured Dynamic response of the load voltage against Periodic square wave pulses with PI Controller.

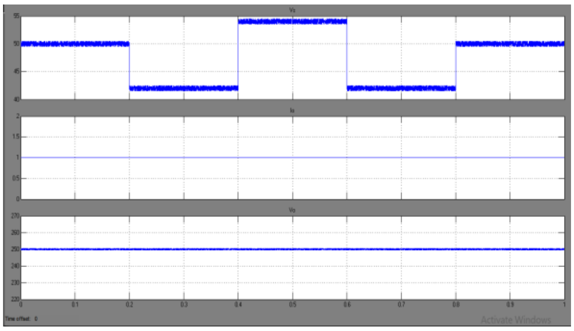

Fig 4.16 - Measured Dynamic response of the load voltage against Periodic square wave pulses with ANFIS Controller.

Comparison:

Reference tracking performance is evaluated by maintaining a constant resistive load while testing the specified controller. The dynamic response of the reference tracker is displayed in Fig. 4.3. The existing controller's response is a little sluggish and it is overcomed by using ZSCBC with ANFIS controller displayed in Fig. 4.4 and it properly follows the programmed voltage references. In ZSCBC with PI controller supply voltage, output current and output voltage noise magnitudes are high shown in Fig.4.7, Fig.4.11, and Fig.4.15. These source voltage, output current and output voltage noise magnitudes are reduced by using ZSCBC with ANFIS Controller are shown in Fig 4.8, Fig. 4.12 and Fig. 4.16.

Conclusion:

A Z-Network plus Switched Capacitor Boost DC-DC Converter (ZSCBC) exhibits a high voltage gainbut it has high noise magnitude in output voltage and output current with PI Controller. The performance of ZSCBC has been improved with an ANFIS Controller. The results of ZSCBC with ANFIS Controller are Compared with the results of PI Controller.

References:

[1] Y. Shindo, M. Yamanaka, and H. Koizumi, "Z-source DC-DC converter with cascade switched capacitor," in Proc. IEEE IECON, pp. 1665- 1670, 2011.

[2] L. Yang, D. Qiu, B. Zhang, G. Zhang and W. Xiao, "A modified Z source DC-DC converter," in Proc. IEEE EPE, pp. 1-9, 2014.

[3] G. Zhang, B. Zhang, Z. Li, D. Qiu, L. Yang and W. A. Halang, "A 3-Znetwork boost converter," in IEEE Trans. on Ind. Electron., vol. 62, no. 1, pp. 278-288, Jan. 2015.

[4] H. Shen, B. Zhang, D. Qiu, L. Zhou, "A common grounded Z-Source DC–DC converter with high voltage gain," in IEEE Trans. on Ind. Electron., vol. 63, no. 5, pp. 2925-2935, May. 2016.

[5] Y. Shindo, M. Yamanaka and H. Koizumi, "Z-source DC-DC converter with cascade switched capacitor," in Proc. IEEE IECON, pp. 1665-1670, 2011.

[6] MATLAB User Manual, MathWorks, Natick, MA, USA, 2015.

[7] Y. Wang, Q. Bian, X. Hu, Y. Guan and D. G. Xu, "A high performance impedance-source converter with switched inductor," in IEEE Trans. On Power Electron., vol. 34, no. 4, pp. 3384-3396, Apr. 2019.

[8] R. W. Erickson and D. Maksimovic, Fundamentals of Power Electronics, 2nd ed. Norwell, MA, USA: Kluwer, Jan. 2001.