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QUASI-Z-SOURCE INVERTER BASED WIND ENERGY CONVERSION SYSTEM WITH SIMPLE BOOST CONTROL

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Abstract- *This paper presents the quasi z-source inverter (QZSI) as an alternate converter system for the wind generation system. As QZSI inherits the main advantages of traditional Z-source inverter which replaces the conventional PWM inverter in the system with some of its additional utilities as well. This system will monitor the wind generator output and adjusts the inverter shoot-through duty cycle employing various boost control technique as per desired value. Thus, the whole system is modeled and verified through simulation where the system can provide stable voltage through proper selection of boost factor and has the suitability of maintaining the terminal voltage at desired level for the direct-driven wind power system.*

Keywords- *Wind energy; PMSG; Shoot through state; Simple Boost Control; QZSI.*

I. INTRODUCTION

The adaption of the renewable energy sources have been very important nowadays because of many reasons and among all one of them one is that the environmental impacts caused by the gases which are emitted by burning of fossil fuels used in conventional power stations which can be avoided, thus, the non-renewable nature of the fuel is used will threats the ability to continue producing electricity using it because it can deplete in any time in future, renewable energy sources are always available for utilization in electrical energy generation and storage[1], the main drawbacks of renewable energy generation are the complexity, increased cost, reduced efficiency and the reduced reliability of the renewable energy conversion system so, researchers are working on reducing all such drawbacks by developing a new types of converters and machines with high efficiency and reliability.

Presently there are mainly three drive systems available for wind power. They are Squirrel cage induction generator, double fed induction generator and Direct drive synchronous generator. PMSG based wind power generation system is been considered to be one of the mainstream systems in today's variable speed constant frequency wind generation technology area due to its lower weight and volume, high efficiency and stability, etc.[2] In the traditional PMSG the AC outputs from the generator are transformed to load via AC / DC / AC converters.

However, traditional VSI is a buck converter, whose input DC voltage must be greater than the peak AC output voltage. So, the voltage of VSI needs to be designed high enough, leading to high voltage stress and capacity of devices. Now to solve this issue, the boost circuit is been usually added in DC link to keep the DC bus voltage constant and thus will reduce the inverter stress, especially in the situations that the ranges of dc source voltage are relatively wide. Therefore, it will increase cost as well as reduce the efficiency of wind power generation system [3]. The main need of wind energy system is to maintain a constant voltage across load terminal consistently using minimum circuitry. One recent application for permanent magnet generator with AC series regulator is proposed in [5], but the control circuit looks complex in nature [4].

Impedance (z) source inverter proposed has replaced the conventional inverter which has the buck-boost capabilities of impedance (z) source inverter with the inclusion of z-network which will compensate both the generator output and the load variations. In respect to the recent advancements of the z-source inverter, this paper proposes QZSI that replaces the traditional inverter system and the suitability of the system is studied for effective conversion of single-phase wind power source into a grid-quality three phase power.

II. Basic Principles of QZSI

The QZSI is claimed to have several additional merits like lower passive component ratings, continuous input DC current and a common dc rail between the source and inverter, and also voltage stress on the capacitor is reduced which ultimately lower the voltage stress on the inverter as compared to the traditional ZSI. QZSI has an impedance network consisting of two capacitors and two inductors coupled between the converter and the dc source with a common ground between source and the load [6].

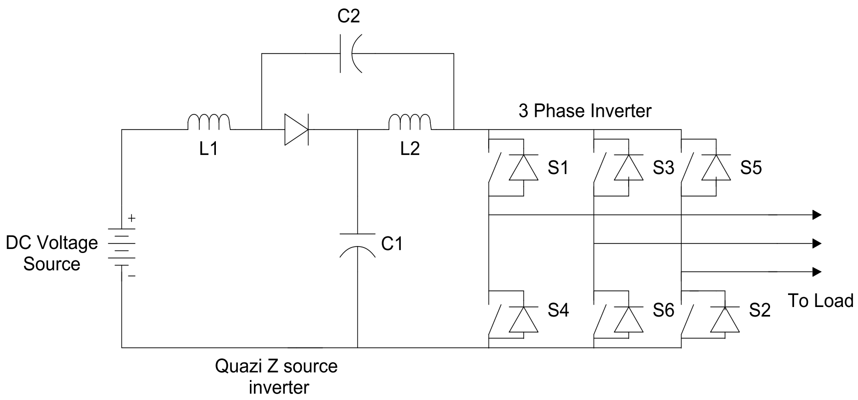

Figure 1. Quasi z source inverter

The quasi-Z-Source network is made of an LC impedance network, which can boost the DC link voltage of inverter with respect to the interval of shoot through zero states during a switching cycle. In QZSI, there is an addition shoot-through state than traditional VSI, which is advantageously utilized to boost a DC bus voltage. The equivalent circuits of QZSI in two basic operation modes which are illustrated in Figure 2.

In Figure 2 (a), the input DC voltage is available as DC link voltage input to the inverter, which makes the QZSI behaves similarly to a VSI. This mode will make the inverter operate in one of the six active states and two traditional zero states, which is referred to as the non-shoot through state.

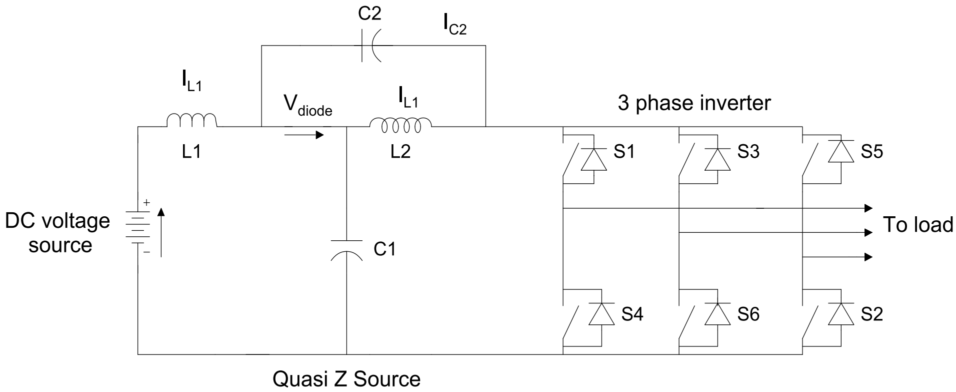

Figure 2(a). Equivalent circuit of QZSI for the Non-shoot through state

In Figure 2 (b), switches of the same phase in the inverter bridge are switched on simultaneously for a very short duration. The source, however, do not get short-circuited when attempted to do so because of the presence of LC network, while boosting the output voltage. The DC link voltage during the shoot through states is boosted by a boost factor, whose value will depend on the shoot through duty ratio for a given modulation index.

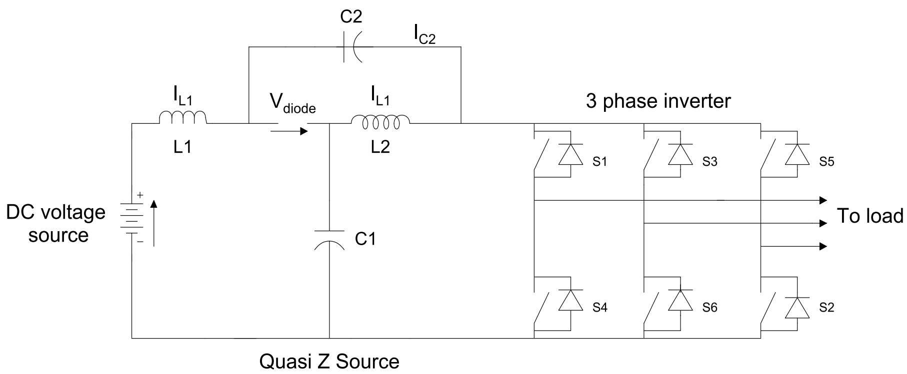

Figure 2(b). Equivalent circuit of QZSI for the Shoot through state

III. Control Techniques

Simple Boost Control

In this method, three modulating signals with 120-degree phase shift is when compared with frequency carrier triangular signal it will generate the switching pulse. The shoot-through for quasi z source inverter is been generated by comparing two straight DC lines with a carrier signal and the magnitudes of these DC lines are $+V_{sh}$ and $-V_{sh}$ is shown in figure 3. Now when the carrier signal is greater than $+V_{sh}$ or less than $-V_{sh}$ it will generate shoot-through pulses [7]. Now actual switching pulses for QZSI are then OR between conventional switching pulses to produce the modified pulses and the invert pulses.

The advantage of this PWM technique is that it is simple to implement but the main disadvantage is that total zero switching state is not utilized during the shoot through so the voltage stress across the switch is more as compared to other techniques. As all the switches turn ON during the shoot-through state so the switching loss is more [7] [8].

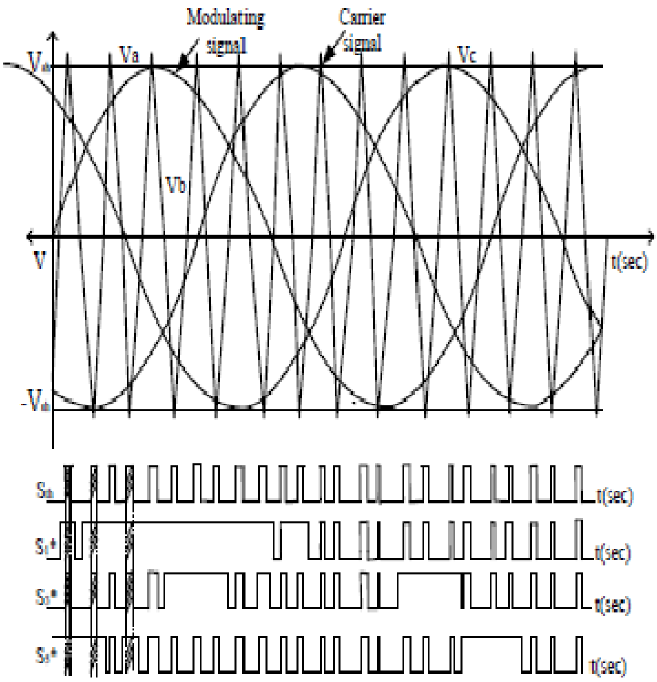

Figure 3. Modulating signal of simple boost control

The peak values of sine waves are as same as those of two straight lines, then the modulation index (M) and Do are dependent on each other and the relation between them can be written as

$$Do=1-M$$

Boost Factor is obtained by introducing shoot-through of minimally one leg of the inverter arm for a short period of time which is called as the shoot through time.

$$B = \frac{1}{1 - 2Do}$$

Where: To = Shoot Through Time
T = Switching Period
Do = Shoot through Duty Ratio
G = Inverter Gain

So,

$$G= BM = \frac{M}{2M-1}$$

The peak phase voltage of the QSZI is given by

$$Vac = M * B\frac{Vin}{2}$$

Here in Fig. 4 Overall system block diagram has been represented where various conversion of energy takes place where a wind turbine with permanent magnet synchronous generator (PMSG) is selected here and the three phase output voltage which is normally variable in nature is been rectified to DC and is connected to the inverter through the quasi z-source network which will provide continuous output voltage.

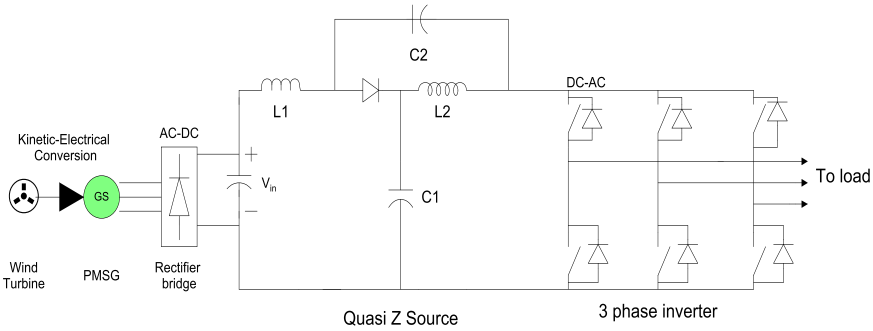

Figure 4. Overall system blocks diagram

IV. Simulation Results

Simulation is carried out for the proposed system under SIMULINK environment. Now in this simulation, the wind turbine, and QZSI parameters are taken as per values are given in the below table.

Now, as the boost factor decreases the oscillations becomes smaller, the system becomes faster and larger power is been injected and also higher rectifier output voltage is obtained until reaching optimum value smaller than it degradation in results starts occurring and thus the Simulation is performed at 3 different wind speed 14, 12,10m/s.

Table 1. Simulation Parameters

System parameter’s	Values
Rated Power of PMSG	2kW
Pole pairs	4
Stator resistance	0.9585Ω
Armature inductance	0.00525H
Switching frequency	10Hz
QZSI Inductance L1=L2	5mH
QZSI Capacitance C1=C2	20μF
R_{load}	77.45Ω
L_{load}	1.82H

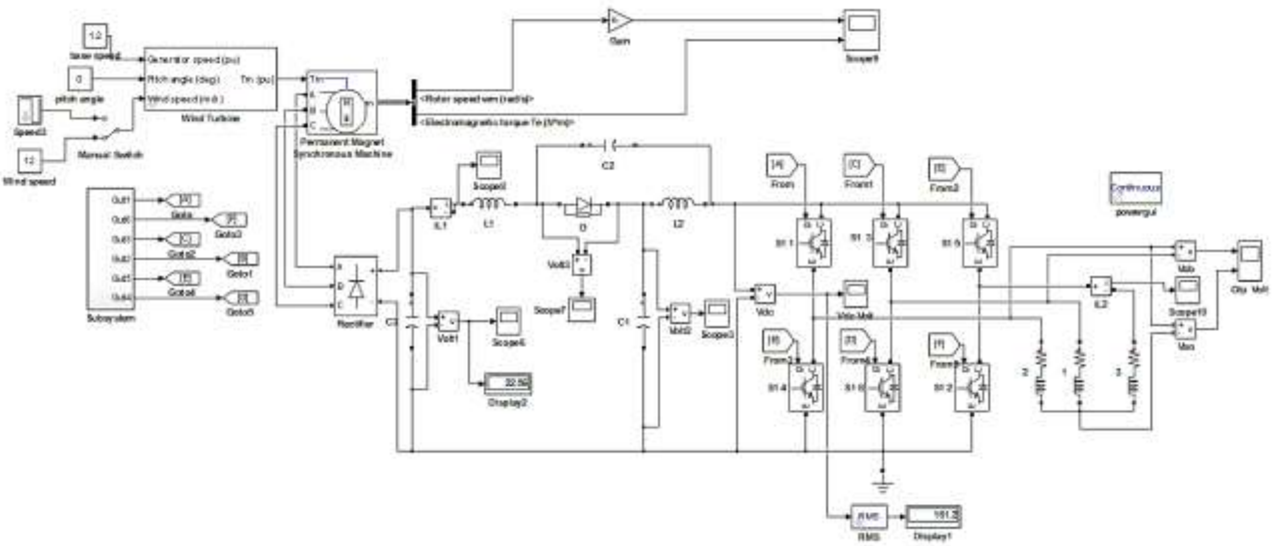

Figure 5. MATLAB model of QZSI with wind system

All the simulation results given below are obtained from the model of QZSI with wind system has been given. The different waveform's are for the line to line output voltage, capacitor voltage, DC link voltage, diode voltage.

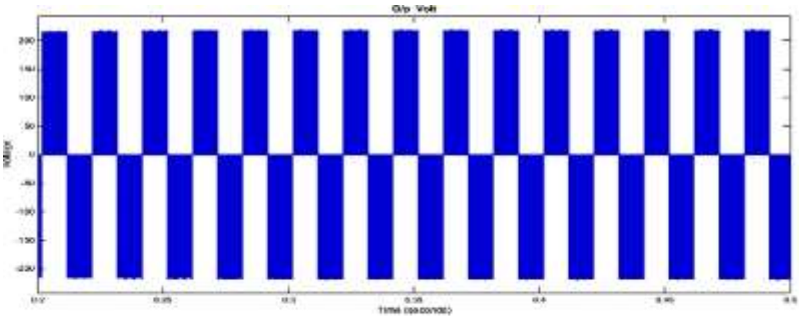

Figure 6. Line to line output voltage

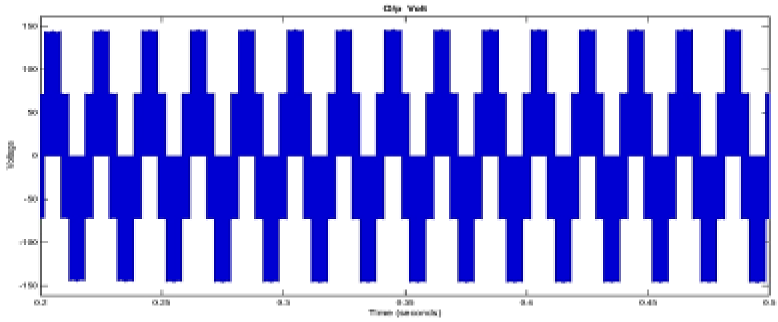

Figure 7. Output Phase voltage

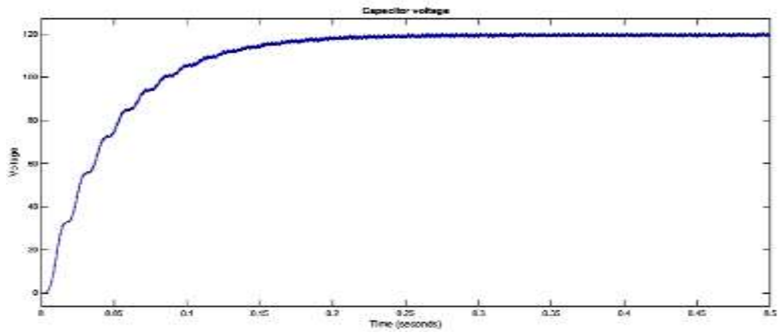

Figure 8. Capacitor voltage

Figure 8 shows the capacitor voltage in the state when the shoot through state has applied the voltage across the capacitor is been charging and thus after some seconds it will be constant which is depend upon the boost factor.

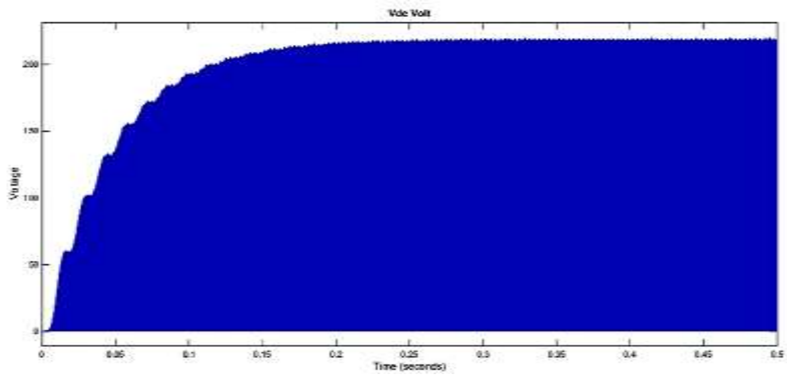

Figure 9. DC link voltage

Figure 9 shows the DC link voltage across the inverter which gives us the continuous input voltage and acts as input to the inverter. In the initial cycle, it is in the non-shoot through state which after a few cycle gives us continuous voltage.

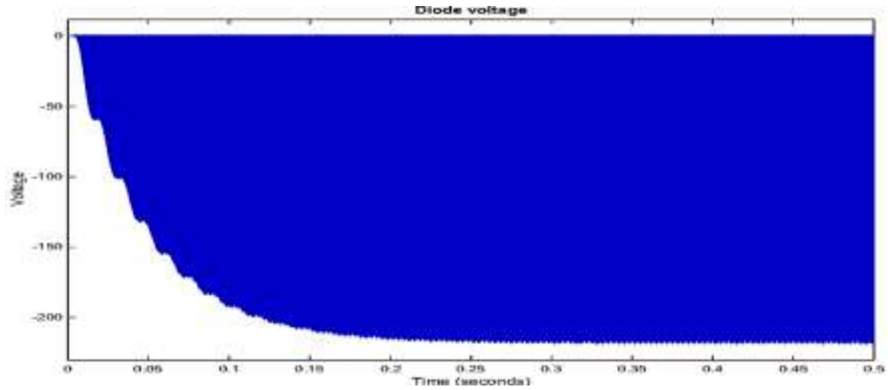

Figure 10. Diode voltage

In figure 10, it is the diode voltage which is the negative voltage due to the shoot through state because in this condition diode will act as a reversed biased.

Table 2. Simulated result at different wind speed

V_{wind}	V_{in}	V_{c1}	V_{c2}	V_{dclink}	V_{diode}
14	34.8	183.5	148.7	332.2	-333
12	22.6	120	97	217	-218
10	11.6	59.5	46.6	106.2	-107

V. Conclusion

A permanent magnet synchronous generator wind power generating system based on quasi-Z-Source inverter is presented in this paper and with the help of traditional SPWM technique which makes it suitable for the special shoot-through characteristic of QZSI and with the use of properly selected boost factor, the DC-link boost voltage is controlled and the AC-side output control has been designed to reduce the effects of voltage fluctuations on the load. The effectiveness of the proposed controllers has been verified by simulations and thus result from shows that it provide us continuous output voltage. Thus, the presented system will illustrates a significant method to reduce voltage fluctuations compared with the traditional wind power generation system.

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