Quasi-Z and Extended Quasi-Z DC-DC Booster for PV Applications

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Abstract

Solar energy is emerging renewable energy resource that has astonishing capabilities to fulfill ever increasing future demands if utilized properly. Changing radiation intensity is an inherent pitfall associated with it and MPPT (Maximum Power Point Tracking) techniques are developed to overcome those. This paper deals with using Quasi Z-source and extended Quasi-Z source for tracking MPPT with the help of P&O method. With DC-DC converter, it boosts the DC link voltage and tracks the MPP so that power extraction capability of integrated system is significantly improved. This paper gives analysis of the proposed converters and idea of the tracking method used. Proposed system also has flexibility to use any type of multilevel inverter for grid integration. This makes the system better than earlier proposed inverter systems for the same purpose in terms of harmonics injection (due to integrated control techniques). The system is simulated in MATLAB software environment and results are obtained.

Index Terms— MPPT, P&O method, Quasi-Z source booster , Extended Quasi-Z source booster

I. INTRODUCTION

Quasi-Z-source converter (Q-ZSC) is a new promising power conversion topology perfectly suitable for interfacing of renewable (i.e., photovoltaic, wind turbines) and alternative (i.e., fuel cells) energy sources. The Q-ZSC has the following advantages:

- One-stage boost-buck conversion;
- Continuous input current (input current never drops to zero, thus featuring the reduced stress of the input voltage source, which is especially topical in such demanding applications as power conditioners for fuel cells and solar panels);

- Low or no in-rush current during start up;
- Low common-mode noise.

However, the efficiency and voltage gain of the Q-ZSC are limited; comparable with the conventional system of a voltage source inverter with the auxiliary step-up DC/DC converter in the input stage. The concept of extending the Q-ZSC gain without increasing the number of active switches was recently proposed.[1]

In this paper, Q-ZSC and extended Q-ZSC are analyzed for their suitability towards PV applications.

II. PV SYSTEMS
### A. *Proposed System*
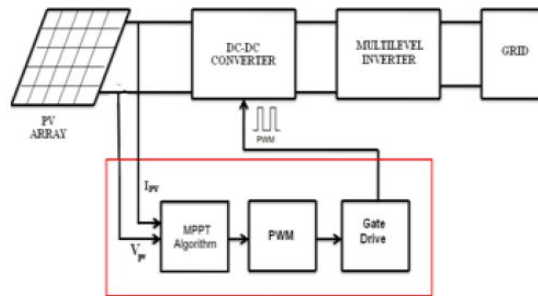
Fig 1: Proposed PV System for Grid Integration

Fig. 1 shows the proposed PV system. The DC-DC converter is heart of the above system. The gain of the converter is controlled by the MPPT algorithm. The gain is adjusted such that the output power is maximum for any available radiation intensity. The multilevel inverter is used for grid integration.

B. *PV Cell and role of MPPT*
A prime attraction of PV systems is that they produce electrical energy by directly transforming a free renewable source of energy, solar radiation, into electricity. This fact, together with the continuing decrease in PV arrays cost due to improved semiconductor technology and the increase in their efficiency imply a promising role for PV generation systems in the near future. The dependence of power generated by a PV array and its MPOP (Maximum Power Operating Point) on atmospheric conditions can readily be seen in the current-voltage (I-*V*) and the power-voltage *(P-V)* characteristics of PV arrays as shown in Fig. 2. [2]
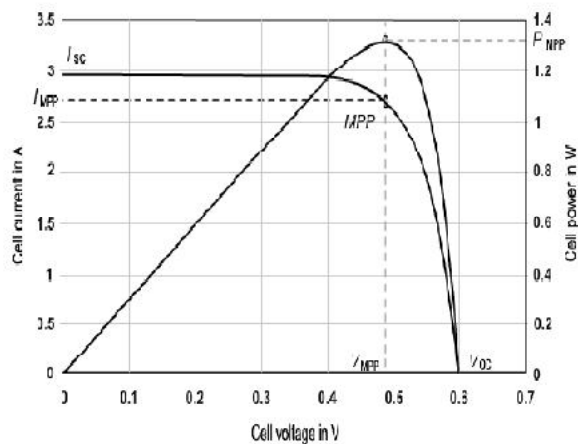
Fig 2: (I-V) and (P-V) Characteristics of Solar Cell

The efficiency of solar cells depends on many factors such as temperature, insolation, spectral characteristics of sunlight, dirt, shadow, and so on. Changes in insolation on panels due to fast climatic changes such as cloudy weather and increase in ambient temperature can reduce the photovoltaic (PV) array output power. In other words, each PV cell produces energy pertaining to its operational and environmental conditions. In addressing the poor efficiency of PV systems, some methods are proposed, among which is a concept called ─maximum power point tracking (MPPT). All MPPT methods follow the same goal which is maximizing the PV array output power by tracking the maximum power on every operating condition.

C. MPPT Methods
There are many methods used for maximum power point tracking a few are listed below:
• Perturb and Observe method
• Incremental Conductance method
• Parasitic Capacitance method
• Constant Voltage method
• Constant Current method

1. Perturb and Observe method
This method is the most common. In this method less number of sensors are utilized. The operating voltage is sampled and the algorithm changes the operating voltage in the required direction and samples dP/dV. If dP/dV is positive, then the algorithm increases the voltage value towards the MPP until dP/dV is negative. This iteration is continued until the algorithm finally reaches the MPP. This algorithm is not suitable when the variation in the solar irradiation is high. The voltage never actually reaches an exact value but perturbs around the maximum power point (MPP). Fig 3 shows the algorithm for P&O method. [2-3]
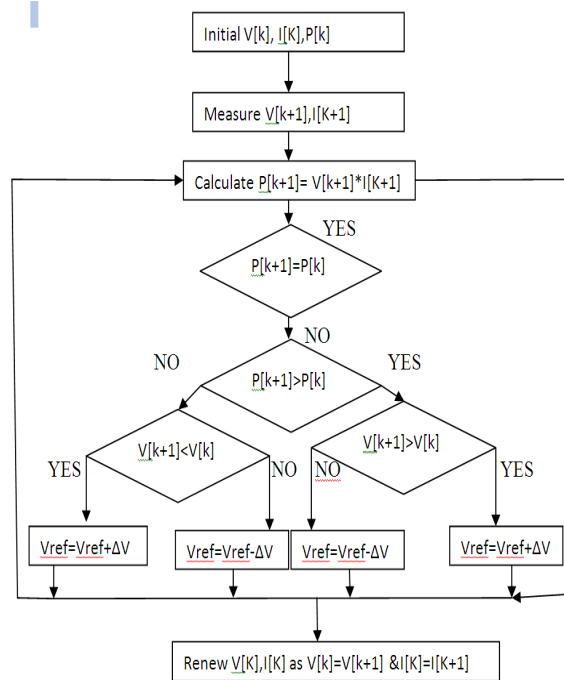
Fig 3: Algorithm for P&O Method

III. QUASI Z-SOURCE CONVERTER

Fig. 4 shows the basic topology of proposed converter. It has single controlled switch and two operational stages. They are called shoot through and non shoot through stages (Fig 5 (a) & (b) respectively). The output stage capacitor is charged during non shoot through stage and supplies load power in shoot through stage. [4]
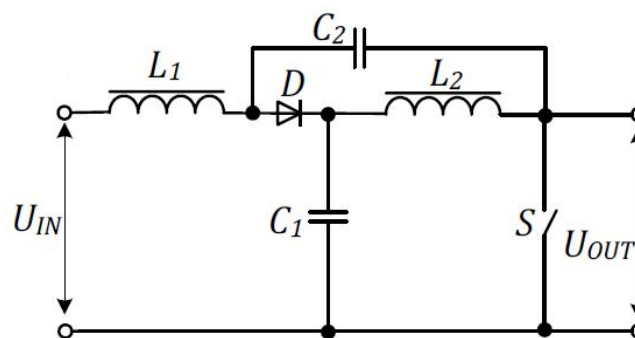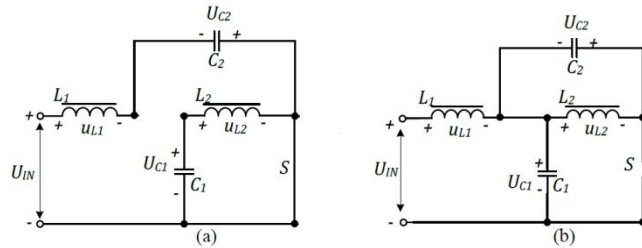

Fig 4: Quasi Z-source Converter topology

When the Switch S is closed, shoot though stage begins. The diode D is reverse biased by Capacitor C1. Inductor L1 and C2 are charged by source voltage (Uin), L2 is charged by C1 as shown in fig 5(a).

When the switch is opened, non shoot through stage begins. The diode D turns on due to current forced by inductors L1 and L2 respectively. The energy stored in inductors is dumped in output stage capacitor (not shown) and DC link voltage is boosted as shown in fig. 5(b).

The gain associated with the boost is given by the following expression (1)[4].

$$U_{OUT} = \frac{1}{1-2D_{ON}} . U_{IN} \qquad (1)$$

Fig 5: Quasi Z-source Converter operational states a) Shoot Through state b) Non Shoot through state

IV. EXTENDED QUASI Z-SOURCE CONVERTER

Fig. 6 shows basic topology of the proposed converter. This also has only one controlled switch and two operational stages like earlier structure. Its operational stages shoot through and non shoot through are shown in fig. 7(a) & Fig. 6(b) respectively [1].
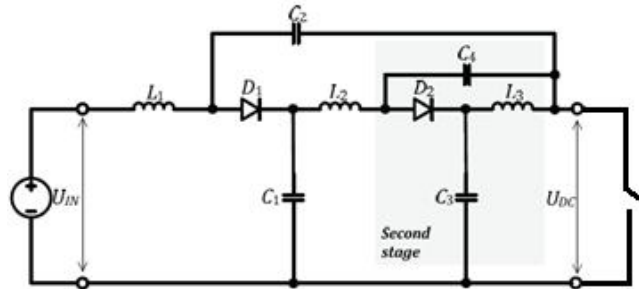
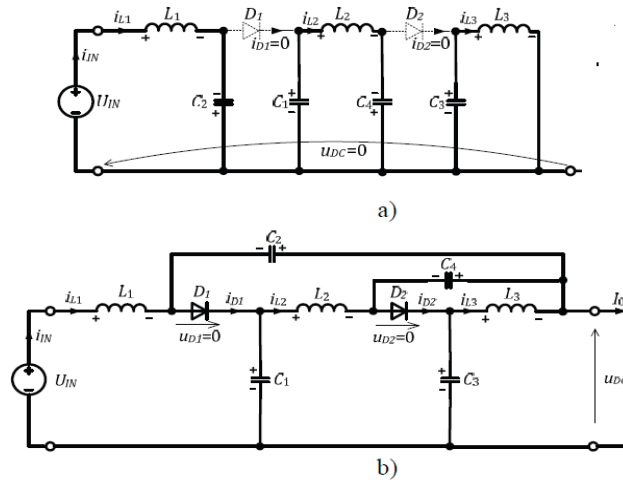**Fig 6: Extended Quasi Z-source Converter topology**

When the Switch is closed, shoot though stage begins. Both the diodes D1 and D2 are reverse biased by Capacitors C1 and C3 respectively. Inductor L1 is charged by source voltage (Uin), L2 is charged by C1 and C4, L3 is charged by C3 as shown in fig 7(a).

When the switch is opened, non shoot through stage begins. Both the diodes D1 and D2 turn on due to current forced by inductors L1 and L2 respectively. The energy stored in inductors is dumped in output stage capacitor (not shown) and Dc link voltage

is boosted as shown in fig. 7(b).

The gain associated with the boost B is given by the following expression (2)[1].
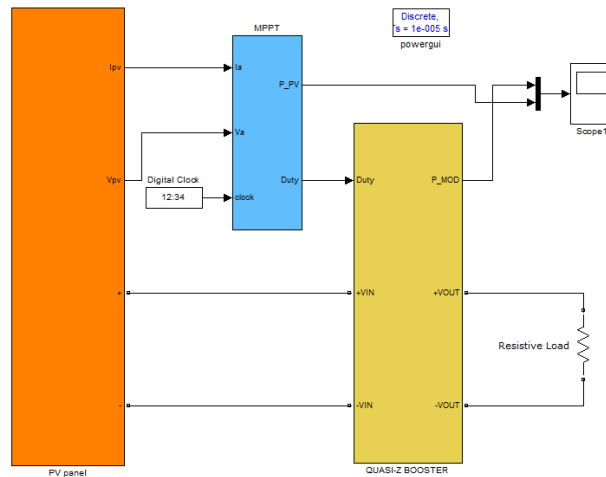
$$B = \frac{U_{DC}}{U_{IN}} = \frac{1}{1-3D_{ON}} \tag{2}$$

a)

b)

Fig 7: Extended Quasi Z-source Converter operational stages a) Shoot Through stage b) Non Shoot through stage
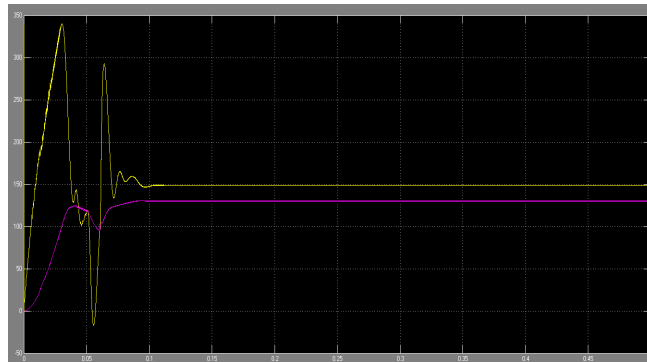
V. SIMULATION AND RESULTS

A. *Quasi-Z source based System*

Fig 8: MATLAB Simulation of Quasi Z-Source based MPPT System

The values of the passive components used for simulation are as follows: L1=L2=10uH C1=C2=10uF Switching frequency=1KHz .

In the results, pink line shows the output power of PV arrays without converter and MPPT, whereas yellow line shows output power of PV array with proposed DC-DC converter and MPPT algorithm under same solar energy input conditions.

Fig 9: Results of MATLAB Simulation of Quasi Z-Source based MPPT System

B. *Extended Quasi Z source based system.*

The values of the passive components used for simulation are as follows: L(all)=50uH C(all)=180uF Switching frequency=1KHz

In the results, pink line shows the output power of PV arrays without converter and MPPT, whereas yellow line shows output power of PV array with proposed DC-DC converter and MPPT algorithm under same solar energy input conditions.
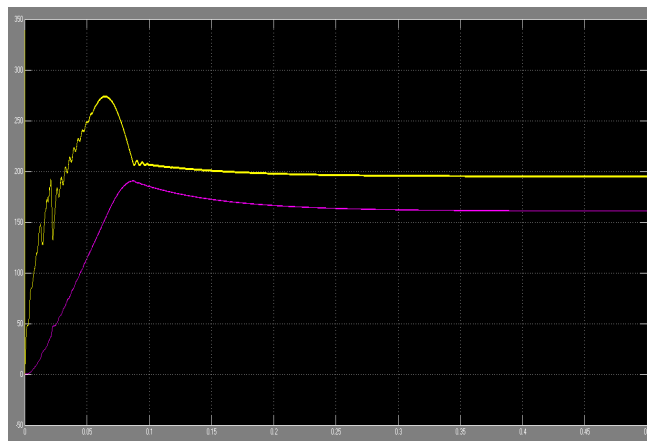

Fig 10: Results of MATLAB Simulation of Extended Quasi Z-Source based MPPT System

VI. CONCLUSION

Q-ZSC and extended Q-ZSC has been introduced in this paper for boosting DC link voltage in PV applications. The proposed system has significantly enhanced the power extraction capability of PV system for grid integration. It is also concluded, from the simulation results, that Extended Z-Source served the purpose better.

REFERENCES

[1]   D. Vinnikov, I. Roasto, T. Jalakas, S. Ott, "Extended Boost Quasi-Z-Source Inverters: Possibilities and Challenge," in *ELECTRONICS AND ELECTRICAL ENGINEERING 2011. No. 6(112). ISSN 1392 – 1215*

[2]   Srushti R.Chafle1, Uttam B. Vaidya2, Z.J.Khan "Design of Cuk Converter with MPPT Technique," Vol. 1 Issue 4, July 2013 IJIREEICE *ISSN 2321 – 2004 ISSN 2321 – 5526*

[3]   M. R. Banaei, M. R. Shirinabady, Mehdi Mirzaey "MPPT Control of Photovoltaic using SEPIC converter to reduce input current ripple," Vol. 4 Issue 1(version 2), January 2014 IJERA *ISSN 2248 – 9622*

[4]   Janis Zakis, Dmitri Vinnikov*, "Study of simple MPPT converter topologies for grid integration of photovoltaic systems," Vol. 29 Scientific Journal of Riga University 2011

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