DUAL CLOSED-LOOP SCHEME WITH LEAD COMPENSATOR AND P CONTROLLER FOR QUASI Z SOURCE INVERTER

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Abstract : Over the last decade, numerous control schemes have been proposed by researchers for quasi-Z source inverter (qZSI) to provide fast dynamic response and good transient performances. This proposed project is an effective tuning method of dual-loop controller based on lead compensator and proportional (P) controller for single-phase qZSI to ensure reliable DC-link power regulation. Specifically, lead compensator and P controller act as voltage control and current control loop, respectively, to generate the desired shoot through duty cycle feeding towards the unipolar carrier-based pulse width modulation (CB-PWM). The lead compensator contributes to move the system poles from the left to the right half of the s-plane while the P controller damps any high frequency oscillation occurrence caused by the newly sited complex conjugate pole pair. All simulation models and results which documented in this paper are carried out using MATLAB/Simulink software.

Index Terms - **Switched inductor quasi z source inverter, Boost inversion ability, Shoot through duty ratio, Total Harmonic Distortion.**

I. INTRODUCTION

In recent years, Power generation systems based on Renewable Energy Sources (RESs), such as photovoltaic (PV), wind power, and fuel cells (FC), have remarkably [1] increased worldwide as alternatives to the conventional generation systems as shown in Figure 1. The main reason is the huge increase in the energy demand. Moreover, being based on RESs, the systems [2] are considered as environment friendly. The main characteristic of RESs is that the primary energy widely varies in nature, where it depends on the temperature, irradiation level, wind speed, stored hydrogen, etc. Therefore, power electronic interfaces functioning as power conditioning units are required. These units must assure an output power with high quality that is able to cope with wide input voltage variations and meet the required IEEE standards [3].

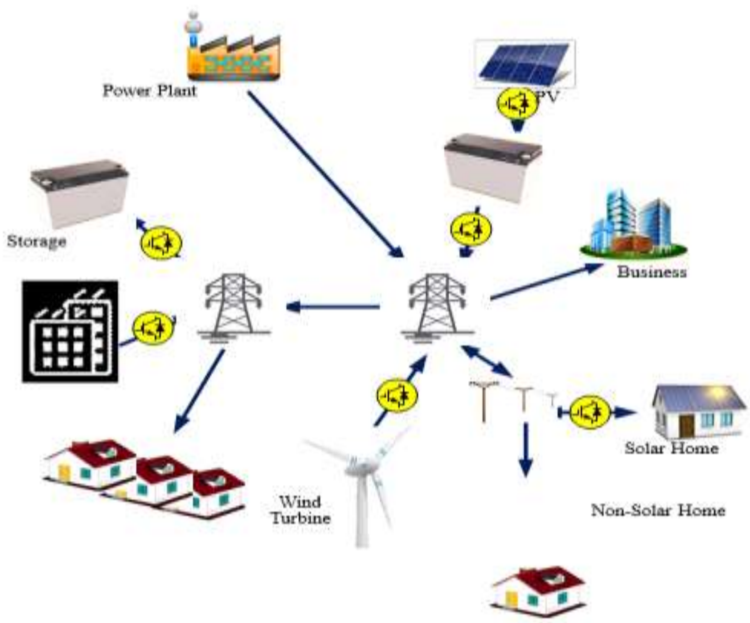

Figure 1. Power generation systems

The cost of power electronic systems represents a substantial portion of the overall installation, so these systems should work with a high efficiency in order to reduce the energy cost [4]-[6]. Batteries have become one of the most promising energy resources in recent years and have increased enormously in the markets. DC/AC inverter is designed as the core of the battery system that inverts DC to AC supply waveform to suit remote stand-alone application or off-grid power system.

II. EXISTING SYSTEM

Voltage Source Inverters (VSIs) have been extensively used in various power electronic applications, including energy-storage systems. However, VSIs has some limitations and constraints [7]. First, the ac output voltage is lower than the input dc voltage and for that reason they can be characterized as buck converters. In order to boost the input dc voltage to the desired dc-link voltage, an additional dc-dc boost converter is needed. Adding the dc-dc boost converter increases the complexity of the controller, decreases the overall efficiency, and increases the overall cost of the inverter [8]. Moreover, to avoid a shoot through (i.e. a short circuit) between the upper and the lower dc-link rails, a dead time is inserted between the pulses which in turn increase the distortion in the output current/voltage waveforms.

To overcome the aforementioned limitations of the VSIs, the impedance source inverters (ZSIs) were proposed as an alternative to the conventional VSI [9]. The ZSI fulfils the buck-boost function in a single-stage converter by utilizing a Z-source network which consists of two identical inductors, two identical capacitors, and a diode as shown in Figure 2. By employing an extra switching state, called *shoot-through state*, the ZSI can boost the input dc voltage to the desired dc-link voltage [10].

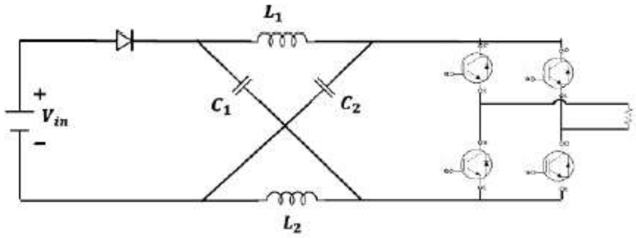

Figure 2. Single Phase Z source

This in turn increases the inverter operating range and improves its reliability since the mis-gating resulting from electromagnetic interference (EMI) does not affect its operation. In comparison with the traditional two-stage inverter (consisting of a dc-dc boost converter and a voltage source inverter), the ZSI comes with a better efficiency, simpler design, and reduced cost [11]-[15].

For dc-side of ZSI/QZSI, the PI controller is commonly applied control strategy and is the easiest to be realized. However, using a PI controller is not a good choice for the ac-side of ZSI/QZSI. Tracking the sinusoidal signal without steady-state error in the stationary frame is unfeasible by utilizing a PI controller [16]-[20]. Because of the limitations of using the PI controller on the ac- side, many researchers have developed new controllers in order to achieve good performance [21]-[25].

III. PROPOSED SYSTEM

The quasi-Z-source inverter (qZSI) was presented as an improved version of the classical ZSI as in Figure 3.

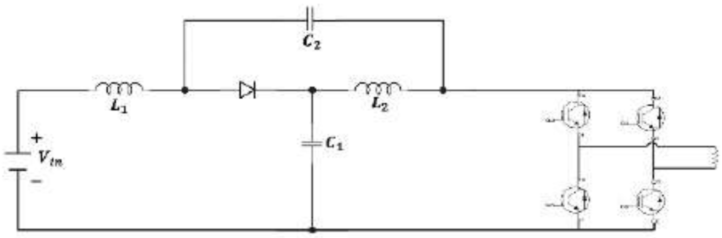

Figure 3. Single Phase qZSI

QZSI is one type of power inverter which can boost the DC input voltage and invert it to AC waveform in a single-stage topology. When compared with conventional DC-AC inverter which requires additional DC-DC converter to buck/boost the DC input voltage, the two series-connected switches from each phase-leg of qZSI can be turned on at the same time. This interval is referred to as the shoot-through state, which the inductors will be charged up. On the contrary, the inductors will release its stored energy and charge up the qZSI network's capacitors in active-state to achieve boosting effect. To achieve this good dynamic performance, we proposed the lead compensator and P controller with dual loop control strategy is proposed. It has many additional advantages such as continuous input current and joint earthing of the dc source and the dc-link bus. Moreover, the voltage of one of the quasi-Z-source network capacitors is significantly reduced resulting in a smaller passive components size. Taking into account the aforementioned characteristics, the qZSI can be considered as an attractive one for several power system applications. Later on, other advanced topologies have been proposed in order to improve the overall performance and efficiency.

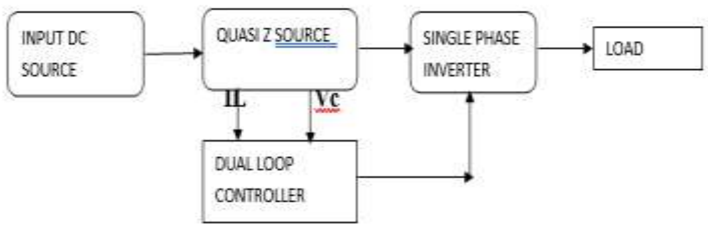

Figure 4. Block diagram of the proposed QZSI System

This project proposed system has DC input source, Quasi z source with an effective tuning method of dual-loop controller based on lead compensator and proportional (P) controller for single-phase qZSI to ensure reliable DC-link power regulation. Specifically, lead compensator and P controller act as voltage control and current control loop, respectively, to generate the desired shoot through duty cycle feeding towards carrier-based pulse width modulation and then to the inverter. To demonstrate the effectiveness and the feasibility of the proposed controller, the qZSI is simulated and results will be carried out using MATLAB/Simulink software.

IV. CIRCUIT TOPOLOGY

In the past five years, numerous control schemes have been applied to battery qZSI based system. Particularly, DC-link voltage control scheme has been developed to balance the DC-link voltage in qZSI network. In most cases, proportional-integral (PI) controller has been the most popular method to perform control actions. However, PI controller shows some drawbacks which include slow response speed as well as poor robust performance against the system uncertainties and exogenous disturbances. Also, there are several existing works revealed that the use of PI controller will lead to poor transient and dynamic responses as well as causing instability to the system when the system parameters and operating points are varying.

The aforementioned phenomena also apply to qZSI module itself, where the DC side impedance design and efficiency calculation methods are not established in any work. These include:

i. The relationship between the generated line voltage total harmonic distortion (THD) and the shoot-through duty cycles.
ii. The relationship between the generated line voltage THD and the modulation index.
iii. The relationship between the shoot-through duty cycles and the pulse width modulation (PWM) modulation index.
iv. The control scheme to provide direct control of shoot-through duty ratio based on different loading conditions.
v. The boundary condition at which the qZSI network will operate in continuous conduction mode (CCM) or discontinuous conduction mode (DCM).

So, we choose that, QZSI is one type of power inverter which can boost the DC input voltage and invert it to AC waveform in a single-stage topology. When compared with conventional DC-AC inverter which requires additional DC-DC converter to buck/boost the DC input voltage, the two series-connected switches from each phase-leg of qZSI can be turned on at the same time. This interval is referred to as the shoot-through state, which the inductors will be charged up. On the contrary, the inductors will release its stored energy and charge up the qZSI network's capacitors in active-state to achieve boosting effect. QZSI can operate in boundary, CCM and DCM. However, CCM mode is preferable because the input current will never fall to zero; hence, resulting in lower voltage stress and higher system efficiency.

The selection of switching frequency has direct proportional relation with the active suppression of THD and the dynamic response of a qZSI. Since a single-stage qZSI topology can be operated with considerable high-equivalent switching frequency (i.e., from 5 kHz [8] to 100 kHz [4, 9]), the qZSI based system will provide fast power compensation across the grid under different loading conditions. Nevertheless, the switching loss, conduction loss, and power handling of qZSI module should be taken into consideration in the design process. qZSI is no doubt the favourable inverter when compared with other DC-DC converters due to its smaller size of LC filters at high switching frequencies. Nevertheless, mathematical formulation to obtain the effective value of each passive component should be proposed to achieve a compromise between size, efficiency, switching frequency, and cost for a given power rating.

There are two capacitors in a qZSI network. Unlike inductor current, DC voltage of capacitors in qZSI network will never fall to zero in any operating mode (i.e., boundary condition, CCM and DCM). Till present, there is no existing work has been done to investigate the fundamental mathematical derivation of the steady-state small-signal equivalent circuit of battery qZSI based system.

V. SIMULATION OF THE PROPOSED SYSTEM

In this chapter, we will be focusing on the simulation of the proposed system by using MATLAB/Simulink R 2018b. The simulation will be done to find suitability of concept. The simulation diagram is shown in the Figure 5 consists of the proposed qZSI and its associated control scheme. The proposed lead controller and P controller maintaining a constant DC-link voltage of 280V from an input DC voltage source of 100V under AC loading conditions. The parameters selected for qZSI impedance network are $C1=C2=470$ micro Farad and $L1=L2=3$ milli Henry. The switching frequency used in the simulation is 10kHz. The desired overshoot percentage value used to design the compensator is 5%. The parameter of the PI control in the voltage control loop and P controller in the inner current loop are obtained by tuning the response speed for P controller.

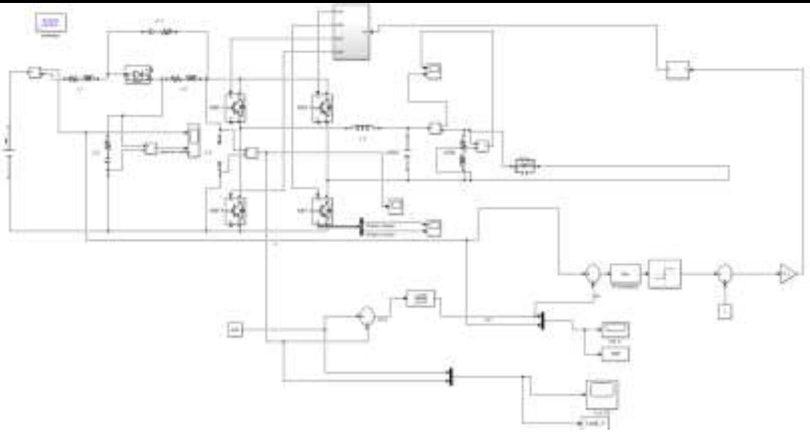

Figure 5. Simulation circuit of the proposed circuit

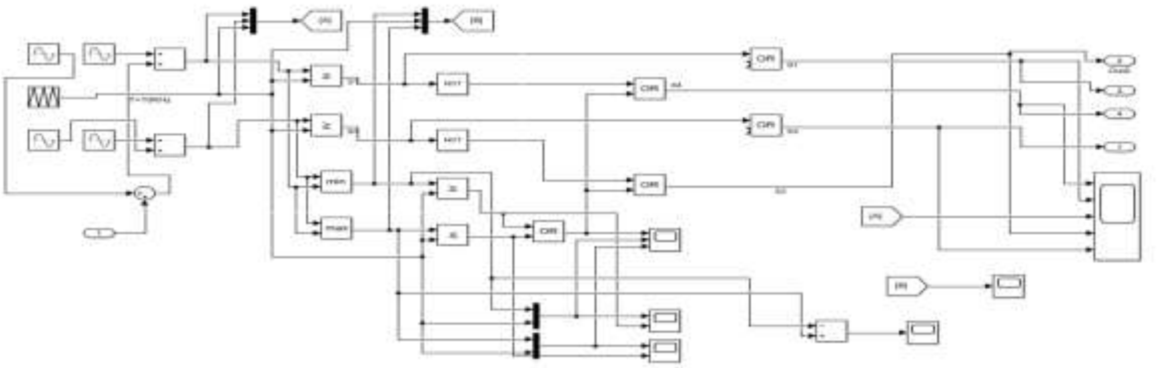

Figure 6. PWM Controller Block

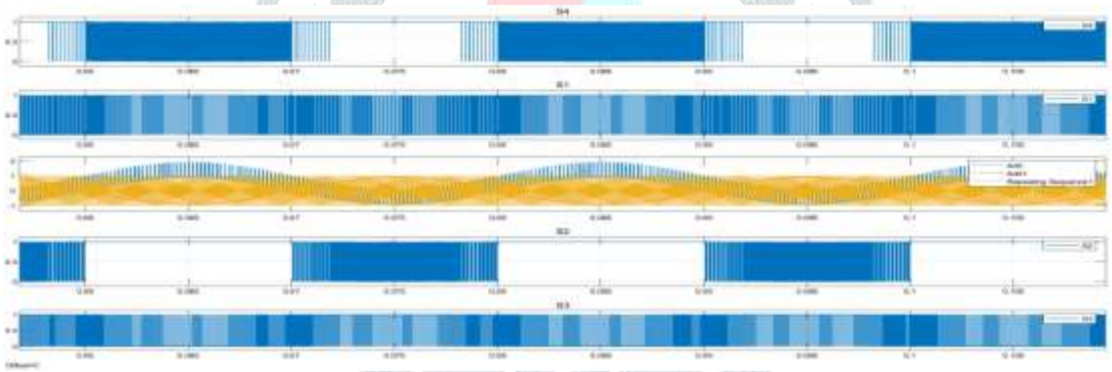

Figure 7. Pulse pattern

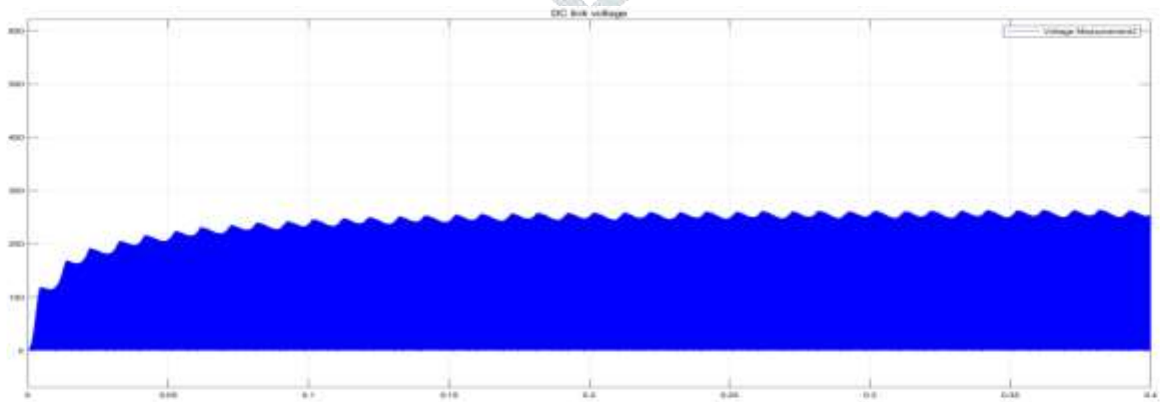

Figure 8. DC Link voltage (250 V)

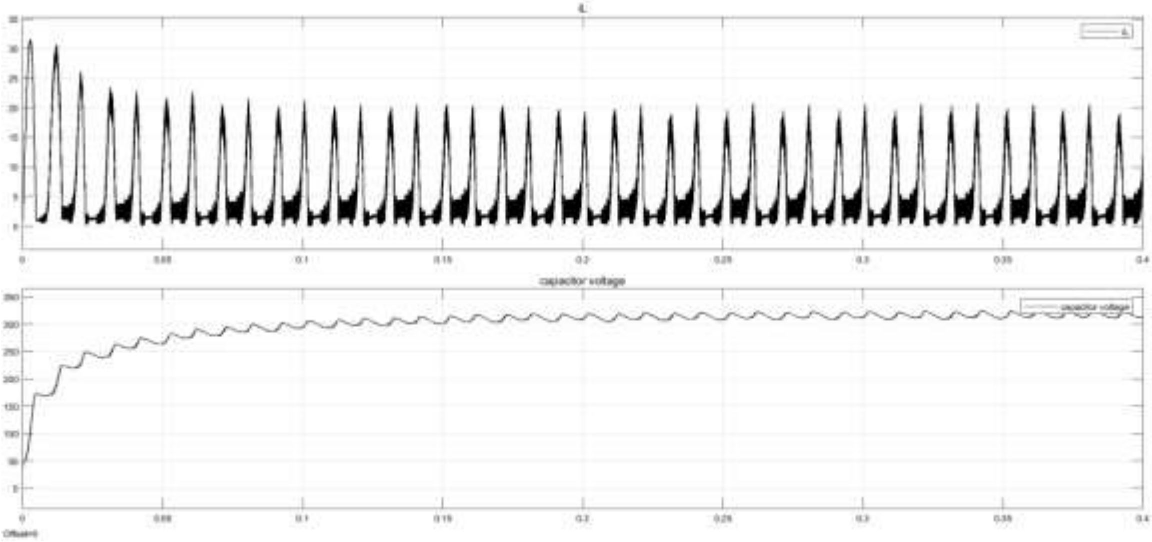

Figure 9. Inductor current (20A) and capacitor voltage (300 V) 33

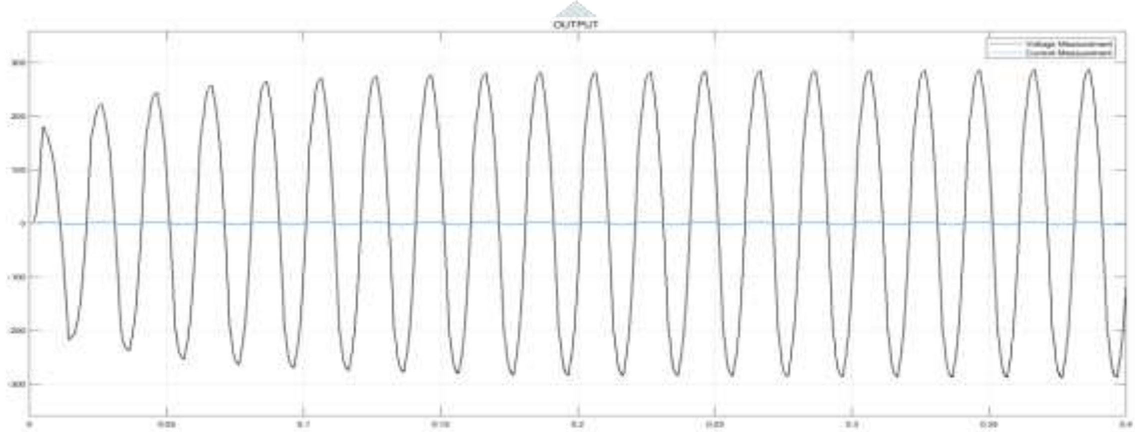

Figure 10. Output voltage (270 V) and Output current (2.5A)

Hence, the proposed system can be an excellent additional technology especially to Single stage conversion systems using QZSI with the above results. From the above figures, it can be observed that P controller associated with lead compensator is quicker in response. This is due to the fact that, it exploits the complete system knowledge and therefore easily enforces any desired behaviour. In this circuit the simulation results are taken for the verification of the circuit.

VI. CONCLUSION

In this paper, the small signal model of qZSI has been derived and analyzed. A lead compensator has been designed to improve the dynamic performance as well as the transient response of the qZSI via frequency response analysis. From the simulation results, it is concluded that the compensator is robust at which the design has fulfilled the requirement of the desired frequency and transient response of the system. Moreover, the proposed P controller and lead compensator was able to achieve zero tracking error. The proposed control strategy cultivates remarkable method to enhance the DC-link voltage stability through different loading conditions. Also, the proposed control method is simple to implement.

The simulation results in this project present a quasi-Z-source inverter with a new controller topology. The proposed qZSI inherits all the advantages of the ZSI and features its unique merits. It can realize buck/boost power conversion in a single stage with a wide range of gain that is suited well for application in renewable source power generation systems. Furthermore, the proposed qZSI has advantages of continuous input current, reduced source stress and lower component ratings when compared to the traditional ZSI.

VII. REFERENCES

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