# Hybrid Two Stage Quasi Z Source Boost Converter for Photovoltaic Applications

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***Abstract:*** *This paper presents a Hybrid Two Quasi Z-source(HTQZS) DC-DC converter for photovoltaic applications. These are mainly employed to full fill the demand of the voltage boost in photovoltaic applications from the lower value voltage. The traditional z source networks have some limitations in voltage boosting, so the modified z source means the different combination of the LC components is combined to form the hybrid quasi z source networks. This hybrid two quasi z source dc-dc converters can be applied for the dc-ac, ac-ac, and ac-dc conversions. The structure of the proposed converter is simpler. This converter adds the benefits to the traditional z source converter. This converter draws the continuous input current. The converter simulated is the combination of two different quasi z source networks. This converter uses the duty cycle less than the traditional z source network and gives the more gain than that. PV panel used as source to converter and then the output is inverted and step up.*
***Key words:*** *PV panel, MPPT, HTZS.*

## I.    Introduction

Nowadays the use of power is increased because of the increased population and use of more number of electronic equipments among which some will be high power rated devices. So there is a demand for large amount of power generation in these days and even it will keep increasing in the future generation. So technologies are developed to generate the large amount of power using the available sources of energy in the nature, which is cost efficient and environmental friendly. The renewable energy sources are available in the form of sun, wind, tidal, biomass and others. Using sun as the source of energy photovoltaic systems are developed.

But the output obtained from the photovoltaic panels is of low value, so there is a need of step up of the output voltage from the PV panels. Because the low value voltage cannot be provided to the inverters. Hence the design oh step up dc-dc converters is most. important in PV systems. Till now, many voltage-boost topologies have been explored, namely voltage multiplier, switched-inductor, switched. capacitor, coupled-inductor, voltage. lift, and cascaded, boost techniques. But these methods are all not simple and have less efficiency and more costs.

Many DC-DC converters can either buck or boost the voltages. The converter fed with voltage will buck the voltage and boost when fed with the current. The Z source converters are those which can do both buck and boost operation and these inverters found applications as active filters to improve the quality of power. The required output obtained from these inverters by varying the shoot through duty ratio. Mitigation of voltage sags can be done using these inverters as they boost the voltage and they provide reliability, flexibility, and reduced harmonics. By controlling the shoot through period makes the z source converter to produce the voltage higher than the line voltage and because of this they are used in compensation of voltage when there is reduction of voltage level in power systems[2].

The Z Source inverter has become a more interested stream because of its buck-boost. inversion capability. Along with the aforementioned. advantages, the original ZSI also has. some drawbacks, such as discontinuous. input current, high voltage. stresses and limited boost, factor $1/(1-2Ds)$ ($Ds$ is the shoot-through duty cycle). On top of that, the dc, voltage source and the inverter bridge do not share a same ground. To overcome. such limitations in the original ZSI, various novel impedance-source network, topologies have been presented in numerous works done by various authors. Among the changed Z-source. network topologies, quasi-Z-source network is a simple but efficient solution.

The proposed converter in this paper has some additional features compared to the traditional Z-source topology, like continuous input. current, and reduction in capacitor, voltage stress. The hybrid two quasi z source boost dc to dc converter is the combination of the two different QZS networks

The traditional z source inverters have some disadvantages among them discontinuity in the current is significant and also the voltage stress on the capacitors and to overcome such drawbacks different combination L and C circuits are formed namely quasi z source networks.

Quasi z source network has both current fed topology and voltage fed topology which is similar to the z source network. Disadvantages with the z source converter are discontinuity of input.current, greater.voltage stress on Switch is more. The *Lf-Cf* output filter is used to reduce ripple in the output.current and load voltage respectively [2]. In the reference [21] & [22] authors have used the MPPT algorithm to obtain the maximum power while harnessing the solar energy.

## II.    Configuration Of Hybrid Two Quasi Z Sorce Converter

The hybrid two quasi Z-source dc-dc converter with the PV panel and inverter is shown in the figure 3. The varied voltage from the PV panel is applied as input to the hybrid 2 quasi z-source converter to obtain the boost output voltage with low duty ratio. The output from the converter is given to the inverter for DC to Ac conversion purpose and then to the load.
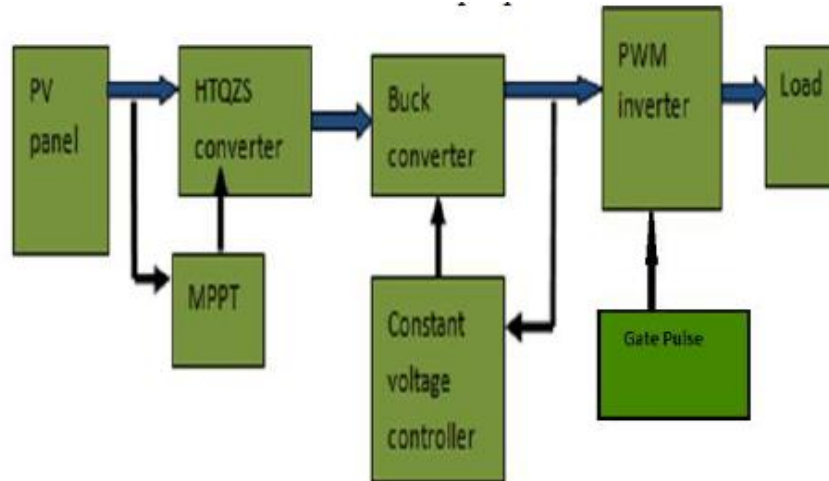
**Fig.3.** Block diagram of the proposed converter.

## III.    Operating Principles Of The Two Quasi Z-Source Converter

State 0: In this period switch is turned ON. The voltage developed across the capacitors reverse bias the diodes. Capacitors discharge and magnetize the inductors. C2 magnetize the L1. C1, C3, C4 magnetize the L2, L3. During this state energy will be stored in the inductors. There is continuous input current.

According to KVL, the voltages across inductors L1, L2, and L3 can be expressed as

$V_{L1} = Vin + Vc2$ ; $V_{L2} = VC1 + VC4$ ; $V_{L3} = VC1 + VC3$; (1)

Because of the symmetry in the circuit shown in fig2. (L2 = L3, C3 = C4), we obtain

$V_{L2} = V_{L3}$; $VC3 = VC4$; (2)

State 1: In this mode switch is turned OFF. Capacitors will now be charged by the energy released by inductors which has been stored in this previous mode. Even in this mode there is a input current. The energy released by the inductors is transferred to the load side.

$V_{L1} = Vin – VC2$; $V_{L2} + V_{L3} = - VC2$; $VC3 + VC4 = VC2$; $VO = VC1 + VC2$; (3)

By applyiing the voltage 2nd balance principle to the inductors L1 and L2 (or L3), from (3.1) - (3.3) we have

$$V_{C1} = \frac{1-2D}{1-3D} Vin; \qquad V_{C2} = \frac{2D}{1-3D} Vin; \qquad V_{C3} = V_{C4} = \frac{D}{1-3D} Vin;$$

$$V_O = \frac{1}{1-3D} Vin; \qquad (4)$$

Therefore, the *M* (voltage gain) of the proposed converter is given as

$$M = \frac{V_o}{V_{in}} = \frac{1}{1-3D} \qquad (5)$$

In the above equation, we can observe that the step-up ability of the proposed hybrid Z-source network is greater than that of the traditional Z-source networks [3].
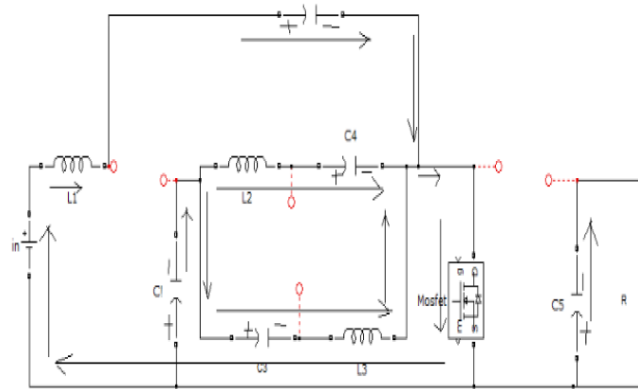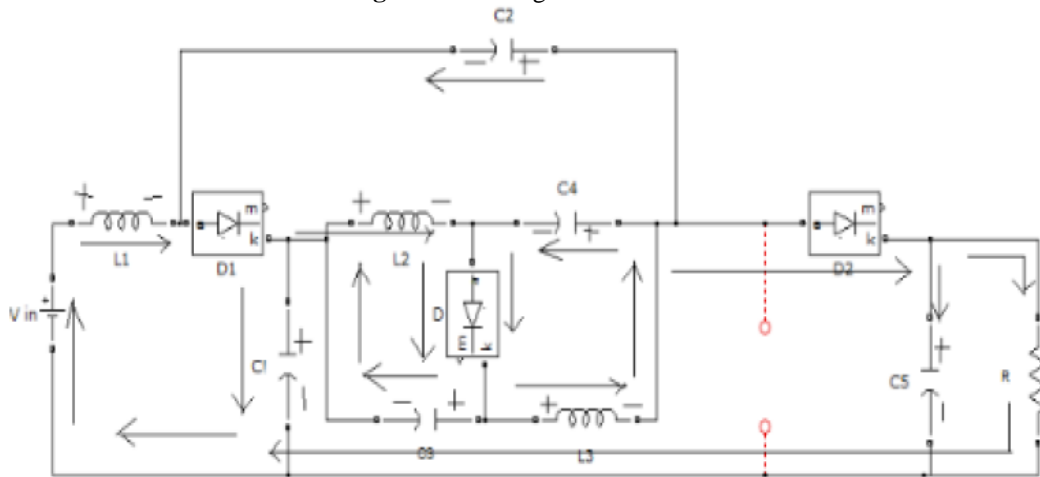
**Fig .4** Circuit diagram of state 0.



**Fig. 5.** Circuit diagram of state 1.

## IV. Parameter Design

In general, the design of parameters of a dc to dc converter depends on the components voltage.and current stresses which are mentioned in table I and II. The hybrid two-quasi-Z-source.dc-dc converter parameters design is illustrated.

### Parameter Design of Inductor

The maximum acceptable ripple in current of the inductor is assumed to be xL%. When the HTQZS.operates in state 0 the equation obtained is

$$L = \frac{v_L dt_L}{di_L} = \frac{v_L DT}{x_L\% I_L} = \frac{v_L D}{x_L\% I_L f} \tag{6}$$

where dtL = DT is the duration of state 0, diL = xL%IL is the ripple in the current of the inductor in the state 0, f = 1/T is the frequency of switching pulses.

Replacing the expressions of vL and L in the above equation the inductances of L1, L2 and L3 can be expressed as,

$$L1 = L2 = L3 = \frac{D(1-D)V_{in}}{(1-4D)x_L\% I_{in} f} \tag{7}$$

### PARAMETER DESIGN OF CAPACITOR

The maximum acceptable ripple in the voltage of the capacitor is considered as xC%. When the proposed topology operates in state 0, the equation mentioned below is derived.

$$C = \frac{i_C dt_C}{dv_C} = \frac{i_C DT}{x_C\% v_C} = \frac{i_C D}{x_C\% v_C f} \tag{8}$$

where dtC = DT is the time interval of state 0, dvC = xC%VC is the voltage ripple of the capacitor during state 0.

Substituting the expressions of iC and VC in the above equation, the capacitances of C1, C2, C3 and C4 can be derived.

$$C1 = \frac{2D(1-3D)I_{in}}{(1-2D)x_C\% V_{in} f} \quad C2 = \frac{(1-3D)I_{in}}{2x_C\% V_{in} f} \quad C3 = C4 = \frac{(1-3D)I_{in}}{x_C\% V_{in} f} \tag{9}$$

**Parameter Design of Switching Device**

The power switch and diodes are choosed with respect to their voltage and current.stresses, as shown in table I and II.

**Table I.** Voltage Stresses of Switches and Diodes

| Hybrid Two Quasi Z-source Boost DC-DC Converter | |
|---|---|
| **Parameters** | **Voltage stress** |
| C1 | $\dfrac{1-2D}{1-3D}Vin$ |
| C2 | $\dfrac{2D}{1-3D}Vin$ |
| C3,C4 | $\dfrac{D}{1-3D}Vin$ |
| D1,D2,D3 | $\dfrac{1}{1-3D}Vin$ |
| S | $\dfrac{1}{1-3D}Vin$ |

**Table II.** Current Stresses of Switches and Diodes

| Hybrid Two Quasi Z-source Boost DC-DC Converter | |
|---|---|
| **Parameters** | **Current stress** |
| L1, L2, L3 | Iin |
| D1 | $\dfrac{I_{in}}{1-D}$ |
| D2 | $\dfrac{I_{in}}{(1-D)^3}$ |
| D3 | $\dfrac{1-3D}{1-D}Iin$ |
| S | 3Iin |

## V. Perturb and Observe algorithm

By observing and adjusting the power by varying the voltage is carried out to obtain the maximum power point. Here in the below diagram shows variations in the voltage and power can be observed. In region1 if voltage is varied in positive direction maximum power point can be obtained, if this voltage varied in negative direction then it moves away from the maximum power point. In region2 if the voltage is varied in the positive direction then it is the movement away from the maximum power point and vice-versa.
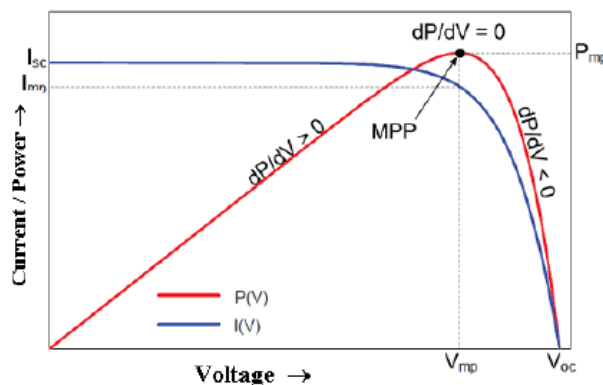


**Fig. 6.** Graph of the current/power versus voltage of PV panel.
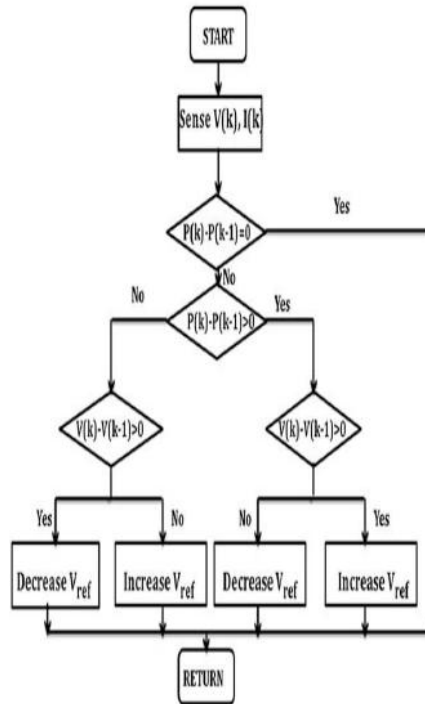
Fig.7. Flow chart of P&O algorithm.

The implementation of P&O algorithm is comparatively easier than other algorithms. So complexity involved in computational process in this method is reduced. Hence applicable to many of the PV devices. The main information it requires is PV voltage. Due to this, the P&O is one of the most-often used MPPT method in these days. The two main cons of this method are the 58 oscillations around the maximum power point in steady state conditions, and under rapidly-changing irradiation values poor tracking may occur.

## VI.    Results And Discussion

Here in this simulation circuit the frequency of switching pulses of the converter's switching device is 30KHz. The results obtained for irradiance value of 1000w/m2. Buck converter is used to obtain the output voltage with unchanged value for variable voltage applied at the input side. Pulses for the PWM inverter switching devices is obtained using pulse generator with duty cycle 25% and frequency is 30kHz. For Vin at 21.58V the obtained output DC voltage is around 78.35V w.r.t. the duty cycle(D = 0.25). This output is supplied as input to the buck and then to the PWM inverter to generate the AC output and finally stepped up using transformer.
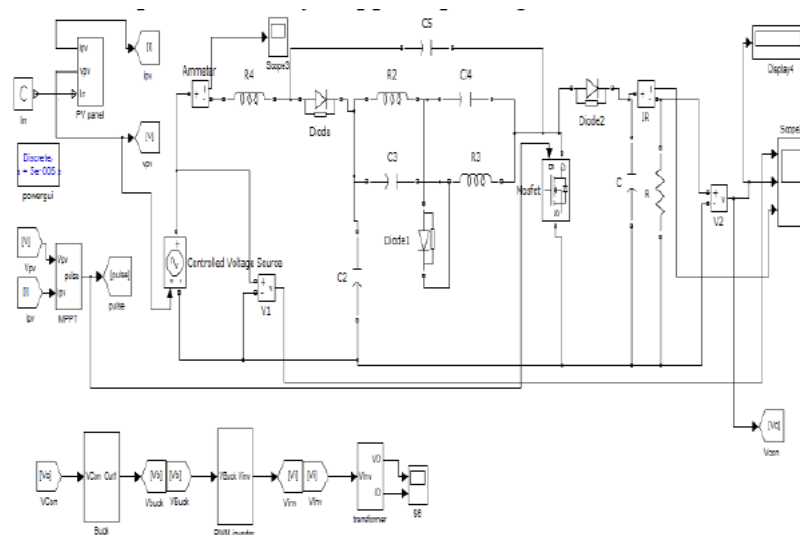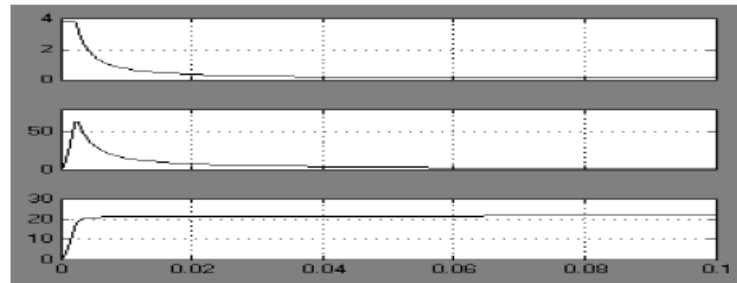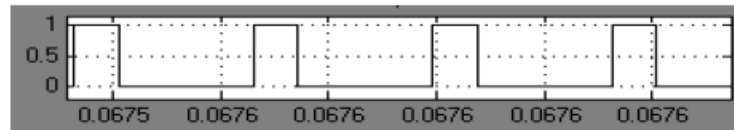


**Fig 8.** Simulink model of HTQZS converter for photovoltaic applications..

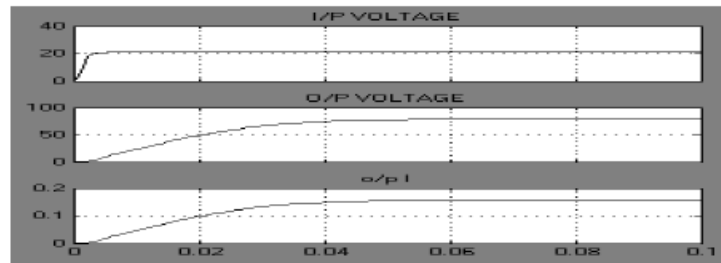**TABLE III.** OUTPUT VOLTAGES ACROSS PV AND Z-SOURCE CONVERTER

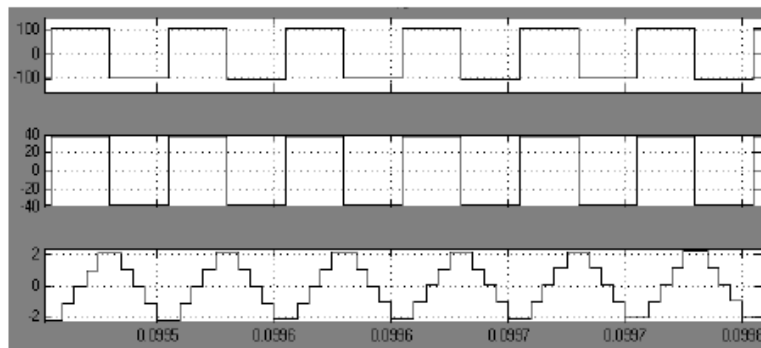| Irradiance Value (W/m$^2$) | PV output voltage (V) | Proposed converter o/p voltage (V) |
|---|---|---|
| 500 | 20.59 | 74.24 |
| 600 | 20.85 | 75.30 |
| 800 | 21.26 | 77.00 |
| 1000 | 21.58 | 78.35 |

**Fig 7.** Simulation waveforms (a). waveform of PV panel output current,power and output voltage; (b). waveform of MPPT pulses; (c). waveform of H2ZS converter's input voltage,output voltage and current; (d) transformer and pwm inverter output voltage and output current respectively. The waveforms of the output voltage of PV and converter are obtained. As per irradiance values different voltage values are obtained.
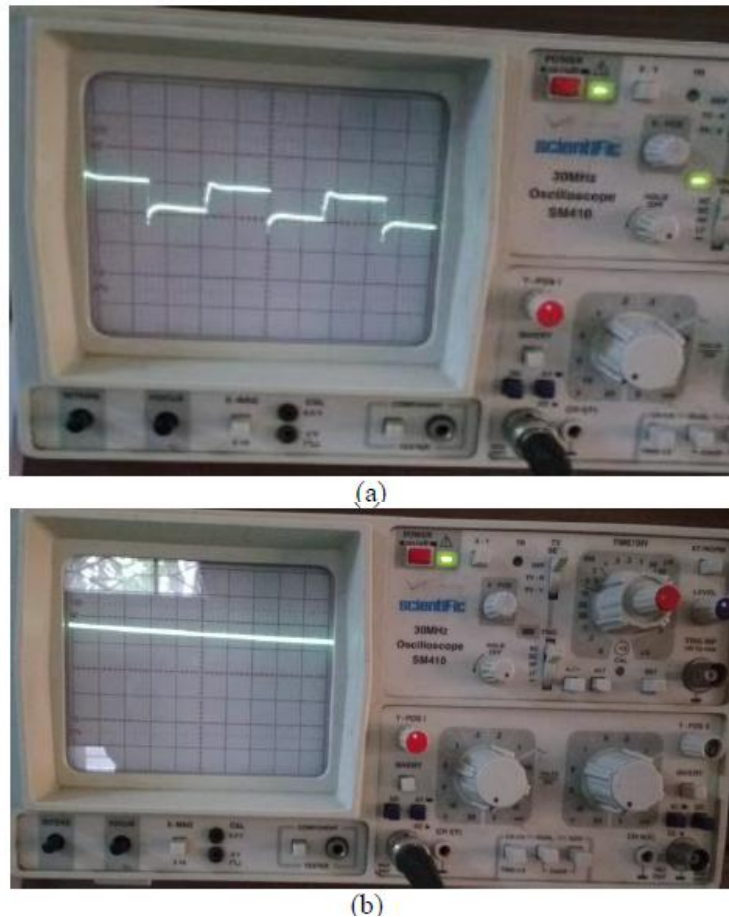
**Fig.8** Experimental results of HTQZS converter.(a).pulse generated from TL494IC.(b).obtained output of 32V for the input of 8V.

## VII.    Conclusions

Z source networks having boost abilities are used to step up the voltages in photovoltaic systems. But the traditional z source networks have some limitations to boost the voltages and there is discontinuity of input current and voltage and current stresses. To overcome the above problems modified and combinational z source networks are built which can be used for the same applications as traditional z source networks with increased efficiency and gain and even cost effective. In the proposed hybrid network, which is combination of two quasi z source networks, in this converter the disadvantages of the traditional z source network has come over and gain is increased. Along with the high step-up abilities, the proposed hybrid Z-source topology possess all the advantages of the previous Z-source networks, such as uninterruptable input current, reduction in capacitor voltage stress and mutual ground between the voltage. source and the inverter bridge. The results of the simulation of the HTQZS converter are obtained. For varied values of Irradiance the simulation is performed and observed the changes. The switching frequency of the device is 30K. Here in this paper along with the proposed converter PWM inverter is used to obtain AC output.

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