

Design of Isolated High Step Up Quasi Z Source Integrated Boost Converter for Grid-Tied PV Application

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ABSTRACT: The efficacy of a quasi-Z-source converter (qZSC) in a solar photovoltaic (PV) system is the subject of this paper. The qZSC topology offers several advantages over traditional converters, including inherent impedance matching, improved power quality, and enhanced voltage gain. This work focuses on designing and simulating a qZSC for a specific solar PV system using MATLAB/Simulink. The simulation model incorporates a detailed representation of the solar PV array, the qZSC with its key components (impedance network, switches, and inductors/capacitors), and a PI controller for regulating the voltage of output. The PI controller is tuned using appropriate techniques to achieve optimal performance in terms of transient response, steady-state error, and robustness to disturbances. The outcomes of the model show how well the qZSC works to maximize power from the solar PV array under a range of temperatures and light situations. The impact of different impedance network parameters on the converter's performance is also analyzed. By offering important insights into the planning and execution of qZSC-based solar PV systems, the simulation results open the door to more dependable and effective renewable energy sources.

Keywords: Quasi-z-source (QZSC) converter, DC-DC converter, PI controller, solar PV system, inverter, grid-tied applications.

1. Introduction

As fossil fuels run out and energy prices rise, solar energy is becoming increasingly important. The majority of home equipment need alternating current (AC), however solar panels provide direct current (DC) power. One essential part that transforms the DC electricity of the sunlight to useable electrical power includes a solar inverter [1]. DC-DC converters are necessary to achieve efficient control of energy and efficiency with sunlight producing systems.. They regulate the variable DC voltage output from solar panels, ensuring it matches the requirements of batteries or other DC loads. This prevents power loss and maximizes energy utilization. The DC-DC converter's operation is controlled by controllers to attain maximum power point tracking (MPPT).

ensuring efficient power extraction from the solar panels and optimized system performance. A quasi-Z-source converter is a versatile DC-DC converter topology that offers several advantages over traditional ZSCs. The PI controller is a critical component of the qZSC, as it regulates the output voltage and ensures stable operation.

To overcome the drawbacks that come with conventional six-switched Volt Sourced Converters are devices that (VSC), the research paper [2] presents high-gain Quasi Z-Source inverters (QZSI) for grid-tied PV/wind use. A Z-source network-based high-gain dc-dc converter with common ground for low voltage solar photovoltaic (PV) applications in[3] and [4]. The study [5]presents a brand-new hybrid control architecture for a grid-connected pv solar energy

method's Capacitor-Assisted Enhanced Amp Z-Source Multifaceted Inverter. The paper [6] examines the Forward-Flyback (AFF) Autotransformer converter. In the manuscript [7] In order to provide a quick reference for choosing the optimum voltage conversion for a given want, thorough evaluation and listing of all the inverter homes is given among the 45 evaluated topologies in PV systems. The book chapter [8] delves into the integration of energy storage systems (ESSs) within multilevel inverters for photovoltaic (PV)-based microgrids, underscoring the critical role of energy storage in PV systems for mitigating intermittency issues and ensuring uninterrupted power supply. The manuscript [9] delineates a dual-input configuration for the three-phase split-source inverter (SSI) intended for integration with photovoltaic (PV) systems. In [10], an extensive analysis of nearly all pertinent facets related to the grid interconnection of photovoltaic power plants, encompassing grid codes, inverter topologies, and control mechanisms, is presented. The investigation [11] offers a thorough review and critical analysis of the control methodologies utilized in pulse-width modulation (PWM) and maximum power point tracking (MPPT) for photovoltaic systems. The document [12] provides information on a number of different types of converters, such as DC-DC isolated, DC-DC non-isolated, three-phase single-stage isolated, three-phase two-stage isolated, three-phase single-stage non-isolated, and single-phase single-stage isolated. The study [13] delivers a detailed review accompanied by a focused evaluation of fuel cell/electrolyze integrated geothermal heat exchanger (FC/EL comprised GHE) storage technologies, aimed at facilitating the extensive interconnection of renewable energy sources (RESs). The study detailed in [14] suggests an innovative hybrid control setup for cascaded multilevel inverters (CMLI), specifically for use in grid-connected hybrid configurations. A thorough review of grid-connected solar PV systems is provided in the publication [15]. The several MLIs, as well as their modulation and control methods for grid-connected applications, are presented in the

study [16]. Single-phase grid-connected solar inverters are thoroughly reviewed in the study [17] with regard to their advancements in management techniques and circuits topologies. The present study [18] has thoroughly reviewed a number of papers. Reviewing the state-of-the-art medium voltage inverter technology from the standpoints of structural analysis, model development, key findings, research gaps, and applications in grid integration of renewable energy sources and grid decarbonization is the goal of the manuscript [19]. The study [20] explores the obstacles that prevent wind power integration, looks at cutting-edge controlling strategies, and gives an improved research of crucial frequency instability issues. A multi-source microgrid (MG) that incorporates electricity from solar photovoltaic (PV), wind turbines, pumped hydro storage systems (PHSS), and diesel-powered generators (DG) was examined in the work [21]. In the study [22], a novel loose-coupled bipolar DC building power system design was created. The illusive protection issues and grounding consequences related to DC microgrids have been thoroughly examined in the work [23]. An introduction to Z-source converters, a kind of impedance-source converter, and its classifications is given in chapter [24]. The important issues and challenges related to electric car converters for direct current quick charging are covered in the studies [25].

The format of this document is as follows: Section 1 It deals with the various literature of design of isolated high step up quasi z sources integrated boost converter for grid tied PV application. Section 2 presents the proposal configuration and algorithm. section 3 describes system discription of the proposed system. section 4, include details simulation result for quasi Z sources integrated boost converter. The conclusion from a comparison analysis is presented in section 5.

2. System Description

Figure 1 shows the layout of the PV solar system with Quasi Z-Source Voltage Source Converter (QZS-VSC) integration in a Back-to-Back (B2B)

configuration. A DC connection capacitor connects the PV array to the GSC. Maintaining the solar module's Maximum Power Point Tracking (MPPT) and controlling the transitional circuit's voltage handling are both crucial. To do this, a DC-DC boost converter is included into the PV module's the result stages to adjust the DC-link voltage. This voltage control loop is intended to manage variations within the solar power generator's working voltage range.



Figure 1: Block Diagram

3. Proposed Configuration and Controller

A solar power generation system refers to a system designed to convert sunlight into electricity, usually by using solar panels. This process is based on photovoltaic (PV) technology, which generates electrical energy from the sun's radiation. A converter is essential to the effective conversion and control of the electricity in solar power generating. Solar power systems employ a variety of conversion variations, all of which perform a distinct function in the manufacturing, change, and store of solar energy. The Z-source converter shown in Fig. 2 includes a unique impedance network (typically formed with inductors and capacitors), which distinguishes it from traditional converters. This impedance network allows the converter to smoothly control the voltage.

The term "Z-source" refers to a specific topology of the converter circuit, which is designed to provide a wide range of functionality and efficiency in power conversion. The Z- source converter was first proposed as an improvement over traditional DC-DC converters, as it offers unique features such

as the ability to operate over a wide voltage range, enhanced efficiency, and protection against various faults. A Z-source converter in solar power generation offers significant advantages due to its unique topology, which makes it ideal for various power electronics applications. The Z-source converter combines the benefits of traditional buck and boost converters into one, providing flexibility in handling both voltage step-up and step-down operations. A controller is essential to maximizing the system's overall performance, safety, and efficiency in sunlight generation. These controllers, which tend to be referred to as charging controllers for solar power controllers, oversee many facets of the collection, storage, and use of solar energy. A Proportional-Integral (PI) controller is widely used in solar power generation systems for its ability to maintain system stability and optimize performance. In solar power generation, especially when using photovoltaic (PV) panels or solar inverters, a PI controller can be crucial for various reasons. Optimizing the performance and efficiency of solar power generating systems requires a PI (Proportional-Integral) controller, whose major job is to maintain the system's stability and dynamic responsiveness by modifying control variables according to the intended output.

In this work consist of PI controller for Z sources DC- converter utilized for grid connected solar photovoltaic system.

4. Simulation Output

The numerical analysis feature set in MATLAB is robust. Dynamic systems, or those controlled by differential equations, may be graphically programmed and their outcomes examined using a program called Simulink. Any logical device of controls of an evolving structure may be built with the basic building blocks included in SIMULINK Libraries. In this work, PV cell is modelled or realized using differential equations (1) and (2). and current while providing flexibility in operation. In the context of solar power generation, a Z-source DC-DC converter is a type of power

converter that plays an essential role in managing and controlling the flow of electrical energy from solar panels to other components of the system, such as the inverter or battery storage.

$$I = I_{ph} - I_o \left(\exp \left(\frac{V + R_s I}{N_c a V_t} \right) - 1 \right) \quad (1)$$

$$I_{ph} = \frac{G}{G_{ref}} \left(I_{ph_{ref}} + K_i (T - T_{ref}) \right) \quad (2)$$

$$I_o = I_{oref} \left(\frac{T}{T_{ref}} \right)^3 \exp \left(\frac{E_g}{a V_t} \left(1 - \frac{T_{ref}}{T} \right) \right) \quad (3)$$

$$a = a_{ref} \left(\frac{T}{T_{ref}} \right) \quad (4)$$

Where,

$I_o \rightarrow$ diode saturation current

$I_{ph} \rightarrow$ photo current

$I \rightarrow$ the cell's output current

$V \rightarrow$ the cell voltage

$Q \rightarrow$ electron charge

$K \rightarrow$ boltzmann's constant

$T \rightarrow$ the cell temperature

$N \rightarrow$ the diode ideality factor

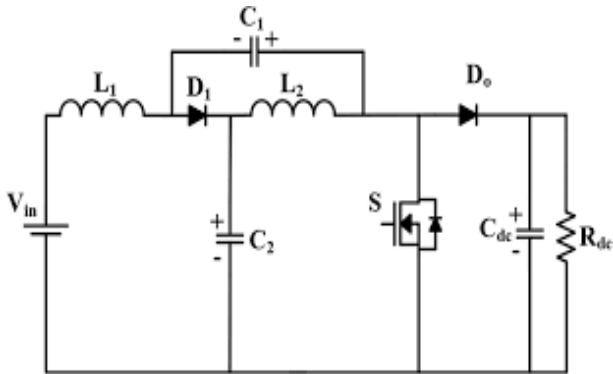


Figure 2: DC-DC conversion sources

Equation (2) realized in Fig. 5 and I_o is modelled as shown in Fig. 6. The mathematical implementation of overall PV cell and panel are shown in Fig. 7. And Fig. 8. Z source DC-DC converter in Fig.2 is implemented in MATLAB Simulink is shown in Fig. 9. The PV system, qZSC, inverter and grid are interconnected and the overall system implementation is shown in Fig. 10.

4.1 Quasi Z source DC-DC converter

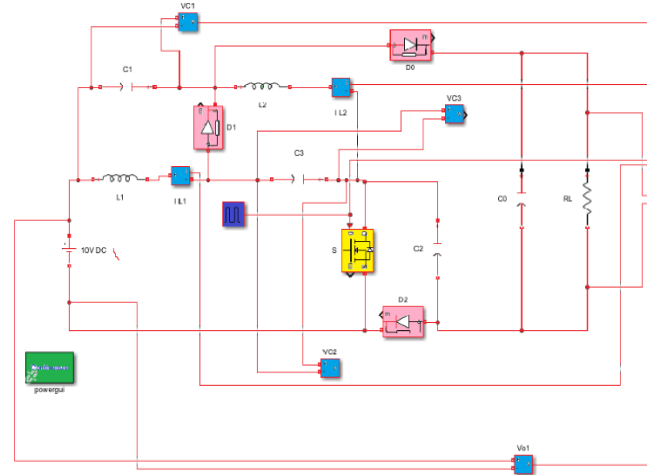


Figure 3: Quasi z sources DC-DC converter

Figure 3 shows the DC-DC converter in action for quasi-Z source in a simulation.

4.2 Simulation PV Panel

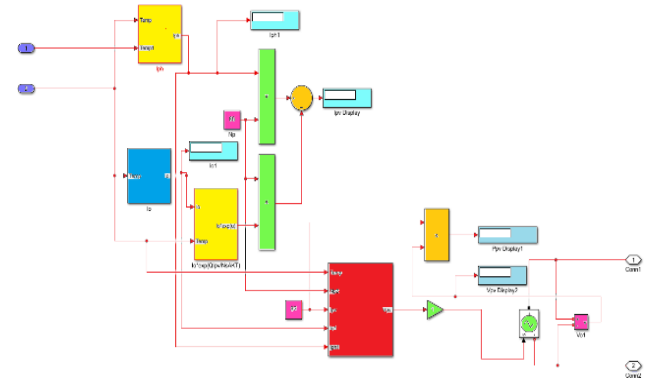


Figure 4: Simulation Panel

Figure 4 Illustrates the simulation of the solar PV panel.

4.3 PV panel I_{PH}

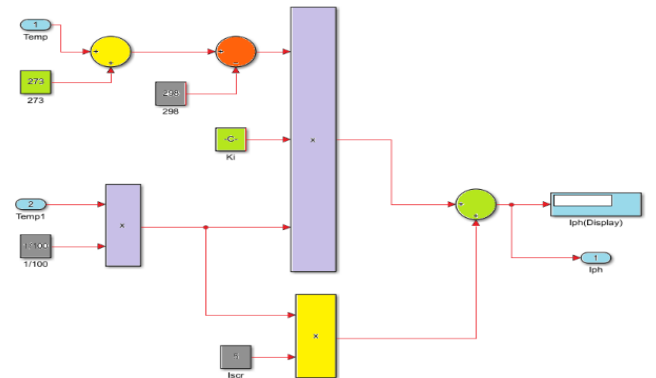


Figure 5: PV panel I_{PH}

Figure:5 Illustrates the simulation of the photocurrent (I_{ph}) in a photovoltaic (PV) panel.

4.4 PV panel Io

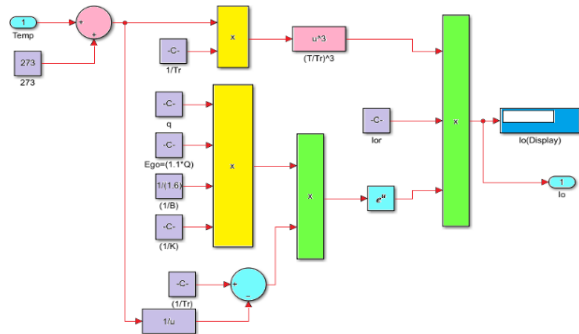


Figure 6: PV panel Io

Figure 6 shows the modeling of the photovoltaic (PV) panel's current-voltage (V-I) characteristics.

4.4.1 Mathematical Implementation of PV cell block

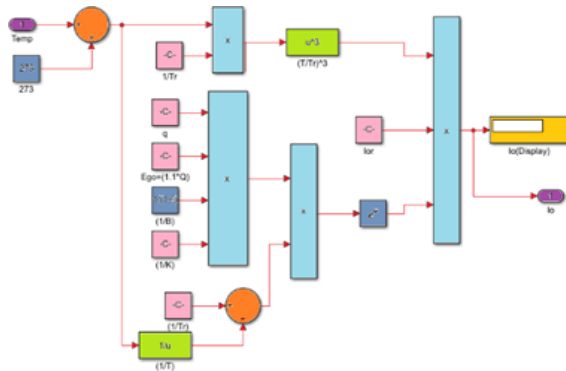


Figure 7: Mathematical implementation of PV cell

Figure 7 Illustrates the mathematical implementation of a photovoltaic (PV) cell block in the simulation.

4.5 PV panel sub system

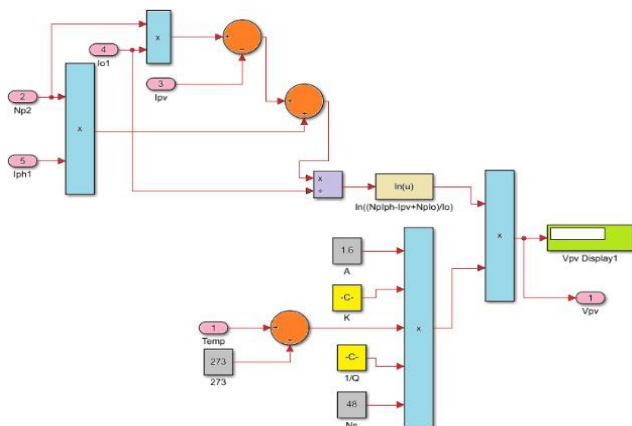


Figure 8: PV panel sub system

Figure: 8 Illustrates the Photovoltaic (PV) Panel Subsystem in the simulation.

4.6 Sub System

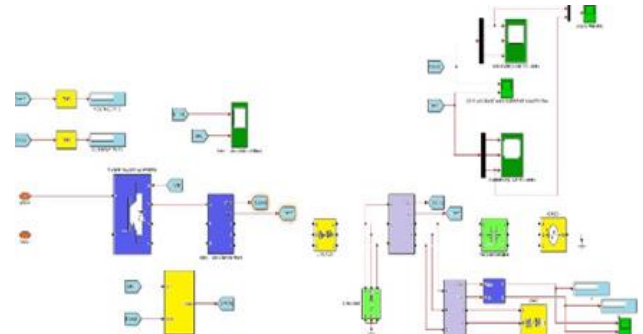


Figure 9: Sub system

Figure:9 Illustrates the subsystem in a simulation

4.7 Output waveform

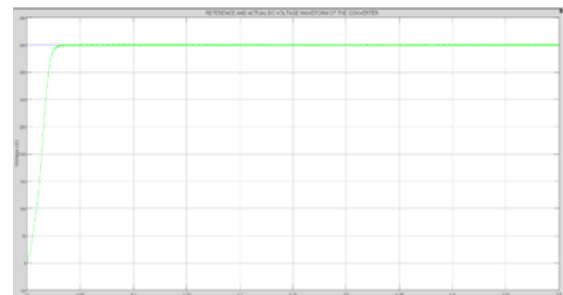


Figure 10: Ref and act voltage

Figure:10 Show the references and voltage in the simulation.

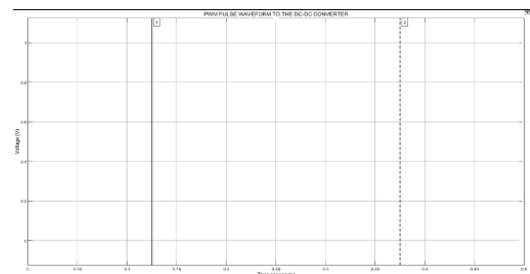


Figure 11: Pulse width modulation

Figure:11 Illustrates the PWM in the simulation.



Figure 12: Power and efficiency waveform

Figure: 12 Illustrates the power and efficiency waveforms obtained from the simulation.

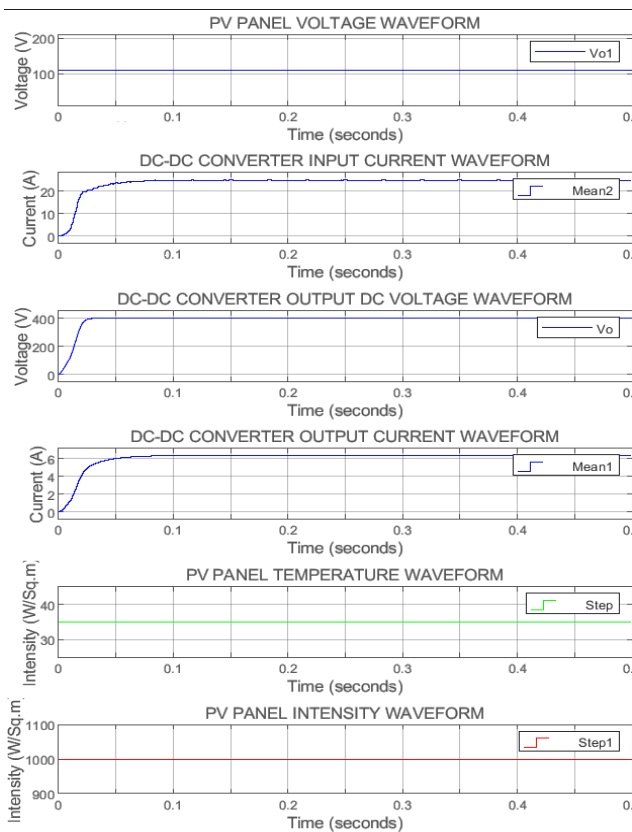


Figure 13: Converter side waveform

Figure:13 Presents the waveform of the converter's side in the simulation.

5. Conclusion

This project successfully demonstrated the feasibility and advantages of employing a quasi-Z-source converter (qZSC) for a solar PV system. Through detailed MATLAB/Simulink simulations, the performance of the qZSC was evaluated under various operating conditions, including varying irradiance and temperature. The simulation results confirmed the key advantages of the qZSC topology, such as Improved Power Quality, Enhanced Voltage Gain, and Inherent Impedance Matching. The PI controller effectively regulated the output voltage of the qZSC, achieving accurate tracking of the desired reference value with minimal steady-state error and fast transient response. The controller demonstrated robustness to disturbances and variations in operating condition.

The parametric study conducted during the simulations provided valuable insights into the impact of different impedance network parameters on the converter's performance. This information can be effectively utilized in the design and optimization of future qZSC-based solar PV systems. In conclusion, the simulation results strongly support the potential of qZSC technology for enhancing the performance and efficiency of solar PV systems. Further research and experimental validation are necessary to fully realize the practical implementation of qZSC-based systems in real-world applications.

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