PV BASED EV CHARGING STATION

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Abstract - *The photovoltaic system has emerged as an attractive alternative for feeding countryside remote charging station and roadside restaurant loads due to the abundant solar energy reserves and cost of energy extraction. The output from a PV needs a high performance step up converter to cater to the consumer loads and EV's charging. The conventional boost converter provides poor power quality and response time, thereby increasing the complexity due to higher magnetic and switching losses, while delivering higher gain, thus making it impractical for applications demanding high output voltage gain. High voltage gain based on voltage multiplier converter with isolation is proposed, which is capable of reducing the voltage stresses across the switches, thus reducing the conduction losses, current ripple and EMI and increasing the efficiency of off grid roadside EV charging bay and restaurant lighting loads, by tapping the energy from the PV source. A converter-inverter model has been simulated using the MATLAB software and implemented practically using a PIC controller.*

Key Words: High voltage gain, boost converter, photovoltaics, EV charging, IVMC.

1. INTRODUCTION

The current levels of dependence on fossil fuels, the necessity of reducing the carbon emissions related to energy use and therefore the prospects of developing an innovative technology sector, make photovoltaics increasingly attractive. Photovoltaics offer consumers the ability to generate electricity in a clean and reliable way. In photovoltaic array multiple panels electrically wired together to form a PV system [1]. Photovoltaics system has photovoltaics cells, devices that convert light energy directly into electricity [2]. The flexibility of photovoltaic system allows designers to create solar power systems that can meet a wide variety of electrical needs.

To increase the uses of electric vehicle at remote location and minimize the grid burdening in urban areas, an off grid charging station plays a significant role. The off grid charging station seeks energy from renewable energy sources. Charging stations provide a variety of heavy duty or special connectors that conform to the variability of standards. For common DC rapid charging, multi-standard chargers equipped with two or three of Combined charging and AC fast charging has become the standard in many regions.

A switched capacitor is a circuit implementing a filter and works by moving charges into and out of capacitors when switches are opened and closed[3].A step up switched mode converter provide high voltage gain using switched capacitor[4]. Full bridge converter is used in application of high voltage requirement[5].DC-DC boost converter is a step up converter which converts a source of direct current from one voltage level to another by storing the input energy temporarily then releasing that energy to the output at different voltage[6]. They are widely used in battery power systems, heaters, welders, communication applications battery charging circuits, fuel cell application and solar cell energy conversion system[7].DC boost converter provide high voltage by using voltage multiplier cells consists of capacitors and diode rectifier[8].An interleaved boost converter is capable of reducing ripple current in both input and output circuits and higher efficiency[9]. Compared with the other converters the DC-DC boost converters has low operating duty cycle, gives high output voltage, low voltage on switches, easy to drive the MOSFET switches and gives high efficiency due to single switch operation [10].

2. SYSTEM CONFIGURATION

The paper proposes an isolated voltage multiplier converter for PV based EV charging station connecting multiple loads in remote locations. The system comprises of a 200W PV panel, high gain boost converter, dc-ac inverter with PWM generator and load.

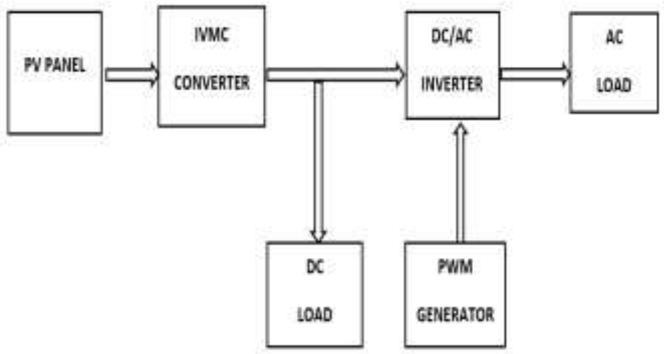

Fig - 1: System Configuration

The PV panel comprises of 54 cells, open circuit voltage (VOC) of 32.9V and short circuit current (ISC) of 8.21 A. Fig.1 depicts the PV panel connected to a proposed high gain boost converter suitable for EV charging applications and other loads in remote locations. An input of 24V from the panel is given to the boost converter. The converter boost up the voltage to 330V that can be maintained constant with the help of a voltage converter. The voltage gain acquired by the converter in the process of switching is 13.75 making it suitable for EV charging applications. The boosted up voltage is given to the DC load and inverter which converts the dc voltage to corresponding AC voltage making it suitable to supply AC loads. The system can be further enhanced by integrating with AC distribution grid through single phase inverter.

3. OPERATION OF IVMC

Fig.2 depicts the circuit diagram of isolated voltage multiplier converter (IVMC) with solar panel generating power at 330V for EV chargers and other loads in remote location.

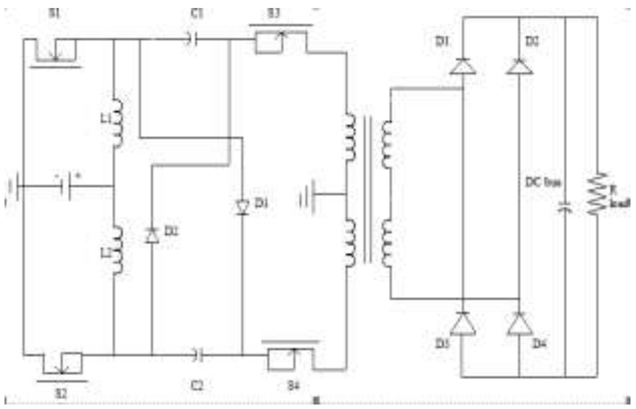

Fig - 2: Isolated Voltage Multiplier Converter

Active power factor correction (PFC) is used as front end in EV chargers to aggregate 330V at the load side. The proposed system tends to gain access in retrofit applications, there are three stages incorporated in the converter namely interleaved boost stage cascaded with voltage multiplier cell, which feeds the centre-tapped transformer to provide galvanic isolation. The converter provides high input current with low ripples, low voltage stress across the switches, high voltage gain and also provides smooth DC voltage curve at the load side of the converter with the help of 4 diodes at the secondary side of the centre-tapped transformer. The converter uses 3 state switching in order to reduce current stress of the switch, size of the core and copper of the transformer, common mode noise which further improves signal integrity of the converter.

3.1 Topological Modes

The proposed converter operates in 4 modes. The converter is just an extension of a boost converter with an added advantage of isolation provided by the centre- tapped transformer. The operating principle of the proposed converter is based on the principle of voltage multiplier. The circuit for the modes of the converter are shown in figures 3, 4, 5 and 6.

3.2 Mode 1

The current flows through the switch S1 while switch S2 is off. Inductor L1 stores the energy and the inductor L2 provides energy to the load. By keeping the switch S1 on the current flows through L1, C1, D2, C2 and switch S4.Switch S1, S4 conducts while switch S2, S3 does not conduct. The sum of the voltage across the multiplier capacitor C1 and C2 are seen across the primary winding of the center tapped transformer and is filtered to the output capacitor and fed to the load.

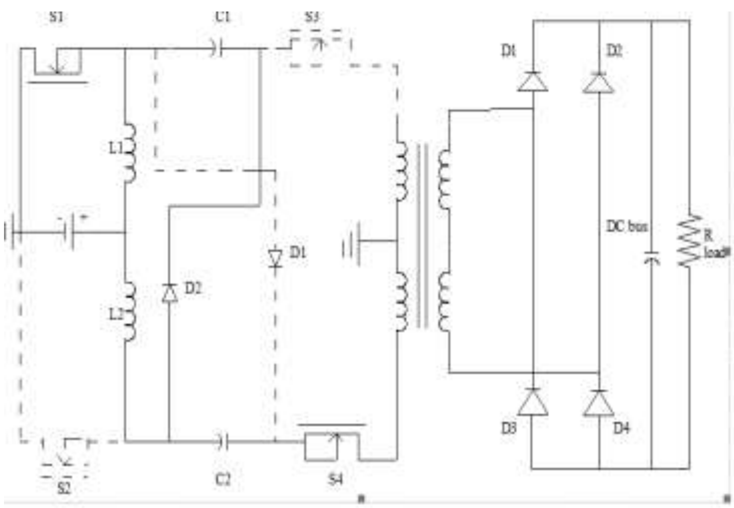

Fig - 3: Mode 1 operation of IVMC

3.3 Mode 2

The current flows through the switch S1 and S2 and energy is stored in both inductors L1 and L2.There is no transfer of energy to the load as the diodes D1 and D2 does not conduct and the high side switches S3 and S4 are off and no voltage is seen across the primary side of the centre-tapped transformer. The multiplier capacitor C1 and C2 maintains the dc voltage. The energy is provided to the load by the output capacitor.

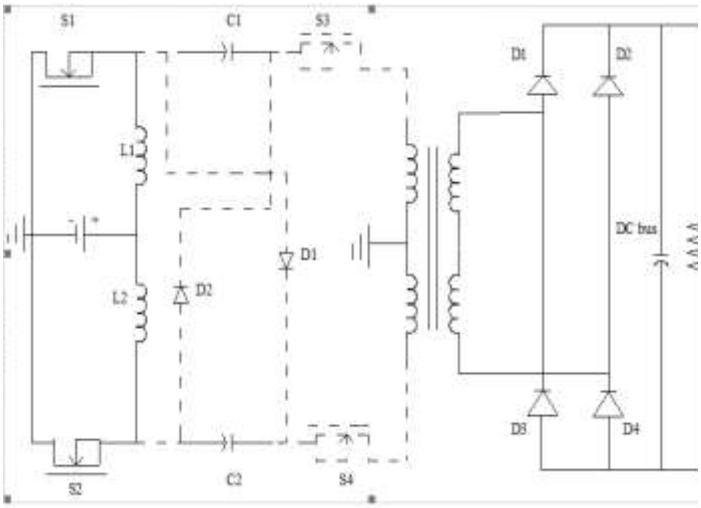

Fig – 4: Mode 2 operation of IVMC

3.4 Mode 3

The current flows through switch S2 while switch S1 turns off. Energy is stored in inductor L2 and L1 provides energy to the load. Diode D1 and high side switch S3 conducts. The sum of the voltage across the multiplier capacitors are seen across the primary winding of the centre-tapped transformer and is filtered to the output capacitor and fed to the load.

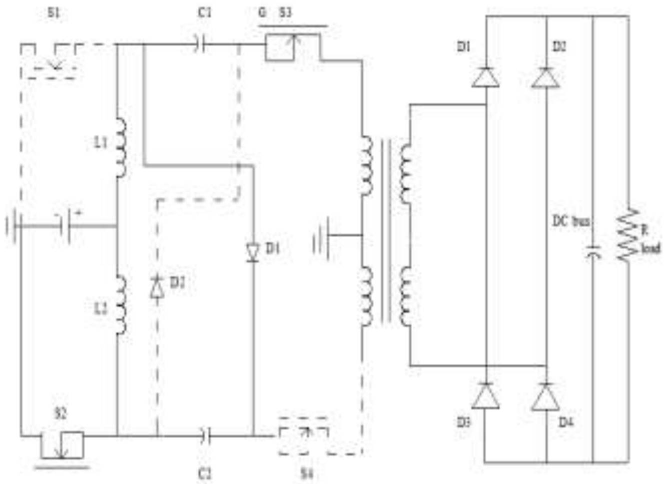

Fig -5: Mode 3 operation of IVMC

3.5 Mode 4

The current flows through the switch S1 and S2 and energy is stored in both inductors L1 and L2.There is no transfer of energy to the load as the diodes D1 and D2 does not conduct and the high side switches S3 and S4 are off and no voltage is seen across the primary side of the centre-tapped transformer. The multiplier capacitor C1 and C2 maintains the dc voltage. The energy is provided to the load by the output capacitor.

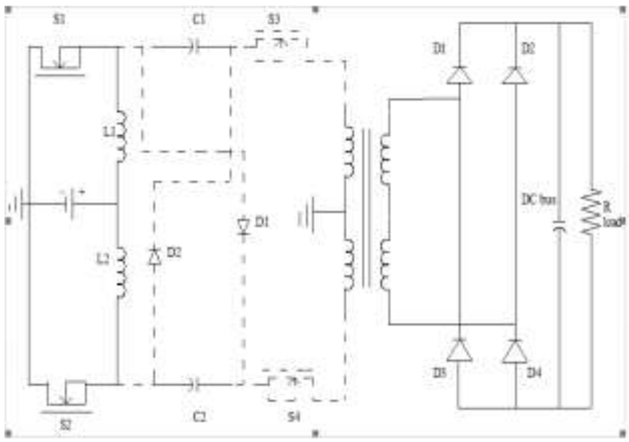

Fig - 6: Operation of IVMC in mode 4

4. DESIGNING OF IVMC

The section provides the design of IVMC. Eq(1) provides the duty cycle of the proposed converter. The voltage gain acquired by the converter is 13.75 . Eq(2) shows the minimum inductance value of the converter where R is load resistance of the converter and D is duty cycle. The multiplier capacitance value is derived from Eq(3). Eq(4) provides the ripple factor where Co is filter capacitance. The input parameters and IVMC design parameters are tabulated below in Table 1 and Table 2 repectively.

$$D = 1 -(Vin/Vo) \quad (1)$$

$$Lmin = (D*(1-D)*Vin*R)/(2*fs*Vo) \quad (2)$$

$$Cmin = (1/ Lmin*(2*3.14*fs)^2) \quad (3)$$

$$r = (1/ 4*1.73*f_s*C_o*R) \quad (4)$$

Table - 1: Input Parameters

S.NO	PARAMETERS	VALUE
1	DC input voltage	24V
2	Switching frequency	20 KHz
3	Output voltage	330V
4	Turns ratio	1:2
5	Power rating	200W

Table - 2: Design Parameters

S.NO	PARAMETERS	VALUE
1	Inductance	1µH
2	Multiplier capacitance	2 µF
3	Multiplier capacitor voltage	105V
4	Voltage gain	13.75

5. CIRCUIT ANALYSIS

Fig. 7 shows the inductor currents and the current at the interleaved input. The primary side of the IVMC can operate with low voltage stresses due to the reflection of multiplier capacitor voltage across the drain to source voltage (V_{DS}) of the switch. The low voltage stress of the switch allows the selection of high current device, thus reducing the conduction losses and improving the converter efficiency. The converter can provide higher gain by increasing the number of multiplier cells. The strength of proposed topology is assessed by witnessing the capability in the intermediate stage. The interleaved voltage multiplier stage accumulates a voltage gain of 13 by aggregating the voltage acquired by each capacitor (100V) to 190V at the input of the isolation transformer. The multiplier capacitor voltage is shown in Fig.8. The transformer winding voltage aggregated at the input side is represented in fig. 9. The input voltage from the solar panel was boosted up to 330 V at the DC bus of the converter which is represented in fig. 10.The inverter output current and voltage is shown in Fig.11.

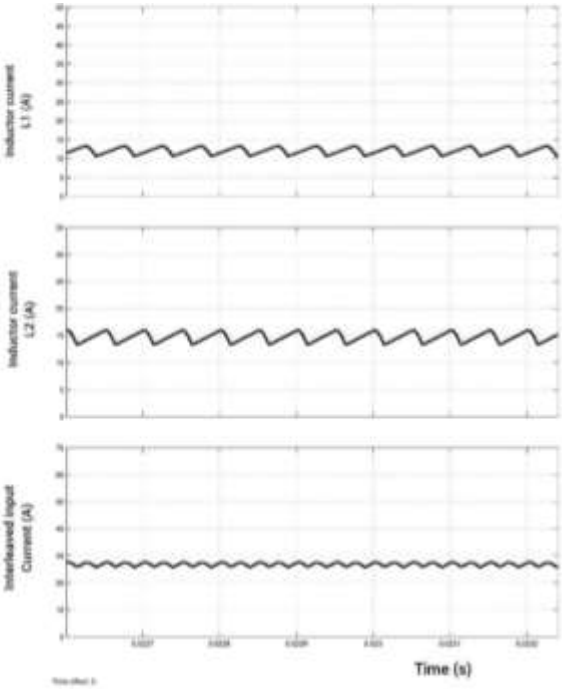

Fig- 7: Inductor Currents and Interleaved Input Current

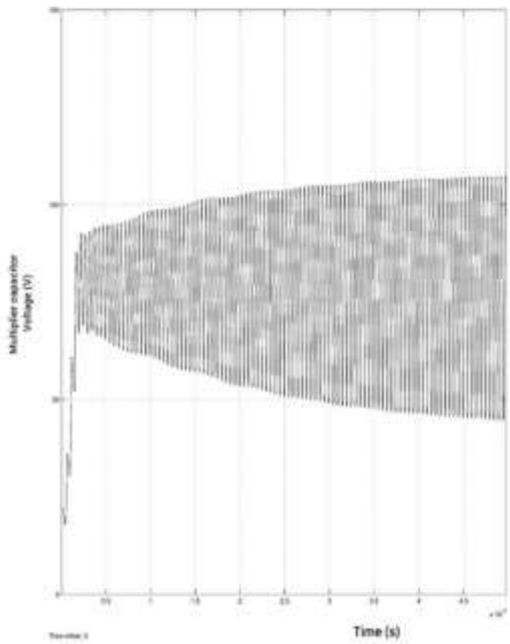

Fig- 8: Multiplier Capacitor voltage

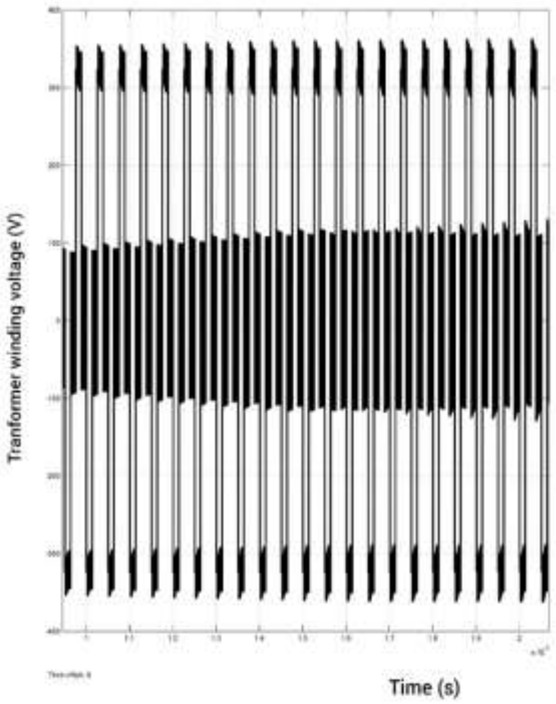

Fig- 9: Transformer winding Voltage

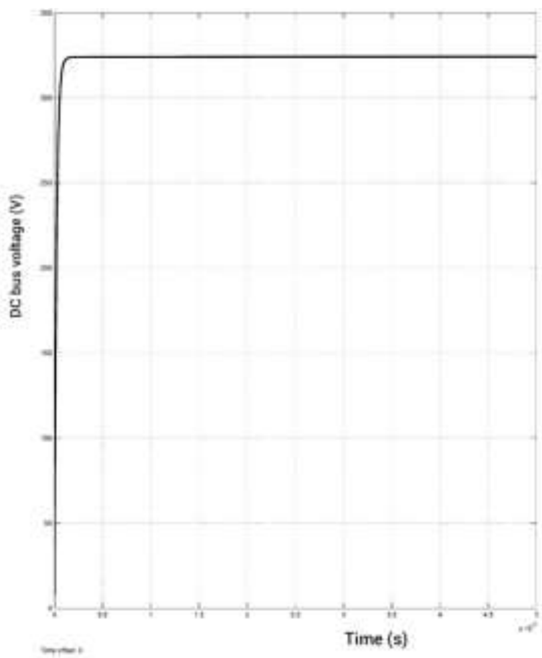

Fig-10: DC bus voltage

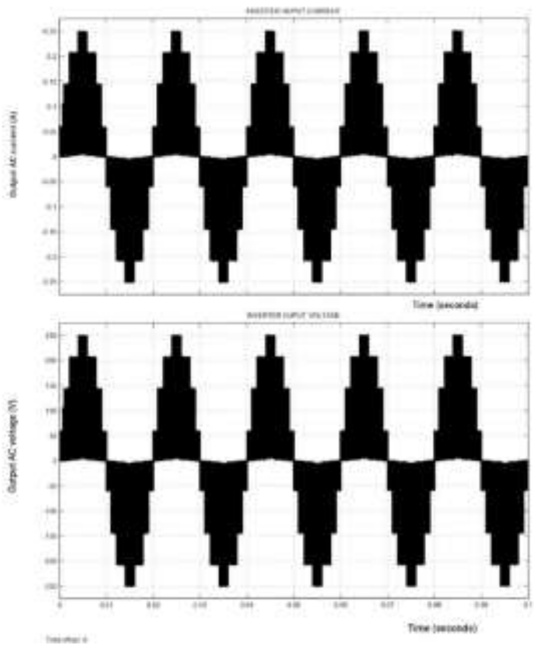

Fig-11: Inverter AC output

6. CONCLUSION

The results show that the proposed isolated voltage multiplier converter is capable of operating successfully for EV charging applications and other loads in off grid environment fed from PV source. It can also be used alongside grid based applications as a backup. The results clearly reflect the capability of the topology to extract energy from PV with very low ripple, transact negligible common mode current, low voltage stress across the switches and galvanic isolation with operation of high frequency transformer with 3 State Switching while maintaining high efficiency to output power with high gain. The converter is modular and employs simple control scheme. This topology offers multiple advantages for applications to off grid retrofit EV charging applications.

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