Efficient utilization of PV by using SSIB converter for medium voltage DC bus

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***Abstract*-Due to downfall in the non-renewable energy resources the focuses of researches have moved towards the renewable sources for the energy requirements. This proposed Soft Switched Interleaved Boost converter technology helps to enhance the power and efficiency of the solar cell by utilizing high gain DC-DC converters for medium voltage DC bus. The SSIB converter is designed in such a way that the efficiency of the PV solar cell should be increased up to (40 to 60%). From this proposed scenario we can easily compare the efficiency of SSB and SSIB converters, so that which is more significant to meet the load demands. Whereas the MPPT and PID controllers are used in designing part.**

Keywords: PV cells, SSIB converter, MMPT algorithm, control logic.

I. INTRODUCTION

Photovoltaic power system change over daylight straightforwardly into power. A private PV power system empowers a property holder to create a few or the greater part of their day by day electrical vitality request all alone rooftop, trading daytime abundance power for future vitality needs (i.e. evening time utilization). The house stays associated with the electric utility at all times, so any force required above what the close planetary system can deliver is essentially drawn from the utility. PV system can likewise incorporate battery reinforcement or uninterruptible force supply (UPS) ability to work chose circuits in the living arrangement for quite a long time or days amid an utility blackout.

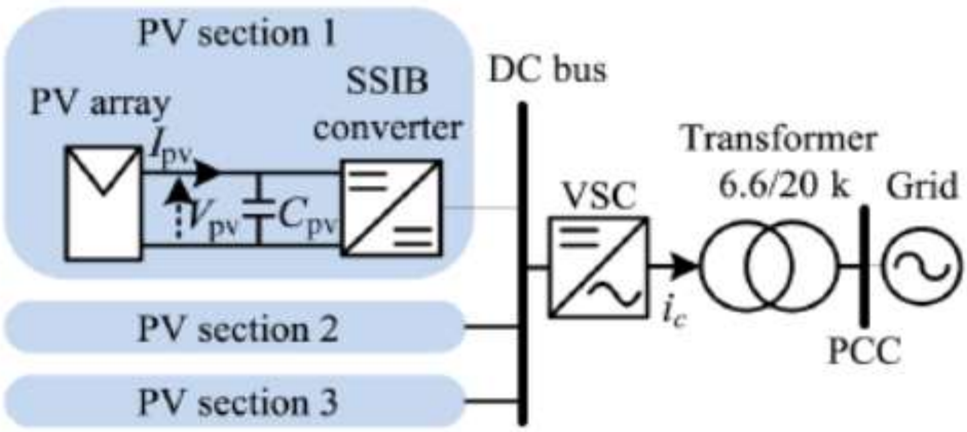


Fig. 1 Large-scale PV system architecture.

Bidirectional dc–dc converters with transformer-based structures are probably the most popular topologies [3–4], and soft-switching techniques are usually applied to reduce the corresponding switching losses. These mechanisms with isolated transformers have high conduction losses because the usual number of power switches is between four and nine. Accordingly, practical implementation is complicated and expensive. Nowadays, switched-capacitor dc–dc converters [4, 5] have attracted much attention as an alternative means of providing bidirectional power flow control. However, increased switching loss and current stress are the critical drawbacks, and the major challenge is to design a circuit with few switch devices and capacitors. Generally speaking, the bidirectional converter in the UPS must have a high step-up/step-down voltage gain. S. B. Kjaer [5] introduced a family of high-efficiency, high step-up \dc–dc converters by adding only one additional diode and a small capacitor. It can recycle the leakage energy and mitigate the reverse-recovery problem. S. Rivera [2], introduced a two-quadrant PWM chopper-type dc–dc converter via a coupled inductor. In this technique, only three switches were applied to achieve bidirectional power flow. Although an additional snubber capacitor was successfully used to clamp the spike voltage, a 250 V voltage-rated switch was employed in a low-voltage (36 V) side circuit, resulting in a large conduction loss because a switch with a higher RDS(ON) was used. Coupled inductors with a lower-voltage-rated (80 V) switch and a passive regenerative snubber circuit [8, 9] were adopted to realise that the high-voltage gain with a 400 V output voltage, and the performance was superior to that in [3]. Unfortunately, these non-isolation topologies presented in [4] only control unidirectional power flow. S. Kai, Z. Li, X. Yan [1], introduced an ultra-high-efficiency bidirectional dc–dc converter constructed by the coupled inductor with the interleaved topology. Although this topology with soft switching can achieve the goal of high-efficiency power conversion, many series strings of storage batteries are required to reduce the input/output voltage diversity.

II. PRINCIPLE OF OPERATION

The solar PV cell is a combination of two types of semiconductors which are named as P-type semiconductor and N- type semiconductor. When the sunlight or irradiation hits or falls on the panel of the PV array then there is production of two categories of electrons. The generated electrons will flow through the electrodes which are connected at the top and bottom of the PV panel which is going to produce electricity from the solar energy. The generated power will be given to the loads to reach some load demands of the customers. When you associate loads, for example, a light electric current streams between the two cathodes.

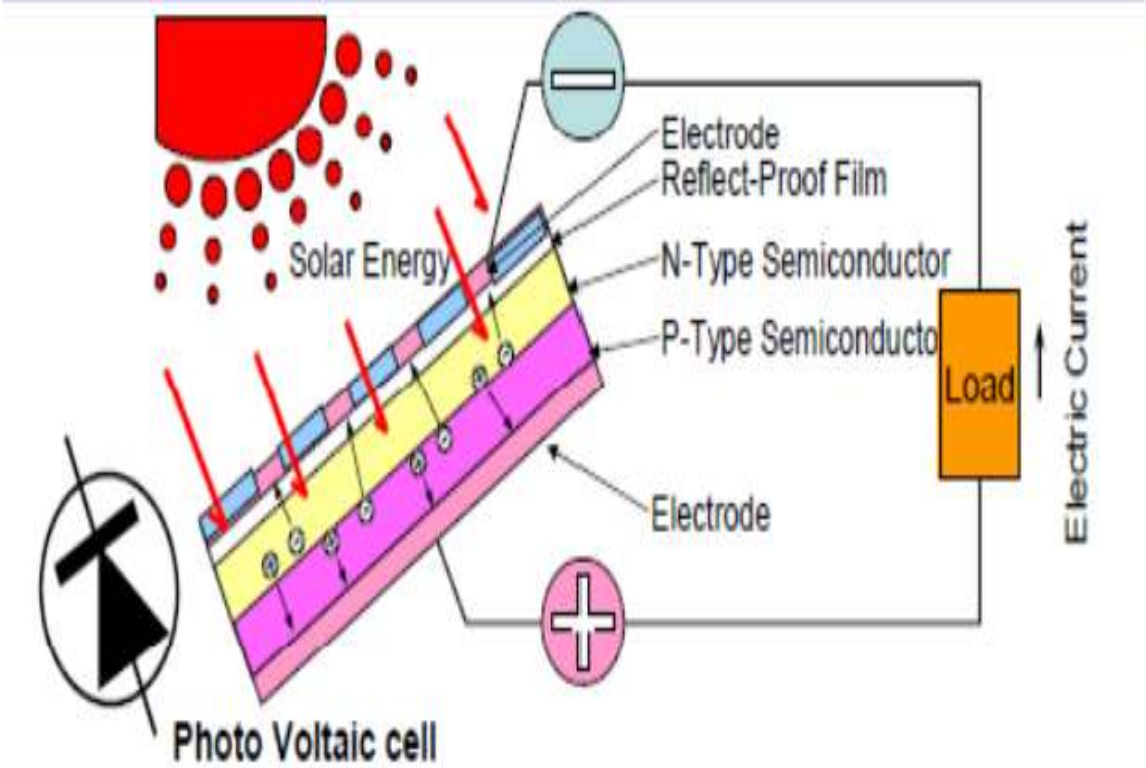


Fig. 2 Generation mechanism of solar energy by photo voltaic cell.

PV systems can be broadly classified in two major groups, they are:

Stand Alone-These systems are isolated from the electric distribution grid. Figure describes the most common system configuration. The system describes Figure is actually one of the most complex; and includes all the elements necessary to serve AC appliances in a common house hold or commercial application. An additional generator (e.g., bio diesel or wind) could be considered to enhance the reliability but it is not necessary. The number of components in the system will depend on the type of load that is being served. The inverter could be eliminated or replaced by a DC to DC converter if only DC loads are to be fed by the PV modules. It is possible to directly couple a PV array to a DC load when alternative storage methods are used or when operating schedules are no to importance. A good example may be water pumping applications were a PV module is directly coupled to a DC pump, water is stored in a tank through the day whenever energy is available.

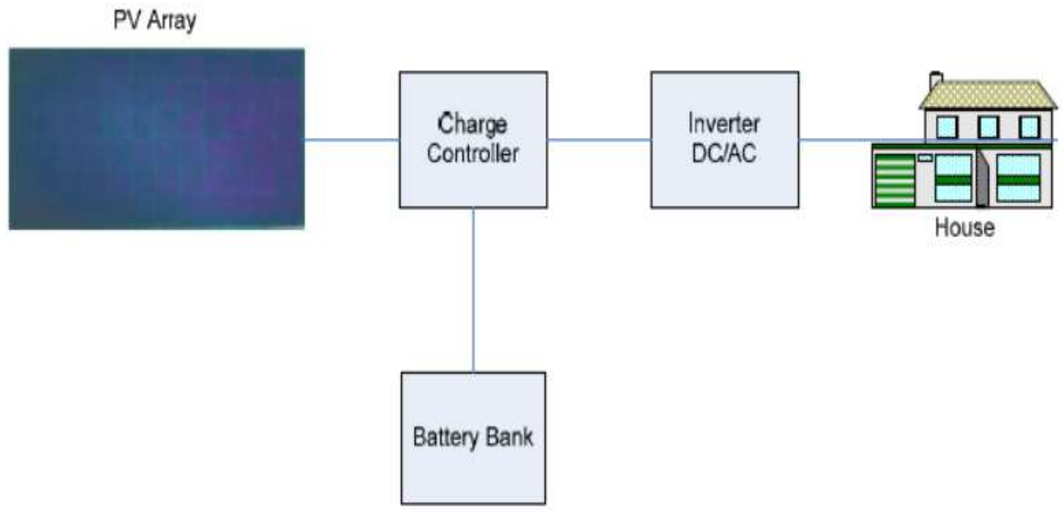


Fig 2.1: Stand alone photovoltaic system.

Grid-Tied-These systems are directly coupled to the electric distribution network and do not require battery storage. Figure describes the basic system configuration. Electric energy is either sold or bought from the local electric utility depending on the local energy load patterns and the solar resource variation during the day, this operation mode requires an inverter to convert DC currents to AC currents. There are many benefits that could be obtained from using grid-tied PV systems instead of the traditional stand-alone systems.

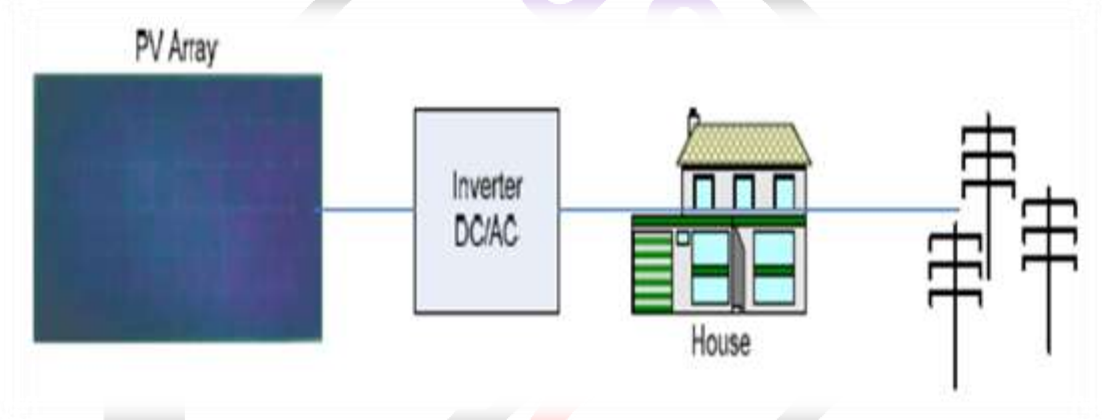
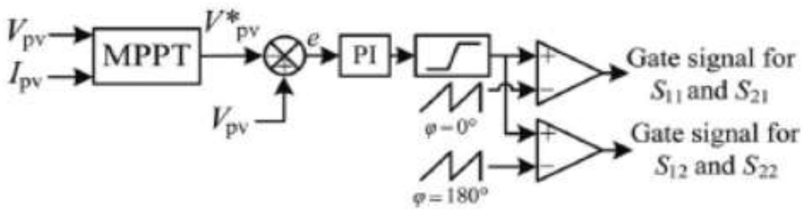


Fig.2.2: Grid-tied photo voltaic system.

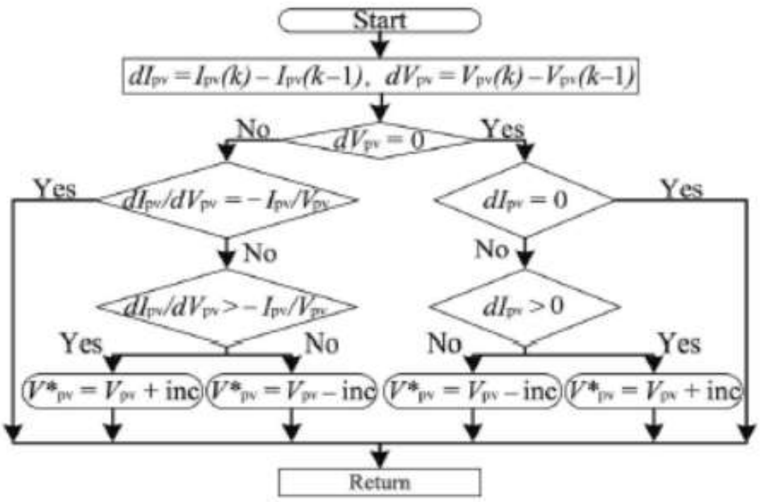
These benefits are, smaller PV arrays can supply the same load reliably, less balance of system components are needed, comparable emission reduction potential taking advantage of existing infrastructure, eliminates the need for energy storage and the costs associated to substituting and recycling batteries for individual clients, storage can be included if desired to enhance reliability for the client, takes advantage of the existing electrical infrastructure, efficient use of available energy, contributes to the required electrical grid generation while the client's demand is below PV output.

III CONTROL METHODOLOGY

The control of an SSIB converter based on an MPPT algorithm is another important issue to be considered when applying the converter to PV application. Based on the incremental conductance method the SSIB converter maintains the PV array voltage at the MPP. The control block diagram is shown in Fig. 4.



(a)



(b)

Fig. 4 Control block diagram. (a) $N = 2$, $P = 1$SSIB converter control loop. (b) Incremental conductance MPPT algorithm.

Most of the existing bidirectional dc-dc converters fall into the generic circuit structure, which is characterized by a current fed or voltage fed on one side. The Bi-directional dc-dc converter fed DC motor drive. In this topology, boost converter operation is achieved by modulating Q2 with the anti-parallel diode D1 serving as the boost-mode diode. With the direction of power flow reversed, the topology functions as a buck converter through the modulation of Q1, with the anti-parallel diode D2 serving as the buck-mode diode. It should be noted that the two modes have opposite inductor current directions. A new control model is developed using modern controller to achieve both motoring and regenerative braking of the motor. A Lithium-ion battery model has been used in this model to verify the motor performance in both motoring and regenerative mode. This controller shows satisfactory result in different driving speed commands.

Converter design: The bi-directional converter is designed based on the input supply voltage and output voltage requirement to drive the electric vehicle at desired speed. The converter power topology is based on a half bridge circuit to control the dc motor.
Converter operation: The bidirectional dc-dc converter shown in Figure1 is operated in continuous conduction mode for forward motoring and regenerative braking of the dc motor. The MOSFETs *Q1* and *Q2* are switched in such a way that the converter operates in steady state with four sub intervals namely interval *1(t0-t1)*, interval *2(t1-t2)*, interval *3(t2-t3)* and interval *4(t3-t4)*. It should be noted that the low voltage battery side voltage is taken as *V1* and high voltage load side is taken as *V2*. The gate drives of switches *Q1* and *Q2* are shown in Figure 5(a). The circuit operations in steady state for different intervals are elaborated below.
Interval 1(t0-t1): At time *t0*, the lower switch *Q2* is turned ON and the upper switch *Q1* is turned OFF with diode *D1*, *D2* reverse biased as shown in Figure 5(a). During this time interval the converter operates in boost mode and the inductor is charged and current through the inductor increases.
Interval 2(t1-t2): During this interval both switches *Q1* and *Q2* is turned OFF. The body diode *D1* of upper switch *Q1* starts conducting as shown in Figure 5(b). The converter output voltage is applied across the motor. As this converter operates in boost mode is capable of increasing the battery voltage to run the motor in forward direction.

Interval 3(t2-t3): At time *t3*, the upper switch *Q1* is turned ON and the lower switch *Q2* is turned OFF with diode *D1*, *D2* reverse biased as shown in Figure 5(c). During this time interval the converter operates in buck mode.
Interval 4(t3-t4): During this interval both switches *Q1* and *Q2* is turned OFF. The body diode *D2* of lower switch *Q2* starts conducting as shown in Figure 5(d).

To design a Bidirectional converter for renewable energy systems, the complete prototype is carried in the following sequences, they are given in steps. Finalizing the total circuit diagram, listing out their components and their sources of procurement. Procuring the components, testing the components and securing the components. Making the model as per the circuit diagram on the breadboard and testing the results. Making layout, preparing the inter connection diagram as per the circuit diagram, preparing the drilling details, cutting the laminate to the required size.

Drilling the holes on the board as per the component layout, painting the tracks on the board as per the inter connection diagram.. Etching the board to remove the unwanted copper older than track portion. Then cleaning the board with water and solder coating the copper tracks to protect the tracks from rusting or oxidation due to moisture. Integrating the total unit, inter wiring the unit and finally testing the unit. Keeping the unit ready for demonstration.

In the bidirectional dc-dc converters, isolation is normally provided by a transformer. The added transformer implies additional cost and losses. However, since transformer can isolate the two voltage sources and provide the impedance matching between them, it is an alternative in those kinds of applications. As a current source, inductance is normally needed in between. For the isolated bidirectional dc-dc converters, sub-topology can be a full-bridge, a half-bridge, a push-pull circuit, or their variations. One kind of isolated bidirectional dc-dc converter is based on the half-bridge in the primary side and on the current fed push-pull in the secondary of a high frequency isolation transformer The converter operation is described for both modes; in the presence of dc bus the battery is being charged, and in the absence of the dc bus the battery supplies power.

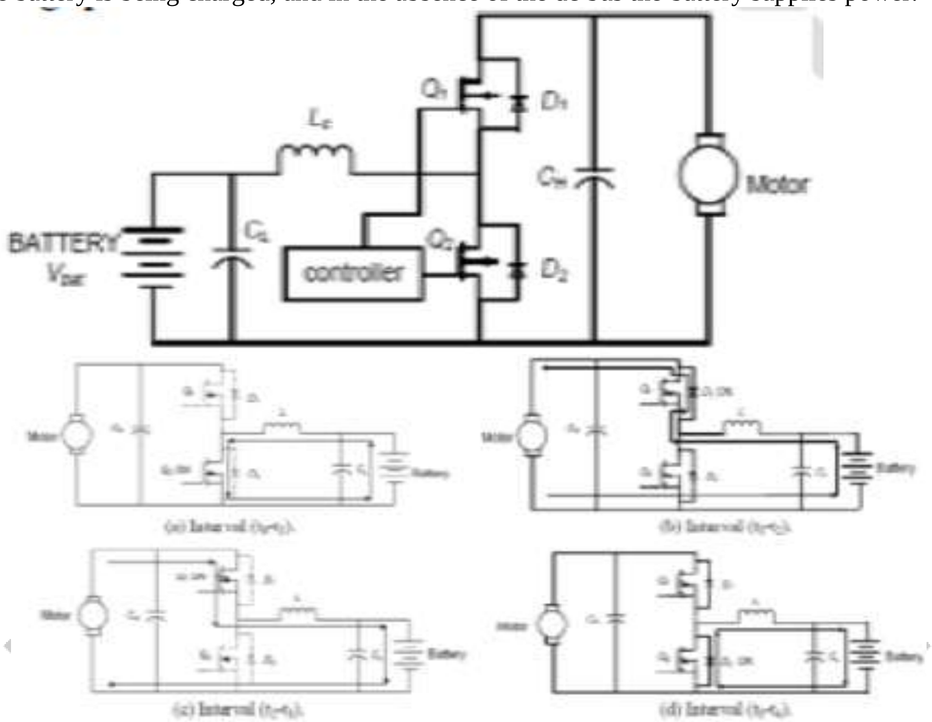


Fig. 5 (a) Bidirectional dc-dc converters with battery and dc motor.
(b) Converter operating modes.

IV. SIMULATION RESULTS

Fig 6 shows an SSIB converter using PV array as a power source (an improve version of SSB converter). The operation priciple of SSIB converter is just similar to SSB with the improved configuration of the network elements, this is done to achieve maximum power gain from the circuit (30% to 60%). So that maximum power can be obtained from the network to meet the load demand.

The network uses 4 MOSFET swithes (M1,M2,M3,M4) for the power boosting purpose and this is achieved by the firing angle control (MPPT, PID, Load parameter requirements). Inductor in a network is used as a current limiter against the rate of change of load. Whereas the capacitor acts as a voltage booster across the output. The diodes in the network used as reverse powerflow protection device (this is because of the grid connection requirements). The inductors which are connected in series are used to reduce the rate of rise of current and the capacitors which are connected in parallel are used to boost the voltage (to balance the momentary fluctuations due to load variation).

Intially when the MOSFET M3 is turned ON the MOSFET M4 will turned OFF, at this stage the inductor L3 gets charged and the switches M4 and M6 will turn OFF and the auxillary inductor L4 provides the charge to the capacitor, the three capacitors C4, C5 and C8 provide the energy to the load. At this stage the time delay of 0.5 has been given between the MOSFET switches M3 and M5, these switches are ON untill the 0.5 time delay.

After 0.5 time delay the 50% of the process is done and the switches M3 and M5 turned OFF and the awitches M4 and M6 will turned ON. The current will flow through the inductor L4 and L6. At this stage the capacitors C6 and C7 are having some charges, due to this the voltage is gets added with the input voltage and given to the load.

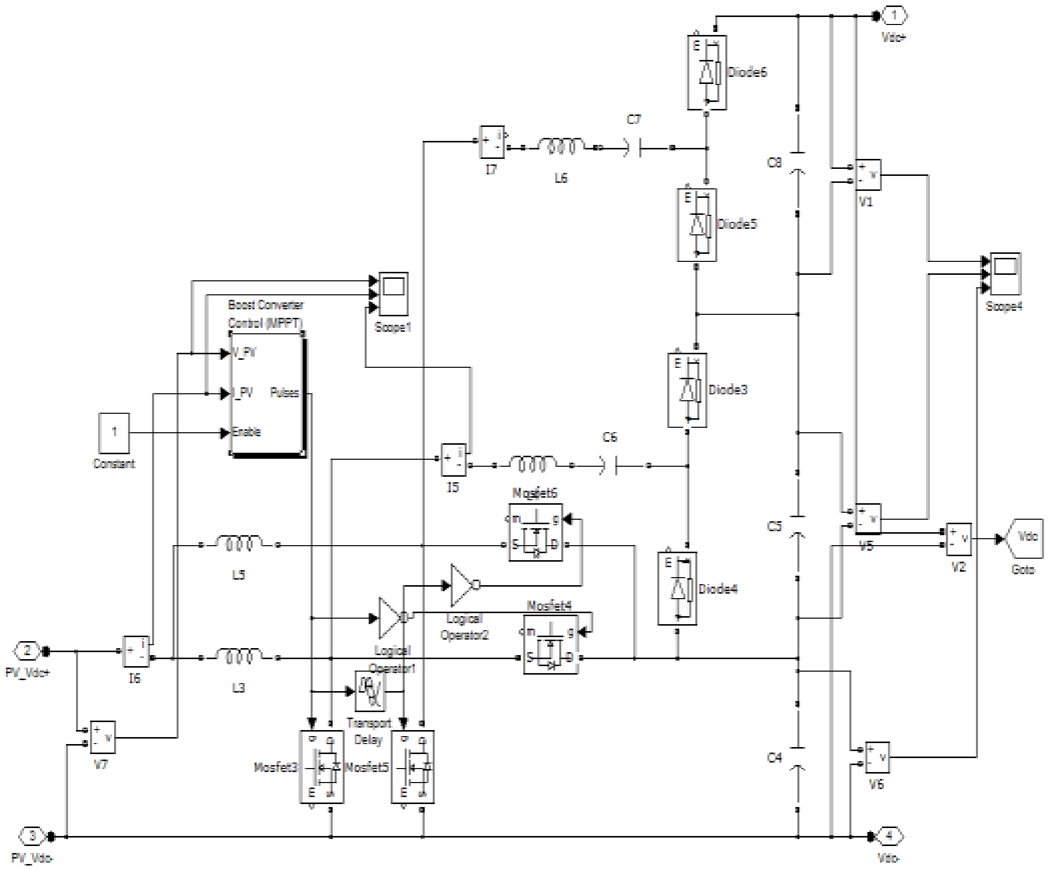


Fig. 6. Simulation model of SSIB converter.

The figure 7 shows the input voltage for both SSB and SSIB converters i.e. the desired value 795V. Fig 8 & 9 represents the current and voltage output of the SSB converter where current is 52A and voltage is 11KV with the time period of 0.1 to 0.2. Fig 10 & 11 represents the current and voltage output of the SSIB converter i.e. 82A and 14KV,there is a gradual increase in both voltage and current using SSIB converter configuration. Fig 12 represents the inverted AC output voltage which can be given to the utility grids.

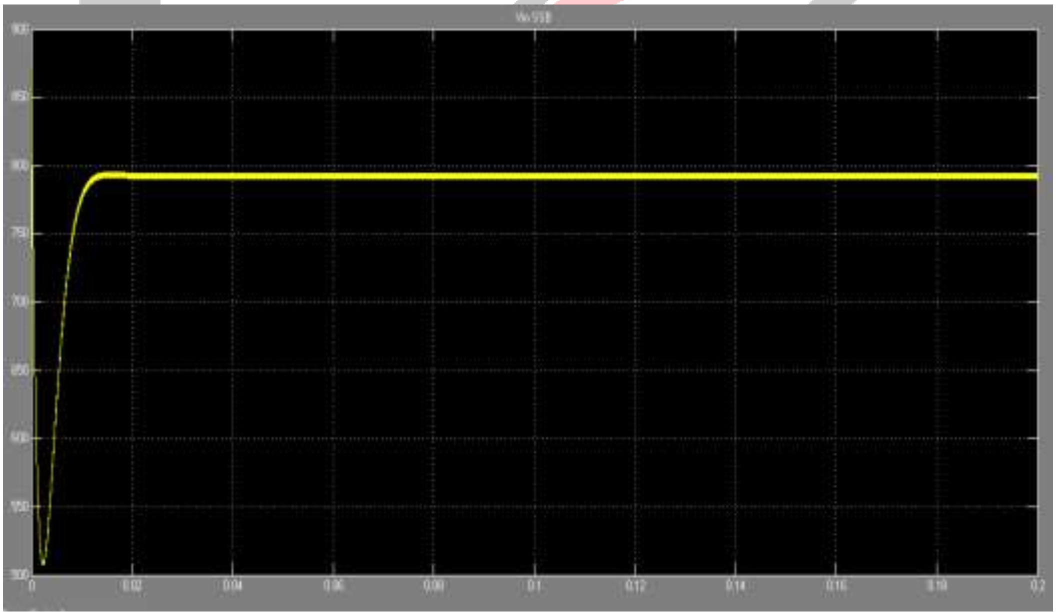


Fig.7: Input voltage for SSB and SSIB converter.

Fig 8 shows the current through the main inductor L1 i.e of 500 A and current through the auxillary inductor L2 i.e of 500 A, in this case the auxillary current is in both positive and negative region because of the reason auxillary current charges and discharges. Here the load current is the output of the SSB converter which is of the value 52 A, is a boosted current by using the SSB converter design.

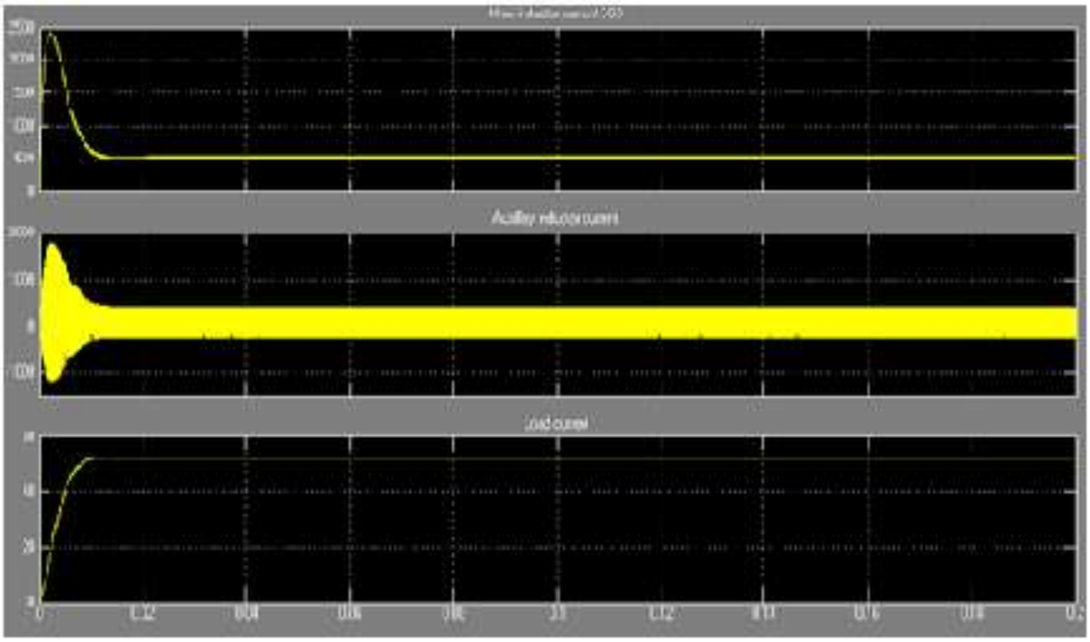


Fig.8: Main inductor current, auxiliary inductor current, load current of SSB converter.

Fig 9 shows an three voltage waveforms which represents the load voltage of SSB converter, voltage across capacitor 1 i.e V_{c1} and voltage across capacitor 2 i.e V_{c2} of SSB converter. By using the SSB converter design configuration we can achieve the load voltage of 7400 V which is a boosted voltage, intially this voltage starts from zero value and gradually increses with time and further maintained constant. The other two graphs in the fig represents V_{c1} which is of a value 3650 V and V_{c2} which is of a value 3720 V, the load voltage is divided by the two capacitors C1 and C2 which can be further given to the DC load.

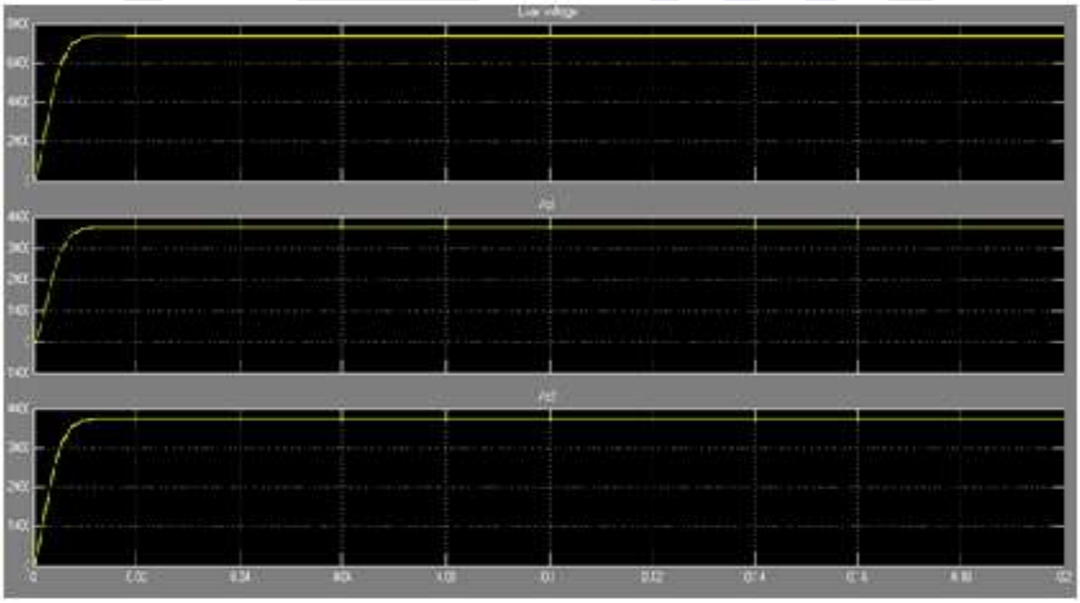


Fig.9: Load voltage and voltage across capacitor 1 & 2 of SSB converter.

Fig 10 shows the current through the main inductor L2 i.e of 1100 A and current through the auxillary inductor L2 i.e of 850 A, in this case the auxillary current is in both positive and negative region because of the reason auxillary current charges and discharges. Here the load current is the output of the SSB converter which is of the value 82 A, is a boosted current by using the SSIB converter design.

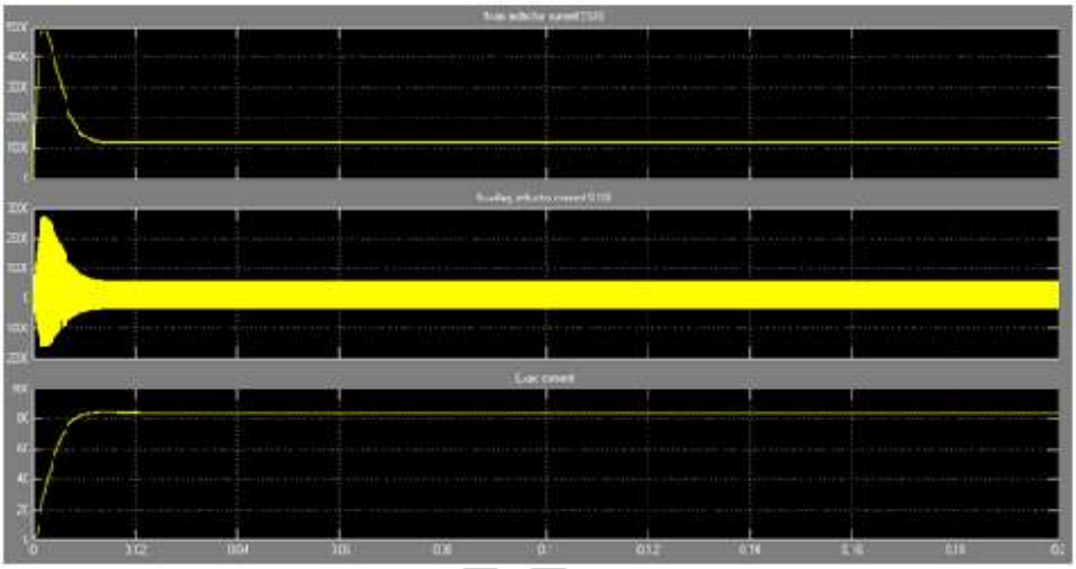


Fig.10: Main inductor current, auxiliary inductor current, load current of SSIB converter.

Fig 11 shows an three voltage waveforms which represents the load voltage of SSIB converter, voltage across capacitor 4 i.e V_{c4}, voltage across capacitor 5 i.e V_{c5} and voltage across capacitor 8 i.e V_{c8} of SSIB converter. By using the SSIB converter design configuration we can achieve the load voltage of 11 KV which is a boosted voltage, intially this voltage starts from zero value and gradually increses with time and further maintained constant. The other three graphs in the fig represents V_{c8} which is of a value 3600 V, V_{c5} which is of a value 3680 V and V_{c4} which is of a value 3600 V. The load voltage is divided by the three capacitors C4, C5 and C8 which can be further given to the DC load.

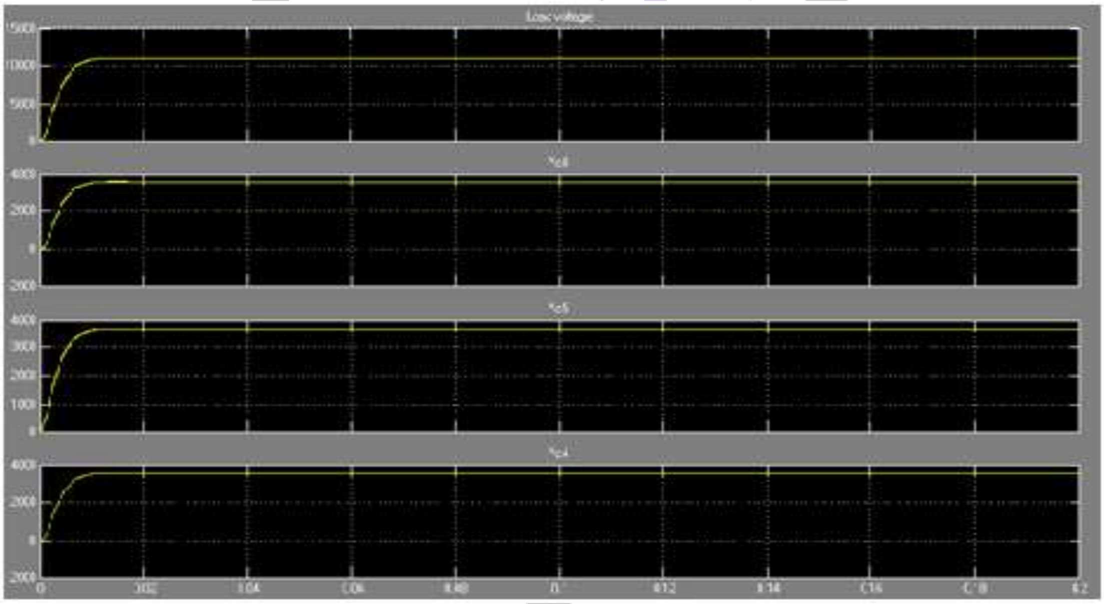


Fig. 11 Load voltage and voltage across capacitor 8, 5 & 4 of SSIB converter.

Fig 12 shows the inverter output of the SSIB converter which is a three phase voltage and we are getting a pure sine wave at the inverter side. The value of the inverter three phase voltage is 11 KV which is a boosted voltage by using SSIB converter design.

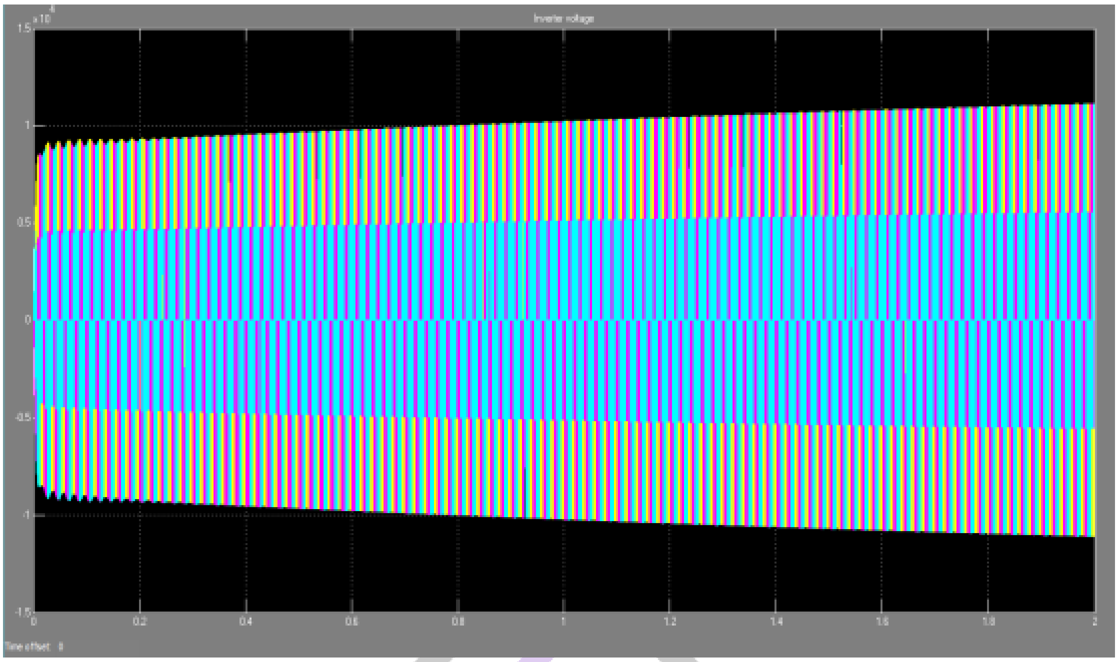


Fig. 12 Three phase AC output voltage at the inverter circuit.

V CONCLUSION

This report has presented the Soft Switched Interleaved Boost converter design for power boosting application. The SSB and SSIB converter technologies have been studied from the obtained results it is seen that SSIB converter is more efficient when it is compared to the gain in voltage, current and power in the network and also the converter efficiency is maximum compared to SSB.

This presented Soft Swiched Interleaved Boost converter design concern with the increasing the efficiency of the PV solar panels using high gain DC to DC converters. The converter efficiency is going to increase upto 95% using presented converter configuration.

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