Z- Source Based High Step-Up DC-DC Converterswith Pi Controller

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***Abstract*— The three high step-up Z-source (ZS)-based dc-dc converters with PI controller, that are suggested in this article combine switched-capacitor (SC) cells with the traditional ZS network. The suggested converters with PI controller provide a straight forward design with a constant input current, high voltage gain, and minimal voltage stress on the semiconductor components. Additionally, the suggested converters do not place any restrictions on the duty cycle of the power switch, in contrast to some other ZS-based topologies that are currently in use in the literature. These qualities make the suggested converters with PI controller, suitable choices for PV applications that require the interface of a low-voltage solar photovoltaic (PV) panel with a high-voltage dc bus. The Proposed converter with PI controller have high voltage gain, simplicity of operation, lower voltage, and lower current stresses on the components. . There are constant voltage variations for converters' outputs as a consequence of changes at the load and source end. in order to achieve a constant output voltage regardless of the source or load change, proportional integral controller is also employed in the proposed system. The Proposed converter with PI controller have high voltage gain, simplicity of operation, lower voltage, and lower current stresses on the components.**

***Index Terms*— Boost converter, high step-up dc-dc converter, impedance network, switched capacitor cell source converter, solar photovoltaic, PI controller.**

I. INTRODUCTION

The use of photovoltaic (PV) panels has increased dramatically over the last decade. The low output voltage of PV panels is one of the key disadvantages of PV generation. The usual technique for increasing the voltage level of PV generating is to connect the PV panels in series. However, partial shadowing and module mismatches significantly reduce PV panel output power. In this scenario, a parallel-connected PV panel design is more efficient than a series- connected configuration.

As a result, high-voltage gain dc-dc converters with PI controllers are necessary to raise the PV voltage to high levels. A traditional dc-dc boost converter can produce a high voltage gain;but, it must operate at a very high duty cycle near unity. Because the power switch conducts for a long time close to the switching period when operating at a high duty cycle, the voltage and current stresses of the components increase, and the converter suffers from large conduction losses. Furthermore, the output diode will conduct for a very short length of time, resulting in a significant reverse-recovery difficulty. Isolated converters often achieve high- voltage improvements by altering the transformer's turn’s ratio. However, they are also burdened by exorbitant costs. For high step-up applications, many non-isolated dc-dc converters have been proposed.

Voltage-boosting techniques such as switched-capacitor (SC) cells, switched-inductor (SL)/voltage-lift (VL) cells, and coupled inductors are used in these converters. There are also high step-up dc-dc converters generated from isolated counterparts.

The proposed topologies differ significantly from other existing ZS-based high step-up dc-dc converters with PI controller. When compared to standard ZS converters, the suggested converters greatly boost voltage gain while decreasing voltage strains on semiconductor devices.

II. COMPARISON BETWEEN EXISTING AND PROPOSED SYSTEM

A. The main difference between the existing system and proposed system is that here high gain can be achieved without having large variation in duty cycle.

B. The proposed SCZS network's structure can be symmetrical or asymmetrical, and the asymmetrical structure can have two different configurations.

C. The proposed topologies are completely different from other existing ZS-based high step-up dc–dc converters with PI controllers. Compared to the conventional ZS converter, the proposed converters significantly increase the voltage gain and reduce the voltage stresses on the semiconductor devices.

III. OBJECTIVES

A . This project aims to give the suggested converters with PI controller provide a straightforward design with a constant input current, high voltage gain, and minimal voltage stress on the semiconductor components.

B. In such conditions, these qualities make the suggested converters with PI controller, suitable choices for PV applications that require the interface of a low-voltage solar photovoltaic (PV) panel with a high-voltage dc bus.

IV. PROPOSED SYSTEM

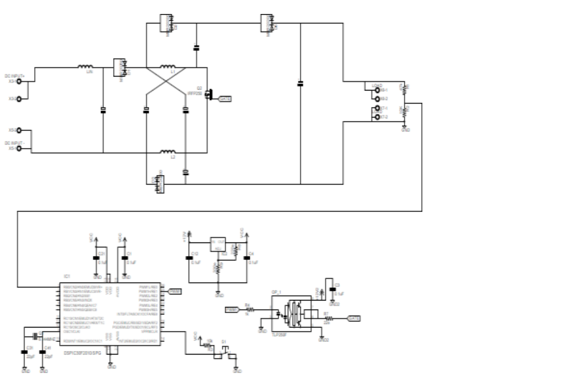


Fig 1 Circuit diagram for proposed system

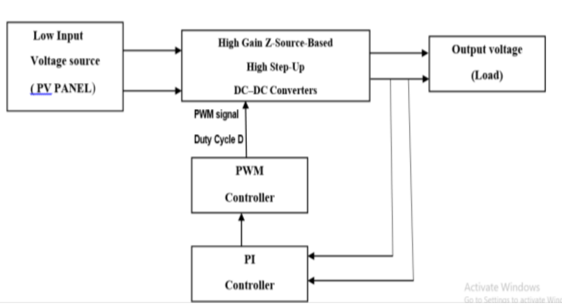


Fig 2 Block diagram of proposed System

There are five blocks in the system. A low input voltage source, High gain Z source based high step up dc-dc converter, Pulse width modulator, PI controller and Resistive load.

A. High Gain Z-Source-Based High Step-Up DC–DC Converters

The proposed high step-up dc–dc converters are comprised of an input inductor (Lin), an input capacitor (Cin), an input diode (Din), an SCZS network, a power switch (Q), an output diode (Do), and an output filter capacitor (Co). the S-SCZS network contains two inductors (L1, L2), four capacitors (C1, C2, C3, C4), and two diodes (D1, D2). The PV panel is represented by a voltage source (Vin), and the load is represented by a resistor (R). The input inductor (Lin) andinput capacitor (Cin) act as the input filter.The operation of the converter is divided into two modes. The circuit and wave forms are shown below.

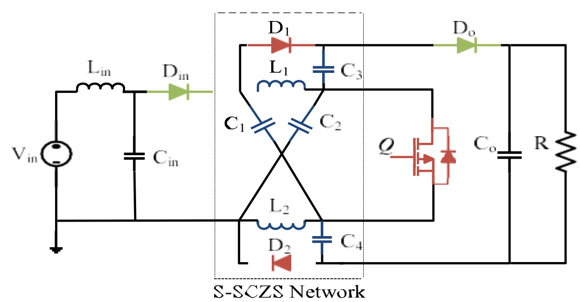


Fig 3 High gain Z source based step-upDC to DC converter

Switching State I ($0 \leq t \leq DT$):

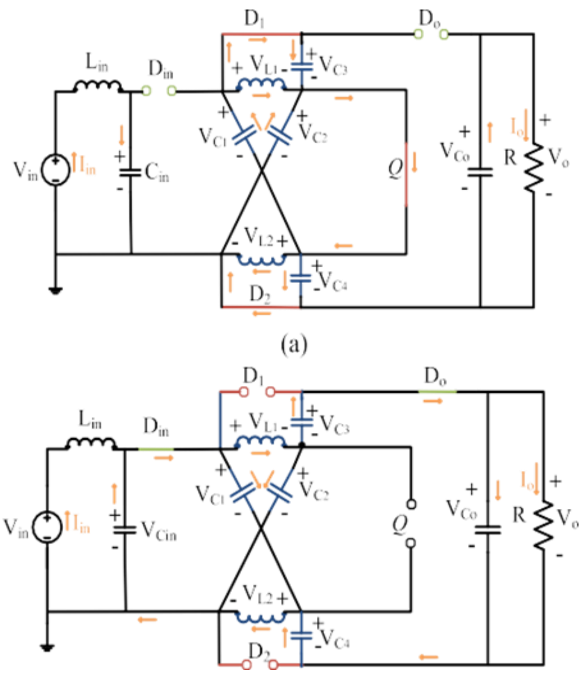
Fig. (a) shows the equivalent circuit of switching state I starting when switch Q turns on. In this state, switch Q and diodes D1 and D2 are in ON state, and diodes Din and Do are in OFF state. According to the

Fig 4 Equivalent circuit of the proposed S-SCZSC for (a) switching state I and (b) switching state II

current flow paths shown for this switching state in Fig. (a), the inductors are charged, capacitors C1, C2,

and Co are discharged, and capacitors C3 and C4 are charged. By applying Kirchhoff's voltage law (KVL), the following voltage relationships are obtained for this switching state:

$$V_{L1} = V_{L1ON} = V_{C1} = V_{C3}$$
$$V_{L2} = V_{L2ON} = V_{C2} = V_{C4}$$



Switching State II (DT ≤ t ≤ T):

Fig. 4(b) represents the equivalent circuit of switching state II, which starts when switch Q turns off. In this operating state, switch Q and diodes D1 and D2 are in OFF state, and diodes Din and Do are in ON state. According to the current flow paths shown for this state in Fig.(b),the inductors are discharged, capacitors C1, C2, and Co are charged, and capacitors C3 and C4are discharged. By applying KVL, the following voltage relationships are obtained for switching state II:

$$V_{L1} = V_{L1OFF} = V_{in} = V_{C2} V_{L2} = V_{L2OFF} = V_{in} - V_{C1}$$

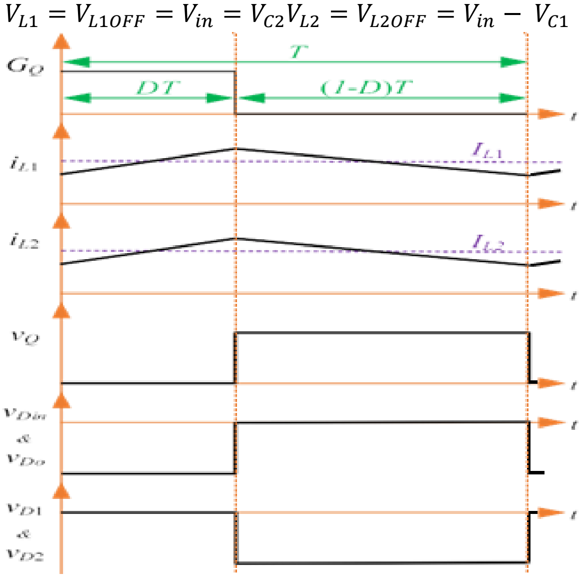


Fig 5 Wave form

B. VOLTAGE STRESS ACROSS THE POWER SEMICONDUCTOR DEVICE FOR S-SCZSC

Examining Fig. (a) and (b), the reverse voltage stresses across diodes Din, D1, D2, Do, and thevoltage stress across power switch Q can be deduced as follows:

$$V_{Din} = V_{C1} + V_{C2} - V_{in} = \frac{V_{in}}{1-2D} = \frac{V_0}{3-2D}$$
$$V_{D1} = V_{C2} + V_{C3} - V_{in} = \frac{V_{in}}{1-2D} = \frac{V_0}{3-2D}$$
$$V_{D2} = V_{C1} + V_{C4} - V_{in} = \frac{V_{in}}{1-2D} = \frac{V_0}{3-2D}$$
$$V_{D0} = V_0 - V_{C3} - V_{C4} = \frac{V_{in}}{1-2D} = \frac{V_0}{3-2D}$$
$$V_Q = V_0 - V_{C3} - V_{C4} = \frac{V_{in}}{1-2D} = \frac{V_0}{3-2D}$$

The voltage stresses across all the semiconductor devices are less than half of the output voltage(<V0/2). This feature results in reducing the losses of the S-SCZSC.

C. CURRENT STRESS ACROSS THE POWER SEMICONDUCTOR DEVICE FOR S-SCZSC

The current stresses (equivalent average currents during the conduction states, not entireswitching period) across diodes Din, D1, D2, and Do, and the switch Q can be derived as

$$I_{Din} = \frac{I_{in}}{1-D} = \frac{3-2D}{(1-D)(1-2D)\, I_0}$$
$$I_{D1} = I_{C3ON} = \frac{I_0}{D}$$
$$I_{D2} = I_{C4ON} = \frac{I_0}{D}$$
$$I_{D0} = -I_{C3OFF} = \frac{I_0}{1-D}$$
$$I_Q = I_{L1} + I_{C3ON} - I_{C2ON} = \frac{2I_0}{D(1-2D)}$$

D. PI CONTROLLER & PWM GENERATOR

Proportional integral controller is employed to attain constant output voltage irrespective of the input. It is formed by combining proportional and integral control action. A PI controller calculates an error as the difference between the measured value and the set value. PI controller improves the steady-state performance of a control system.

A Pulse Width Modulation (PWM) generator is an essential component in a Boost Converter with a PI (Proportional-Integral) controller. The PWM generator produces a series of pulses that control the switch in the Boost Converter. The duty cycle determines the fraction of time that the switch remains on during each switching period. By controlling the duty cycle, the output voltage of the Boost Converter can be regulated.

The PI controller will ensure the boost converter deliver a sufficient amount of voltage to the load

An error signal was generated by comparing the output voltage with the constant input voltage. After that, the error was connected to the PI block and the output was compared to the saw tooth signal to generate an equivalent duty cycle that was used to drive the switching devices of the converter.

V. ADVANTAGES DISADVANTAGES

Advantages

- High voltage gain
- Reduced voltage stress on the components
- Simplicity of operation
- High precision due to addition of the PI controller, which continuously adjust the converters duty cycle to maintain stable output voltage ensuring high precision and accuracy
- Better efficiency
- Fast response
- Flexibility
- Reliability

Disadvantage

Since this converter offer advantages, it also has some disadvantages that needs to be considered

- Limited current output.
- Complex design: The Z-source converter has a complex design, which can increase the cost and complexity of the system.
- Limited availability: Z-source converters are not as widely available as otherconverters, which can make them difficult to obtain and service.

VI.APPLICATION

High gain boost converter are used in various application where a high voltage level is required. They provide an efficient way to generate high voltage level from a low input voltage

- Can be used in renewable energy system to boost the voltage from solar panel or wind turbines to a level that can be used to charge batteries or feed the grid
- Power supplies for electronic devices
- Can be used in Electric vehicles to boost the voltage from batteries to a level that is required to drive the motor and other electrical component.
- Can be used in telecommunication applications to provide high voltage for various electronic systems.

VII. RESULT AND DISCUSSION

The high gain DC –DC boost converter with PI Controller is simulated in MATLAB/SIMULINK

The Simulink model and waveforms are shown below

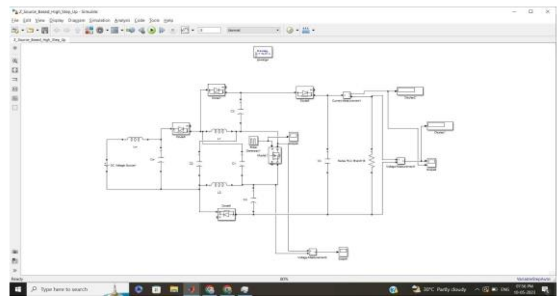


Fig 6 Simulink Model of proposed system

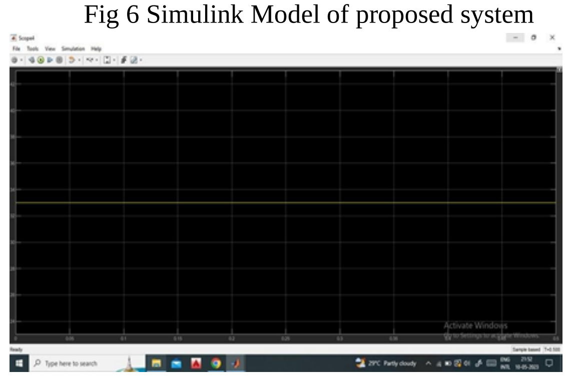


Fig 7 Input Wave form

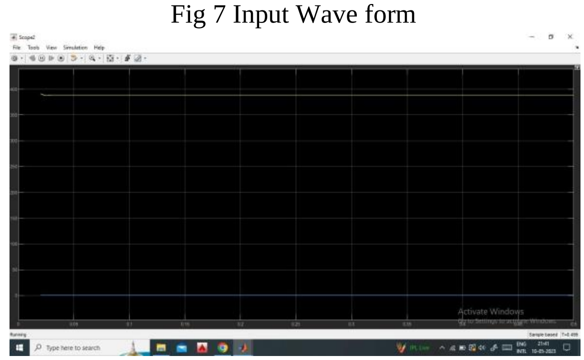


Fig 8 Output Wave Form

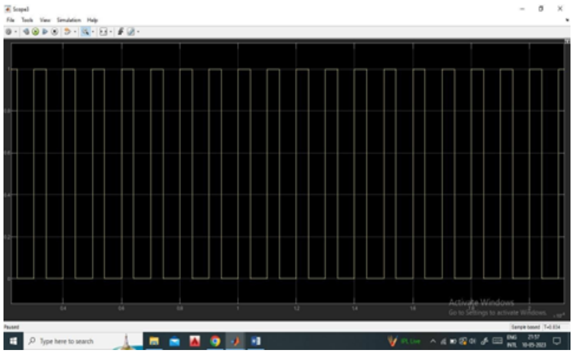


Fig 9 Gate Pulse

VIII.CONCLUSION& FUTURE SCOPE

In conclusion, the Z-source high step-up DC-DC converter with PI controller is an efficient and effective solution for high voltage DC power conversion. The Z-source network providesa unique buck-boost operation mode, which enables the converter to step up the input voltageto a higher output voltage with high efficiency, while maintaining a reduced ripple and noise. The PI controller provides good control of the output voltage and ensures the stability of the converter.

The future scope of this technology is promising, as it can be further optimized for higher efficiency and better performance. Some potential areas for improvement include the use of advanced control techniques such as fuzzy logic or neural networks, optimization of the Z- source network for better utilization of the input voltage, and the use of wide bandgap semiconductor devices to reduce switching losses and improve efficiency.

Additionally, this technology can be applied in various fields such as renewable energy systems, electric vehicles, aerospace, and telecommunications. The Z-source high step-up DC- DC converter with PI controller has the potential to play a significant role in the development of sustainable and efficient energy systems.

REFERENCE

1. V. V. R. Scarpa, S. Buso, and G. Spiazzi, "Low-complexity MPPT technique exploiting the PV module MPP locus characterization," IEEE Trans. Ind. Electron.,vol. 56, no. 5, pp. 1531–1538, May 2009
2. T. Shimizu, O. Hashimoto, and G. Kimura, "A novel high-performance utility- interactive photovoltaic inverter system," IEEE Trans. Power Electron., vol. 18, no. 2,pp. 704–711, Mar. 2003.
3. K. M. Smith and K. M. Smedley, "Properties and synthesis of passive lossless soft- switching PWM converters," IEEE Trans. Power Electron., vol. 14, no. 5, pp. 890–899,Sep. 1999.
4. R. Rahimi, S. Habibi, P. Shamsi, and M. Ferdowsi, "A high step-up Zsource DC–DC converter for integration of photovoltaic panels into DC microgrid," in Proc. IEEE Appl. Power Electron. Conf. Expo. (APEC), Jun. 2021, pp. 1416–1420.
5. N. P. Papanikolaou and E. C. Tatakis, "Active voltage clamp in flyback converters operating in CCM mode under wide load variation," IEEE Trans. Ind. Electron., vol. 51, no. 3, pp. 632–640, Jun. 2004.
6. A. Alzahrani, M. Ferdowsi, and P. Shamsi, "A family of scalable nonisolated interleaved DC–DC boost converters with voltage multiplier cells," IEEE Access, vol. 7, pp. 11707–11721, 2019.
7. A. Alzahrani, M. Ferdowsi, and P. Shamsi, "High-voltage-gain DC–DC step-up converter with bifold Dickson voltage multiplier cells," IEEE Trans. Power Electron., vol. 34, no. 10, pp. 9732–9742, Oct. 2019.
8. M. Veerachary and P. Kumar, "Analysis and design of sixth order quasiZ-source DC– DC boost converter," in Proc. IEEE Int. Conf. Sustain. Energy Technol. (ICSET), Feb. 2019, pp. 347–352.
9. P. Kumar and M. Veerachary, "Z-network plus switched-capacitor boost DC–DC converter," IEEE J. Emerg. Sel. Topics Power Electron., vol. 9, no. 1, pp. 791–803, Feb. 2021.
10. M. M. Haji-Esmaeili, E. Babaei, and M. Sabahi, "High step-up quasi-Z source DC–DC converter," IEEE Trans. Power Electron., vol. 33, no. 12, pp. 10563–10571, Dec. 2018.
11. V. P. Galigekere and M. K. Kazimierczuk, "Analysis of PWM Z-source DC–DC converter in CCM for steady state," IEEE Trans. Circuits Syst. I,Reg. Papers, vol. 59, no. 4, pp. 854–863, Apr. 2012.
12. L. Yang, D. Qiu, B. Zhang, G. Zhang, and W. Xiao, "A modifiedZ-source DC–DC converter," in Proc. 16th Eur. Conf. Power Electron.Appl., Aug. 2014, pp. 1–9.
13. J. Anderson and F. Z. Peng, "Four quasi-Z-source inverters," in Proc.IEEE Power Electron. Spec. Conf., Jun. 2008, pp. 2743–2749.
14. Y. Zhang, C. Fu, M. Sumner, and P. Wang, "A wide input-voltage rangequasi-Z-source boost DC–

DC converter with high-voltage gain for fuelcell vehicles," IEEE Trans. Ind. Electron., vol. 65, no. 6, pp. 5201–5212,Jun. 2018.
15. B. P. Baddipadiga and M. Ferdowsi, "A high-voltage-gain DC–DCconverter based on modified Dickson charge pump voltage multiplier,"IEEE Trans. Power Electron., vol. 32, no. 10, pp. 7707–7715, Oct. 2017.
16. T. Takiguchi and H. Koizumi, "Quasi-Z-source DC–DC converter withvoltage-lift technique," in Proc. 39th Annu. Conf. IEEE Ind. Electron. Soc. (IECON), Nov. 2013, pp. 1191–1196.