Abstract: This paper compares the control strategies of Quasi z source inverter for wind power generation. The generator in the conventional wind energy conversion system uses kinetic energy from the wind to produce electrical energy. Owing to wind fluctuations, the generator's output is connected to the load via a rectifier and inverter to keep the voltage at the load side constant. The 2-stage conversion phenomenon has its limitation of being expensive along with possessing lower efficiency. Z source inverters offer a novel conversion approach and can utilized to alleviate the limitations. However, they come with certain downsides as well, such as unequal input current, high inrush current, and high voltage stress. The quasi-Z source inverter (QZSI), a single-stage power converter based on the Z source inverter topology, can overcome it. It performs this by using an impedance network that couples with the source and the inverter to provide a voltage boost for the wind power generating system. In this paper, a comparative study of different control strategies of quasi-z source inverter is performed for a wind power system to find out one efficient strategy.

Keywords: Quasi z source inverter, shoot through state, simple boost control, maximum boost control, maximum constant boost control.

I. INTRODUCTION

For the renewable power generation, various components such as generators, rectifiers, inverters, converters etc. are widely used. In situations wherein higher voltage output is desired we employ a boost converter along with the voltage source inverter. Albeit the said approach adversely impacts the system cost, volume and efficiency. Therefore, an impedance source network, or Z source network, is used for the combined operation of boost-up and inverter in a single stage, as it helps mitigate these challenges [1] [2].

Z-source inverter utilizes an impedance network between the source and inverter circuit, which enables the combined operation with a voltage boost by turning on both switches of a single phase. Previously this was not achievable while using the conventional inverters.

The Z-source inverter operates in nine different states in which six states are active, two are zero states, and there is an additional shoot-through state. It comprises of two operation modes: shoot-through mode and non-shoot-through mode. During the non-shoot-through mode, it operates like the six active states of a conventional inverter, whereas during the shoot-through mode, it shortens the phase lag in 7 different ways. [2] [3]

Limitations of Z source inverters includes unequal input current, high inrush current, and high voltage stress. These limitations can be addressed by employing modifications in the impedance network, which is termed as a Quasi Z
source inverter [4]. The modified version will operate similarly to the original, but it overcomes the limitations of the Z source inverter. The circuit for the Quasi Z source inverter is illustrated in Figure 1.

As compared to the conventional inverter in a Z-source inverter, while operating in a shoot-through mode for preventing the damage in circuit the switches of only a single leg are ON. There are numerous control strategies employed to control the Z-source inverter, permitting it to operate in the shoot-through mode and further boost up the voltage level. The next section will explain some widely used control strategies.

II. CONTROL STRATEGIES

A. SIMPLE BOOST CONTROL (SBC)

This control strategy resembles with the traditional wherein the six active states and two zero states of SPWM. In addition, two more straight lines are added which includes a positive line equal to the positive peak value of sinusoidal voltage, and a negative line equal to the negative peak value of sinusoidal voltage [5]. The inverter operates in the shoot-through mode in the condition when the triangular signal is higher than the positive straight line and lower than the negative straight line which leads to a higher stress on the device due to less modulation index. This results in higher voltage stress across devices in this method. Control strategy is depicted in Fig. 2.

B. MAXIMUM BOOST CONTROL (MBC)

For reducing the high voltage stress across the switches of inverter and increasing the shoot-through duty ratio, the zero states in the shoot through is utilized, which increases the boost factor. In this approach, the six active states are the same as traditional SPWM. The carrier wave is a triangular wave and the modulating wave is a sine wave. To control the shoot-through state, the triangular waves are compared with the maximum values of all three-phase sine waves. If the triangular signal is greater than the positive peak values of any phase sine wave and is less than the negative peak values of any phase sine wave, then the inverter operates in a shoot-through state. The duty ratio varies in maximum boost control, leading to variations in the voltage across the capacitor and the current.
flowing through the inductor [6]. This leads to the higher values of passive components. The maximum boost control is illustrated in Fig. 3.

C. MAXIMUM CONSTANT BOOST CONTROL (MCBC)

This control method reduces the voltage stress across switches simultaneously it maintains a consistent shoot-through duty ratio along with a high boost factor. Additionally, it also utilizes the zero state of a traditional inverter. The strategy involves two periodic envelopes with a frequency thrice the reference frequency and employs five modulating signals [6]: three sine waves Va, Vb, and Vc, and two shoot-through envelope signals Vp and Vn. Triangular wave is compared with the positive envelope Vp and the negative envelope Vn. The inverter operates in the shoot-through state when the triangular wave is greater than Vp and less than Vn, whereas in rest of the conditions, it operates in the non-shoot-through mode which is equivalent to the traditional inverter's active state. Maximum constant boost control is shown in Fig. 4.

For designing the inverter circuit parameters, finalization of the optimum values of components is done using standard formulas mentioned below: [7]

- Input DC voltage of 3 phase inverter
\[ V_i = \frac{V_{(L-L)\text{rms}}}{0.612\ M} \]

Where, M is the modulation index

- Output DC voltage of Z source impedance network as well as input of the 3-phase inverter is
  \[ V_l = B \times V_{in} \]

Where B is the boost factor and Vin is the input DC voltage of Z source impedance network

Value of the Z source impedance network parameters can be found by following formulas [8],[9],[10],[11]

- Average current through the inductor is
  \[ I_L = \frac{P}{V_{in}} \]

Where P is the total power

- Due to maximum shoot-through, maximum current ripple (\( \delta_i \)) in inductor current appears. The peak-to-peak current ripple is
  \[ \Delta I_L = 2\delta_i\% I_L \]

- During shoot-through state
  \[ V_{L1} = V_{C1} + V_{in} = V_{L2} = V_L \]

- The inductor value can be calculated by
  \[ L = \frac{V_L DT_s}{\Delta I_L} \]

- The capacitors value can be calculated by
  \[ C = \frac{I_L D T_s}{\Delta V_c} \]

Where, \( \Delta V_c = \frac{r\% V_L}{T_s} \) & \( T_s = \frac{1}{f_s} \)

<table>
<thead>
<tr>
<th>parameters</th>
<th>SBC</th>
<th>MBC</th>
<th>MCBC</th>
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<td>( R_{ph} )</td>
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<td>( L_{ph} )</td>
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<td>( C_f )</td>
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<tr>
<td>C</td>
<td>11.9 ( \mu )F</td>
<td>51.49 ( \mu )F</td>
<td>34.09 ( \mu )F</td>
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IV. SIMULATION AND RESULT

After designing the inverter, simulations are performed to compare three strategies for a wind power generation application. The circuit network is given in Fig. 5.

Fig 5 Quasi Z source inverter-based wind power generation

A. Results of Simple boost control

After simulating the SBC model, following results obtained.
Fig. 6 (a) capacitor C₁ voltage (b) capacitor C₂ voltage (c) DC link voltage (d) & (e) output line and phase voltage before filter (f) & (g) output line and phase voltage after filter (h) output current after filter for SBC method

B. Results of Maximum boost control

After simulating the MBC model, following results obtained.
Fig. 7 (a) capacitor $C_1$ voltage (b) capacitor $C_2$ voltage (c) DC link voltage (d) & (e) output line and phase voltage before filter (f) & (g) output line and phase voltage after filter (h) output current after filter for MBC method
C. Results of Maximum constant boost control

After simulating the MCBC model, following results obtained.
From the Simple Boost Control strategy, it is observed that the voltage of capacitor $C_1$ is higher than that of capacitor $C_2$. The output voltage is boosted up to 2.5 times the input voltage as the peak value of line-to-line voltage, as shown in the figure. The peak value of the DC link voltage is the same as the peak value of the line-to-line voltage.

In the case of maximum boost control, the capacitor voltage is higher than that in the case of simple boost control. The output voltage is boosted 6.314 times higher than the input voltage, which is shown in the waveform. A large boost factor is observed in the maximum boost control strategy. Additionally, the capacitor voltages remain constant as compared to that in the simple boost control, likewise transients are less as compared to the simple boost control.

From the results of MCBC it is observed that the capacitor voltage is higher as compared to that in the simple boost but lower than that of maximum boost control. From MBC and MCBC results, it is observed that the transient time reduces and the steady-state time increases as compared to the SBC. Additionally, higher boost voltage is achieved than that with the SBC.
Following table shows the comparison between three strategies.

<table>
<thead>
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<th>Parameters</th>
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<td>$V_{C2}$</td>
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<td>THD %</td>
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V. CONCLUSION

It has been observed that at the same voltage and the modulation index, a simple boost converter (SBC) has the lowest boost factor, while a maximum constant boost (MCBC) converter has the highest boost factor. However, due to the variation in duty cycle in MBC, the inductor current ripple leads to a higher passive component values. The MCBC possesses a higher boost factor with a constant duty ratio, utilizing the lowest value of passive components Additionally the voltage stress of the SBC is the highest, while the MBC has the lowest, and the MCBC has slightly higher stress than the MBC. Comparing the total harmonic distortion (THD) analysis of the output voltage, the MCBC has the lowest harmonics in the output voltage. Based on the above results it can be deduced that the MCBC is an efficient strategy for use in wind power generation.

References