RESEARCH SCRIPT

IJREE - International Journal of Research in Electrical Engineering ISSN: 2349-2503

High Gain Voltage DC-DC Converter Based on Three-State Switching Cell for Battery Charging Using PV System

M.Vignesh[1] | G.Abirami[2]

[1](Department of EEE, SNS College of Technology, Coimbatore, Tamilnadu, India, mvicky1828@gmail.com)
[2](Department of EEE, SNS College of Technology, Coimbatore, Tamilnadu, India, abiganes18@gmail.com)

Abstract: *The Renewable energy source is large, due to the perceptive energy in the day today life. This paper present moment a novel high voltage gain boost converter topography based on three state commutation cell for battery charging using Photo Voltaic panel to reduce ripples in output and its shortened number of conversion stages. The proposed converter operates in zero voltage switching of entire switches. By utilizing the modern concept of single stage access, the converter can produce a dc bus with battery bank or a photovoltaic panel array, allowing the concurrent charging of the batteries according to emission level. In this paper analyze the output voltage ripple by using perturb and observe (P&O) algorithm. Simulation is concluded by using the MATLAB/SIMULINK software.*

Keywords: - Battery Charger, Step up DC-DC power conversion, Three port converter, PV power systems, MPPT Techniques (P&O) Algorithm, Quasi Switched Capacitors.

I. INTRODUCTION

Today PV power systems are becoming more and more popular, with the increase of energy demand and the concern or environmental pollution around the world. The challenge to build a high output dc voltage bus (from 200 to 400Vdc) used to feed inverters, etc from low output voltage levels has been studied for some years, now which leaded to several new converter topologies.

1.In this paper, a grid-connected PV system with high ZVT interleaved boost converter is existed. The grid-connection of PV control system added two operating stages thatare a ZVT converter for boosting a low voltage of PV panel array up to the high voltage DC bus which is not lower than the grid level voltage and a bridge inverter for inverting the current into a sinusoidal waveform adjust with grid side. In addition, the boost converter is subject for the MPPT Techniques and the inverter has stabilizing the voltage of DC bus to a exact value. The ZVT interleaved boost converter with capacitors-clamp circuit can be high voltage gain and guarantee PV voltage is lower than 60V, while the power system in combine the utility grid side. Thus the power can be maintained in a large range the quantity of PV module.

2.This paper configuration of the converter which used a coupled inductor and three switches S1, S2, and S3. The battery is low-voltage side and the DC-bus voltage is high-voltage in output side. The converter can be operated in bidirectional characterized flow for charged and discharged to the battery. A discharged mode of operation the energy is transfer from the battery to dc-bus at the time of S2 and S3 are always turned off and S1 is controlled. The steady-state analysis are discussed.

3.This paper presents a soft-switching boost converter integrated in such a way to obtain, in a single conversion stage approaches, the high amount of energy from PV panels, battery, dynamic control and high voltage boost-up to the inverter DC bus and also operating with soft-switching capability. High voltage gain, low switching stress, switching losses and high efficiency are also presented and studied. However, multiple-stage topologies are generally more complex and have high component count than their single stage counter parts, which implies increased volume, weight and cost. The global efficiency can also be increased by reducing the number of power processing stages.

II. PROPOSED TOPOLOGY

1. Concept of Topology

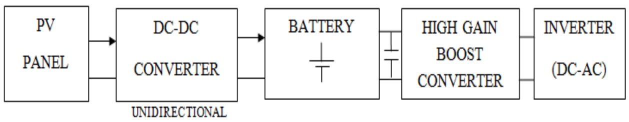

Fig. 1 Existing Block Diagram

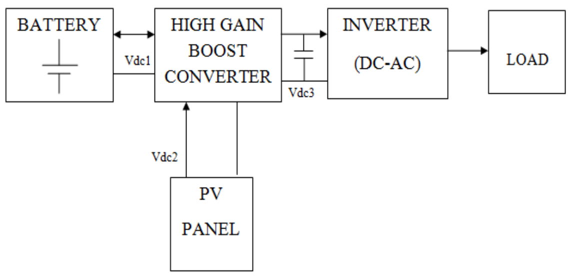

Fig. 2 Proposed Block Diagram

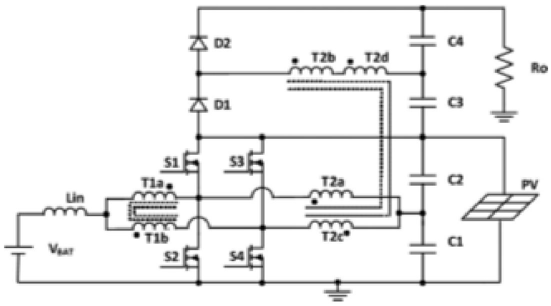

Fig. 3 Proposed topology using a PV Array

2. Principle of Operation

The converter has two operation regions which work comparably. To duty cycle has applied in the power switches of each leg (S2 & S4) are operating in opposite region. By applied the duty cycle has acts as a converter and the operation region to be defined.

If the duty cycle is higher than If the duty cycle is higher than 50%, the lower switches working in overlapping mode. However, if the duty cycle is lower than 50%, the upper switches are overlapping mode. As the switches are likewise, only the case for D > 50% is observed.

The current through the input inductor has a frequency which is two times higher than the switching frequency, which characterized the three-state switching act. This current is equally shared between the windings of the linear transformers, which can be reduced current stresses.

The windings T2a and T2c compare to the transformer primary side, which are responsible for increasing the voltage rise and allowing the switches to operate in the Zero Voltage Switching mode, increase to the system efficiency.

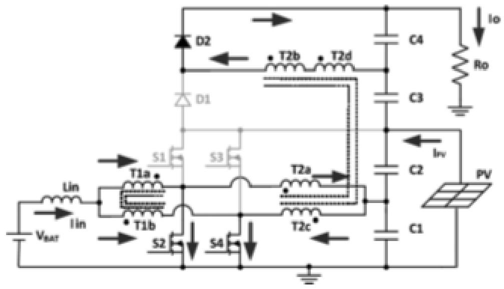

Fig. 4 Mode I Operation

Stage I: when Switch S1 is off condition causing a current flow through the anti-parallel diode of S2, entering the operate condition in the zero voltage mode. At this moment, S3 is turned OFF and S4 is turned ON. The current passing through the input inductor input increases linearly and is equally divided between the two switching cells reducing the stresses.

The transformer in the primary side T2a low to linearly while the current through T2c increases linearly. The final stage ends to the currents in T2a and T2c reach zero state.

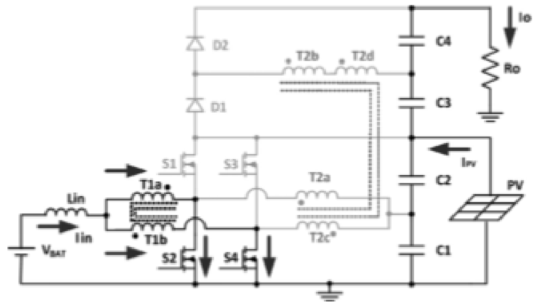

Fig. 5 Mode II Operation

Stage II: A Current "Iin" which increases linearly and is equally divided through the commutation cells. Additionally, all the rectifier diodes are reverse biased. The current through T2a and T2c at zero condition. Thus the ends when S4 is turned OFF.

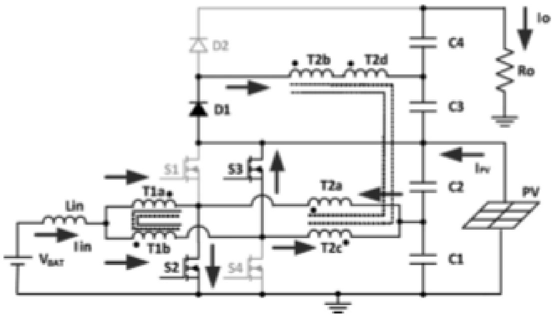

Fig. 6 Mode III Operation

Stage III: The beginning stage when Switch S4 is off condition causing the current to flow through the anti-parallel diode of S3, allowing the turn on in ZVS mode .In the moment Switch S2 in on state. The input inductor can passing through the current will be decreased in the current path through transformer T1a and T1b increase and decrease. The current in transformer of primary side T2a decreases the current flowingthroughT2cincreases. Final stateendswhenS4 is turned ON and S3 is turned OFF.

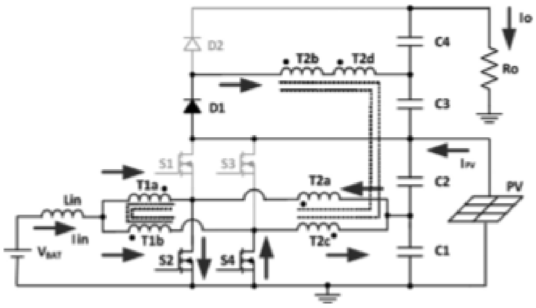

Fig. 7 Mode IV Operation

Stage IV: When Switch S4 is turn on condition at the time of Switch S2 is turn on to the input current increases linearly current flowing in transformer 1a & 1b.The current through S4 increases and has flow in the opposite direction. A current will flowing to transformer 2a can be increased, while the one through T2c decreases. This stage ends when the currents in T2a and T2c stop at null condition, the switch S2 and S4 are equal level of current.

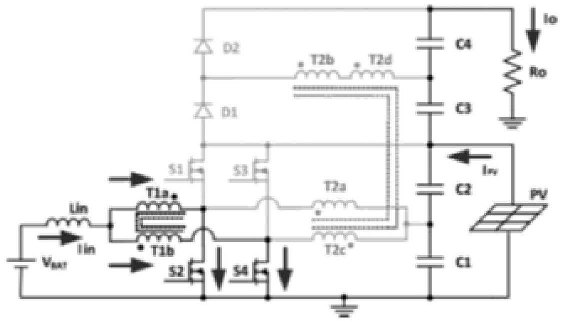

Fig. 8 Mode V Operation

Stage V: Same condition of operation in this stage also. The input inductor can equally to the commutation cells. All the rectifier diodes are reverse biased. The current through T2a and T2c remain null. This stage ends when S2 will zero position.

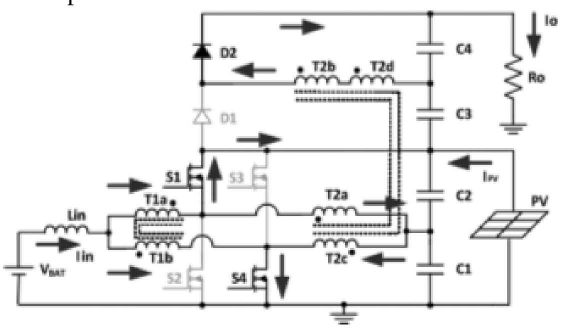

Fig. 9 Mode VI Operation

Stage VI: ThisstagebeginswhenS2isturnedOFF, causing a current flow through the anti-parallel diode of S1, allowing its turn ON in the ZVS mode. At this moment, S3 is already turned OFF and S4 is turned ON. The current flowing through the input inductor "IIN" decreases linearly. The current in the primary side T2a increases the current through transformer 2c to be reduced. This stage ends when the currents through T2a and T2c become zero,S2 in current level and S4 are equal. After this stage, a new switching cycle begins from the first stage.

III. STATIC GAIN

This section presents the study of the converter static gain for two operation regions. The duty cycle is applied to the switches; there are two possible operation modes. For *D*>50%, there is an overlapping period for the lower switches, which remain turned ON simultaneously during a certain time interval. On the other hand for *D* <50%there is an overlapping period of the upper switches The output voltage can be obtained as,

$$V0 = VC1 + VC2 + VC3 + VC4\text{----}(1)$$

If the duty cycle is higher than 50%, the lower switches operate in overlapping mode. However, if the duty cycle is lower than 50%, then the upper switches are in overlapping mode .It can be seen that the static gain (G)depends exclusively on the duty cycle (D), the transformer turns ratio (n) and the normalized load current (α). On the other hand, parameter α depends on the battery voltage (Vbat), the load current (Io), the switching period (TS), n, and the transformer leakage inductance (LP).

It is important to mention that for high static gains are not feasible in practice i.e. when the duty cycle is higher than 0.8 and the turns ratio is higher than 2. This is due to the great variation of the output voltage caused by small variations of the duty cycle, thus leading the boost converter to instability. The converter behaviour and the operation region are defined by the applied duty cycle. If the duty cycle is higher than 50%, the lower switches work in overlapping mode.

However, if the duty cycle is lower than 50%, then only the upper switches are in an overlapping mode. As the operation principle the switching tables is given below. Soft-Switching Condition presents the analysis of minimum and maximum dead times necessary to obtain the soft-switching condition for the switches. In order to obtain soft switching, the leakage inductance of the transformer and the intrinsic capacitance of the switches are considered. the maximum dead time that allows soft switching depends on the time interval necessary for the current to become zero during the firststage.

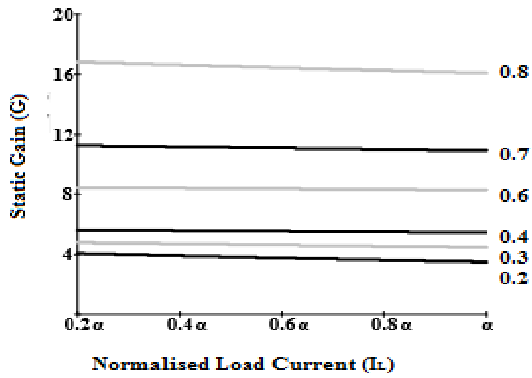

Fig. 10 Static gain as a function of the load current for various values of the duty cycle

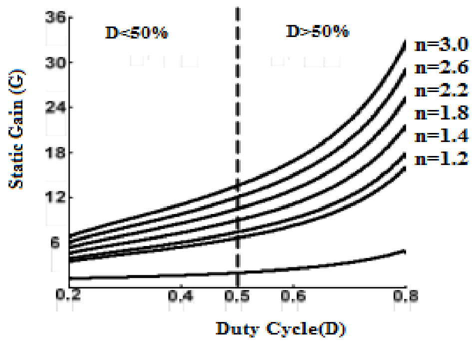

Fig. 11 Static gain as a function of the duty cycle for various values of n.

IV SWITCHING CHARACTERISTICS

The converter behaviour and the operation region are defined by the applied duty cycle. If the lower switches work in overlapping mode and the upper switches are in an overlapping mode as table shown in below.

Table I Switching Sequence for Six Stages

No of Switches	SWITCHING STAGES					
	1st Stage	2nd Stage	3rd Stage	4th Stage	5th Stage	6th Stage
Switch 1	OFF	OFF	OFF	OFF	OFF	ON
Switch 2	ON	ON	ON	ON	ON	OFF
Switch 3	OFF	OFF	ON	OFF	OFF	OFF
Switch 4	ON	ON	OFF	ON	ON	ON

The switching sequence for six stages values of time (t), Frequency (kHz), Duty cycle (D) are shown in T=0.04e-3 Frequency=25 KHz, Duty cycle=16.6667.

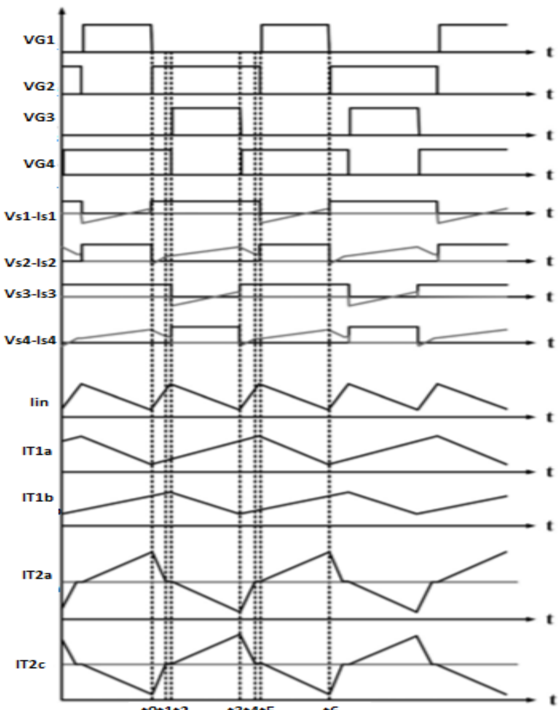

Fig. 12 Main Theoretical Waveforms

V EXPERIMENTAL SPECIFICATIONS

Table II Magnetics Used In

Parameter	Core E	Core volume
Transformer (T)	42/21/15	17.6
Input Inductor (Lin)	55/28/21	40.5
Leakage Inductance(Lp)	30/15/14	8
Three-State Switching Cell	42/21/15	17.6

Table III Design Specifications

Parameter	Value
Switching Frequency	50 kHz
Input Voltage	24 V
Output Voltage	230 V
Output Power	550 W
Output Current	2.5 A
Input Inductance	100 µH
Leakage Inductance	14 µH
Output Capacitors(C1)	30 µF
Output Capacitors(C2,C3)	100 µF
Transformer turns ratio	1:1.2

Experimental results are presented and discussed to demonstrate the performance of the proposed topology, from a 550-W prototype which has been developed and tested in three conditions: energy flow from the battery bank (*VBAT*) to the load (*RO*), energy flow from the PV array (*PV*) to the load (*RO*); and energy flow from the array (*PV*) to the battery bank (*VBAT*). Table II shows the design specifications of the prototype.

The behaviour of both converters is nearly the same. Despite the similar performance, the proposed converter presents better efficiency due to lower component count. Table III and Table IV present the characteristics of the magnetic elements used in each converter.

Table IV Magnetics Used in the Proposed Topology

Parameter	Core E	Core volume
Transformer (T)	42/21/15	17.6
Input Inductor (Lin)	55/28/21	40.5
Leakage Inductance(Lp)	30/15/14	8.0

The total core volume is 66.1 cm3 and 93.3 cm3 for the proposed topology with respectively. Thus, there is significant reduction of the magnetic elements by about 30%, with consequent reduction of cost.

VI SIMULATION RESULTS

1.MPPT Controller

In a (Power-Voltage or current-voltage) curve of a solar panel, there is an optimum operating point such that the PV delivers the maximum possible power to the load. the optimum point changes with the natural conditions so it is very important to track the maximum power point (MPP) for a successful PV system. So in PV systems a maximum power point tracker (MPPT) is very much needed.

2 .Perturb and Observe MPPT Algorithm

PV module's output power curve as a function of voltage (P-V curve)as the constant irradiance and the constant module temperature, assuming the PV module is operating at a point which is away from the MPPT. In this algorithm the operating voltage of the PV module is perturbed by a small increment, and the resulting change of power, P is observed. Thus, further voltage perturbations in the same direction should move the operating point toward the MPPT. If the P is negative, the operating point has moved away from the MPP, and the direction of perturbation should be reversed to move back toward the MPPT.

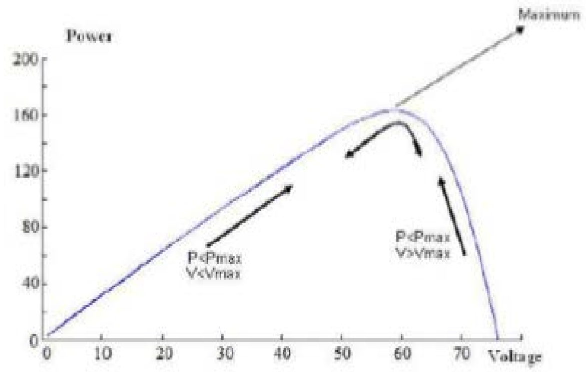

Fig. 13 Curve of P&O MPPT Algorithm

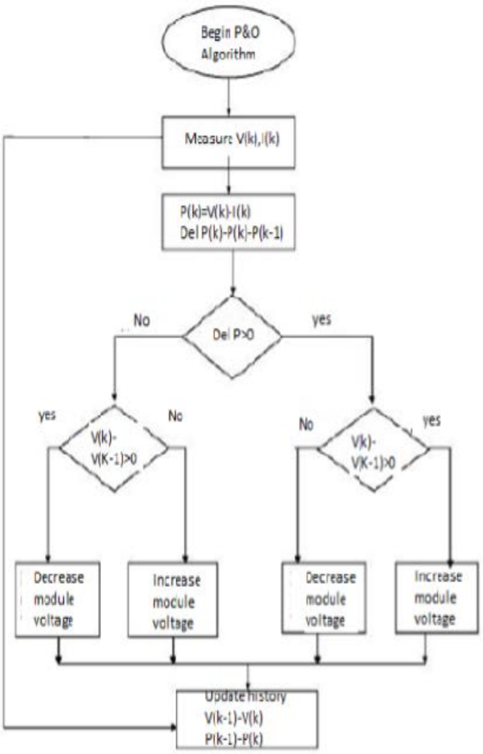

Fig. 14 P&O MPPT Algorithm Flow Chart

The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions.

3. Control Strategy

The strategy can be used in the proposed converter, where it is necessary to measure only three quantities that are the PV panel voltage *V*PV, the PV panel current *I*PV ,and the voltage across the battery bank *V*BAT. Let us suppose that constant power is supposed to be injected in the inverter stage.

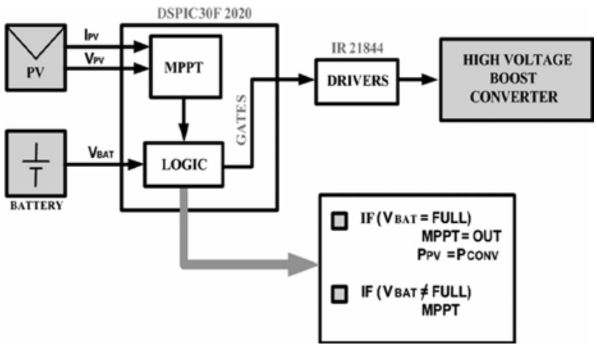

Fig. 15 Control Strategy

Considering that the battery has a low charge, the MPPT can be performed in any radiation and output power condition. The power difference is naturally transferred to or from the battery and the inverter can easily support the resulting dc-bus voltage variation. If the battery is fully charged, the MPPT is not performed and the operation point is changed until the current through the battery becomes zero. The high gain achieved by such topology and the good performance in all operation modes validate this approach s prominent solution for applications where 200-V or 400-V dc links must be obtained from low input voltages i.e. typically 12V, 24 V, or 48 V as provided by batteries, PV modules or other renewable energy sources.

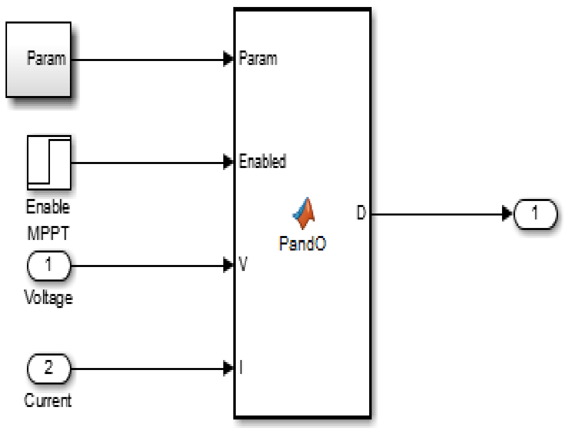

Fig. 16 MPPT Controller

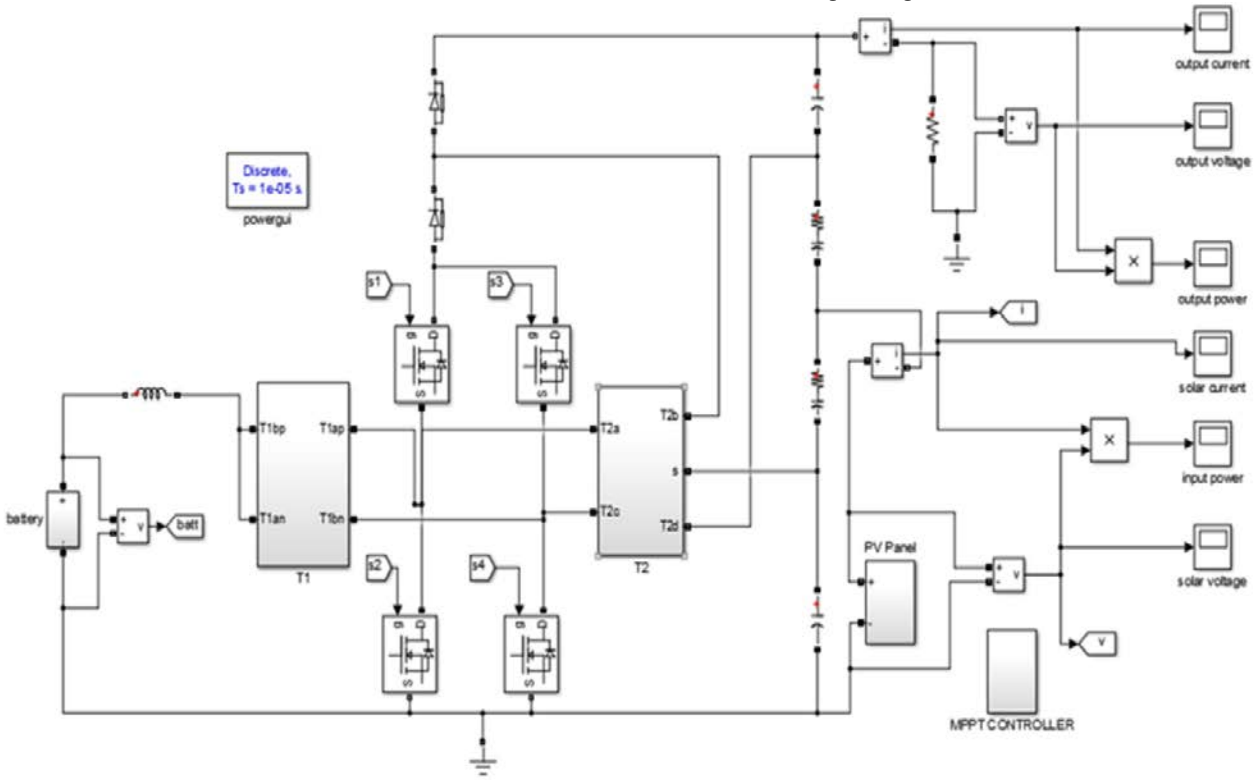

Fig. 17 Overall Simulation Diagram

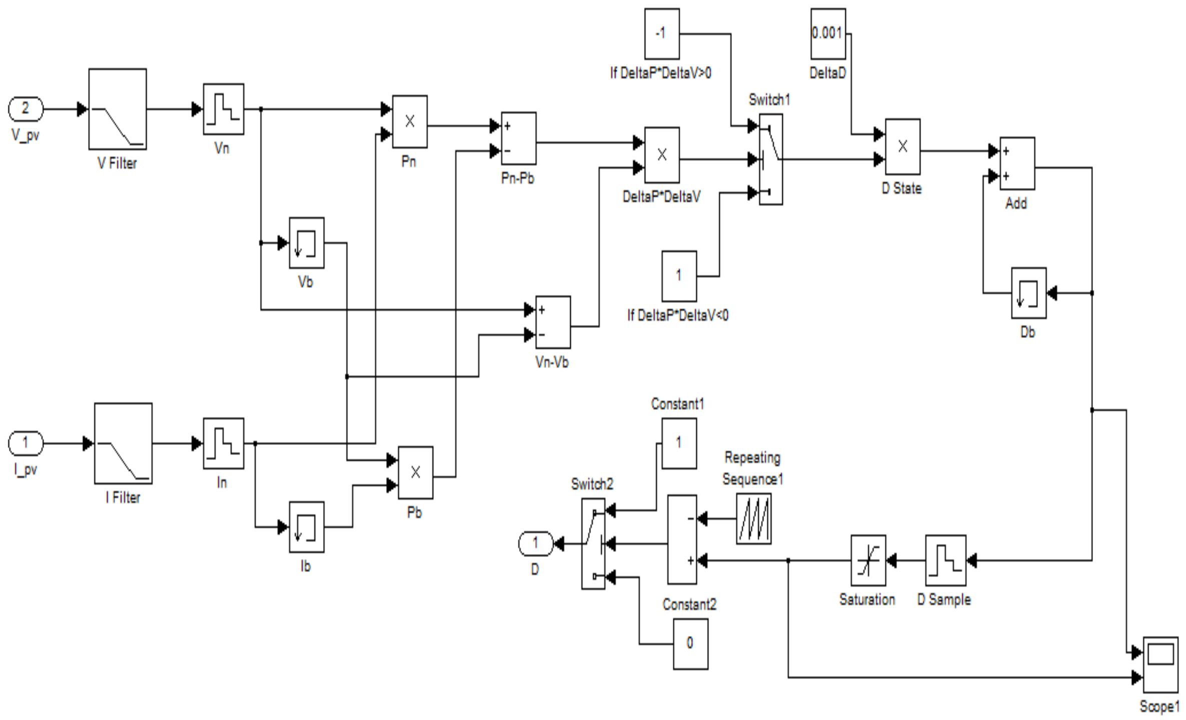

Fig. 18 MPPT Control Scheme

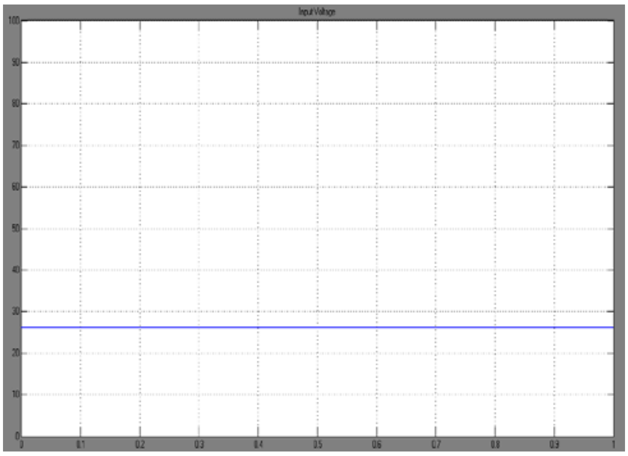

Fig. 19 Battery Voltage

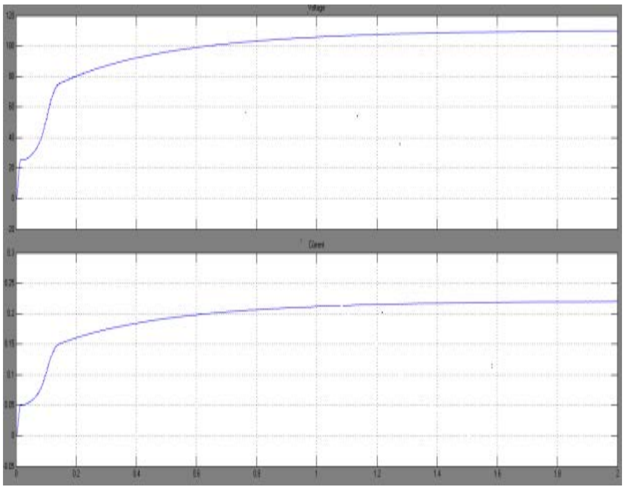

Fig. 20 PV Voltage & Current Waveform

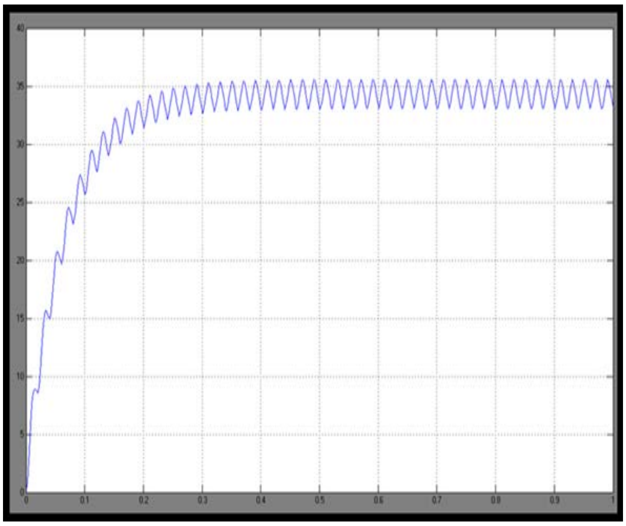

Fig. 21 Boost Converter Output Voltage

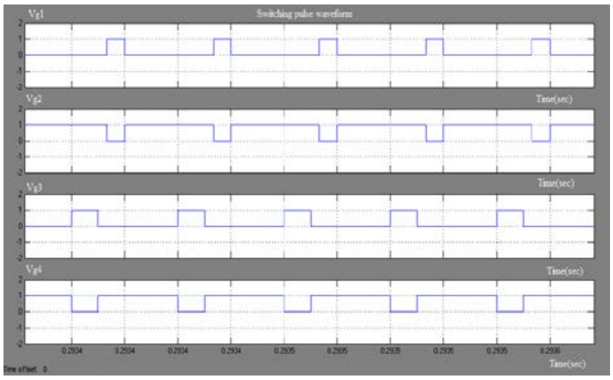

Fig. 22 Six Stages Pulse Waveform

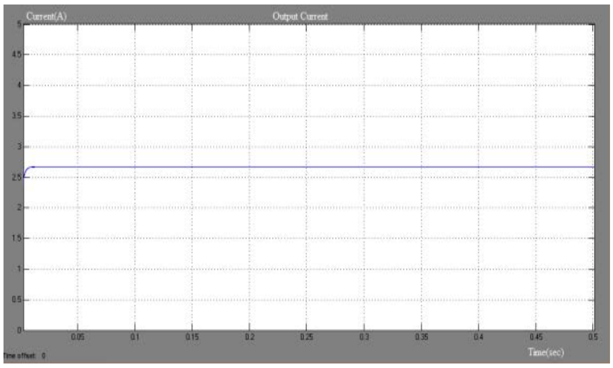

Fig. 23 Output Current Waveform

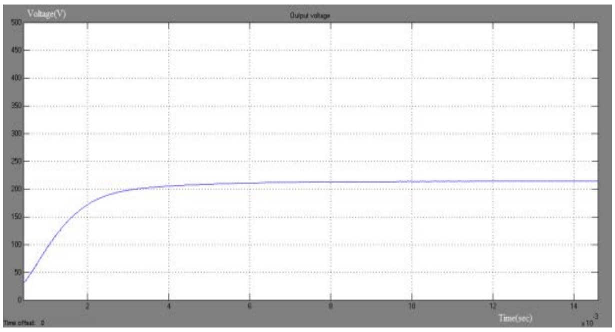

Fig. 24 Output Voltage Waveform

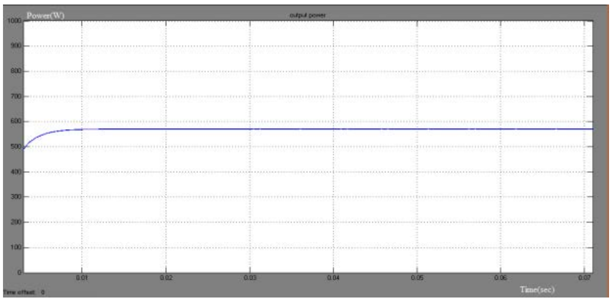

Fig. 25 Output Power Waveform

VII CONCLUSION

The major advantage of the proposed converter with high voltage gain topology is voltage boost-up ratio with reduced voltage stress across the main switches in stand-alone or grid connected system based on battery storage. The efficiency of the system will be over a wide load range which gives the satisfactory performance of design in renewable energy systems especially PV applications. In PV applications the conduction losses reduce and its improved efficiency in rated position. The performance of the structure in all operation modes has been accepted with the bi-directional flow between the input sources of battery and PV systems. Besides all, the switches operate in the soft switching condition, which is switching losses are reduced.

The high gain achieved by such topology and the good performance in all operation modes validate this approach as prominent solution for applications as 200-V or 400-V dc links must be obtained from low input voltages i.e. typically 12V, 24 V, or 48 V as provided by batteries, PV modules or other renewable energy sources.

FUTURE SCOPE

Efficiency can still be improved at the rated condition as performance of the design. The proposed boost converter stage approach is to be encouraging with additional topologies feasible to both photovoltaic and fuel cell applications in future.

REFERENCES

[1]. C. K. Cheung, S. C. Tan, C. K. Tse, and A. Ioinovici, "On energy efficiency of switched-capacitor converters," IEEE Trans. Power Electron., vol. 28, no. 2, pp. 862–876, Feb. 2013.

[2] K. Zou, M. Scott, and J. Wang, "Switched-capacitor cell based voltage multipliers and dc-ac inverters," IEEE Trans. Ind. Appl., vol. 48, no. 5, pp. 1598–1609, Sep./Oct. 2012.

[3] S. M.Chen,T. J.Liang,L. S.Yang,andJ. F.Chen,"A cascaded high step up DC-DC converter with single switch for micro source applications," IEEE Trans. Power Electron., vol. 26, no. 4, pp. 1146–1153, 2010.

[4] Y. Bo, L. Wuhua, W. Jiande, Z. Yi, and H. Xiangning, "A grid-connected PV power system with high step-up ZVT interleaved boost converter," in Proc. 34th Annu. Conf. IEEE Ind. Electron., 2008, pp. 2082–2087.

[5] G. A. L. Henn, R. N. A. L. Silva, P. P. Prac¸a, L. H. S. C. Barreto, and D. S.Oliveira," Interleaved boost converter with high voltage gain "IEEE Trans. Power Electron., vol. 25, no. 11, pp. 2753–2761, Nov. 2010.

[6] F. L. Tofoli, D. de Souza Oliveira, R. P. TorricoBascop´e, and Y. J. A.Alcazar,"Novel non isolated high-voltage gain DC–DC converters based on 3SSC and VMC," IEEE Trans. Power Electron., vol. 27, no. 9, pp. 3897–3907, Sep. 2012.

[7] Y.Alcazar, D.deSouza Oliveira, F.Tofoli and R.Torrico-Bascope,"DC- DC non isolated boost converter based on the three-state switching cell and voltage multiplier cells," IEEE Trans. Ind. Electron., to be published.

[8]S.de Oliveira ,and C. G. C.Branco,"A high step-up DC-DC converter based on three-state switching cell," IEEE Int. Symp. Ind. Electron., vol. 2, pp. 998–1003, Jul. 9–13, 2006.

[9] L. S. Garcia, L. C. de Freitas, G. M. Buiatti, E. A. A. Coelho,V. J. Farias, and L. C. G. Freitas, "Modeling and control of a single-stage current source inverter with amplified sinusoidal output voltage," in Proc. 27th Annu.IEEEAppl.PowerElectron.Conf.Expo.,Feb.5–9,2012,pp.2024–2031.

[10] L. G. Junior, M. A. G. de Brito, L. P. Sampaio, and C. A. Canesin, " Evaluation of integrated inverter topologies for low power PV systems," in Proc. Int. Conf. Clean Elect. Power, Jun. 14–16, 2011, pp. 35–39.

[11] A. G. de Brito, L. P. Sampaio, L. G. Junior, R. B. Godoy, and C. A. Canesin, "New integrated Zeta and Cuk inverters intended for standalone and grid connected applications," in Proc. Power Electron. Conf., Sep. 11–15, 2011, pp. 657–663.

[12] H. Ci-Ming, Y. Lung-Sheng, L. Tsorng-Juu, and C. Jiann-Fuh, "Novel bidirectional DC-DC converter with high step-up/down voltage gain," in Proc. Energy Convers. Congr.Expo., 2009, pp. 60–66.

[13] Li Wuhua, Weichen Li, Deng Yan, and He Xiangning, "Single-stage single-phase high-step-up ZVT boost converter for fuel-cell micro grid system," IEEE Trans. Power Electron., vol. 25, no. 12, pp. 3057–3065, Dec. 2010.

[14] L. H. S. Barreto, P. P. Prac¸a, D. S. Oliveira, Jr., and R. P. T. Bascop´ e, "Single-stage topologies integrating battery charging, high voltage step up and photovoltaic energy extraction capabilities,"Electron.Lett.,vol.47, no. 1, pp. 49–50, Jan. 2011.

[15] L. H. S. C. Barreto, P. P. Prac¸a, G. A. L. Henn, R. A. C ˆ amara, N. A. L. S. Ranoyca, and D. S. Oliveira, "High voltage gain boost converter battery charger applied to PV systems," in Proc. 26th Annu. IEEE Appl. Power Electron. Conf. Expo., Mar. 2011, pp. 1526–1531.

[16] L. H. S. C. Barreto, P. P. Praca, G. A. L. Henn, R. N. A. L. Silva, and D. S. Oliveira, "Single stage high voltage gain boost converter with voltage multiplier cells for battery charging using photovoltaic panels," in Proc. 27th Annu. IEEE Appl. Power Electron. Conf. Expo., Feb. 2012, pp. 364–368.

[17] Y.Alcazar,D.deSouzaOliveira, F.Tofoli and R.Torrico-Bascope," DC-DC nonisolated boost converter based on the three-state switching cell and voltage multiplier cells," IEEE Trans. Ind. Electron., to be published