SINGLE-PHASE H6 TRANSFORMERLESS INVERTER WITH A SIMPLE BOOST CONVERTER FOR PV-GRID TIED POWER SYSTEMS

Aparna Das[1], Sheeja G[2]

[1]*Power Electronics, VAST, Kerala, India*
[2]*Power Electronics, VAST, Kerala, India*

Abstract

Inverters with transformers of conventional type, connected in PV grid-tied generation systems have now being replaced by transformerless inverters due to various reasons such as reduction in size, weight and cost, improvement in efficiency etc. Transformerless inverters cause a number of technical challenges in grid-connected PV systems, among which flow of leakage currents is a major problem. This leakage currents that flows between the parasitic capacitance of PV array and the grid has to be eliminated, which otherwise leads to serious safety problems. This paper deals with an H6 transformerless full- bridge inverter topology with low leakage currents that can be used in PV grid – tied applications. The operation modes for the proposed topology are discussed in this paper. A closed loop has been developed for maintaining the voltage constant at the grid side irrespective of changes in the input voltage. Aforementioned transformerless topology is simulated that validates the effectiveness of the converter.

Keywords: *Common-mode voltage, grid-connected inverter, leakage current, photovoltaic (PV), transformerless inverter.*

---***---

1. INTRODUCTION

Nowadays, the invention and development of new energy sources are increasing due to the poisonous results caused by oil, gas and nuclear fuels. This has led the renewable energy sources especially the solar PV systems to the prime position in the generation of electricity [4]. Photovoltaic have applications ranging from small power supplies to power grids. Photovoltaic systems connected to the grid have several advantages such as simplicity in installation, high efficiency, reliability and flexibility [5]. With a reduction in system cost PV technology seems to be an efficient means of power generation. A solar grid connected power generating system usually consists of a solar panel in which the solar cells are arranged to track sunlight, an inverter to convert the DC to AC and the grid. This paper evaluates a single phase transformerless inverter topology called H6, which can minimize the dangerous leakage currents between the solar power generation system and the electrical grid. Transformers are employed in the grid tied systems to provide a galvanic isolation between the PV panel and the grid for safety considerations [2].Line frequency transformers were employed in most of the PV grid tied inverters. But in line frequency transformers due to their low frequency, the size, cost, weight etc. will be higher. The next option is the high frequency transformers. The usage of high frequency transformers increases the number of power stages which affects the efficiency in an adverse manner [1]. When these transformers are eliminated there will be a galvanic connection between the solar module and the grid which results in a potential fluctuation between the PV array and the ground .The potential variation leads to the flow of common mode leakage currents that has to be eliminated which otherwise leads to electromagnetic distortions, interferences, harmonics and other power quality issues. The H6 transformerless inverter topology with unipolar sinusoidal PWM strategy seems to be a better solution to reduce these leakage currents by maintaining the common mode voltage constant. A simple boost converter is employed to boost the voltage available from the PV panel so as to connect to the grid. The block diagram for the system is shown in fig 1.

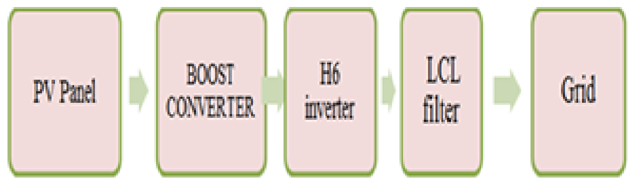

Fig -1: Block Diagram

A full bridge topology is suitable since it requires only half the input voltage as required by the half bridge topology [3].

1.1 Assumptions

1. Filter inductors used L1 and L2 are assumed to be of same value.
2. Common mode voltage, VCM is expressed as VCM = $(V\_AN + V\_BN)/2$
3. The switches and diodes are ideal and the dead time between the switches are neglected.
4. Inductors are ideal without any internal resistance

1.2 Comparison of H6 Topology with Other Transformer less Inverter Topologies

Table -1: Comparison table

H6 TOPOLOGY	H5 TOPOLOGY	HERIC TOPOLOGY
Includes two extra switches on the DC side of the inverter	Includes one extra switch on the DC side of the inverter	AC sides of the inverter have two extra switches
Total device number is six.	Total device number is five.	Total device number again six.
Device cost is same as that of HERIC	Have lowest device cost	Device cost same as that of H6
H6 topology has four modes of operation	H5 topology has four modes of operation	HERIC topology has four modes of operation
Conduction loss higher than HERIC	Have highest conduction loss	Conduction loss lesser than H6
Thermal stress distribution is in between H5 and HERIC	Worst thermal stress distribution	Best thermal stress distribution
Leakage current characteristics similar to that of HERIC topology	Best leakage current characteristics	Occupies second place in the case of leakage current characteristics
Switching losses are same as that of H5 and HERIC	Switching losses are same as that of H6 and HERIC	Switching losses are same as that of H6 and H5
Diode freewheeling loss same as that of H5 and HERIC	Diode freewheeling loss same as that of H6 and HERIC	Diode freewheeling loss same as that of H6 and H5
European efficiency is about 97.09%	European efficiency is about 96.78%	European efficiency is about 97%

2. CIRCUIT DIAGRAM

Fig 2 shows the circuit diagram of the proposed H6 inverter topology. It consists of six MOSFET switches S1, S2, S3, S4, S5 and S6. The modulation technique used is the unipolar sinusoidal PWM. The photovoltaic panel is represented by Vpv. An LCL filter is used for filtering purpose. Vgrid represents the electrical grid. Cdc represents the input dc capacitance.

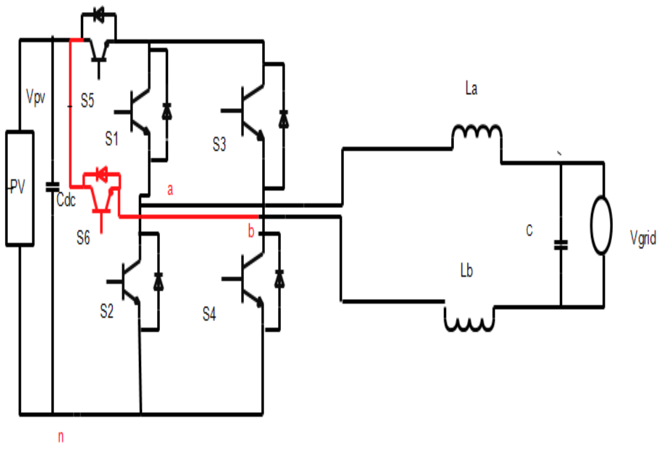

Fig -2: Proposed transformer less H6 inverter topology

2.1. Modes of Operation

There are four modes of operation for the proposed H6 inverter. The four modes include two active modes and two freewheeling modes.

Mode 1: Active Mode

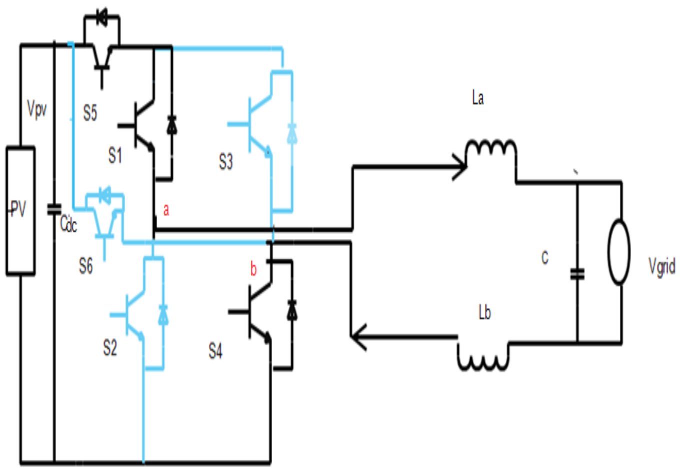

Fig -2.1: Active mode in positive half period

During active mode of positive half period switches S1, S4 and S5 will conduct and switches S3 and S6 remains in the Off position. The direction of current flow is indicated by the arrows. The common mode voltage VCM is given by VCM = (Van + Vbn)/2 ≈ 0.5VPV.

Mode 2: Freewheeling Mode

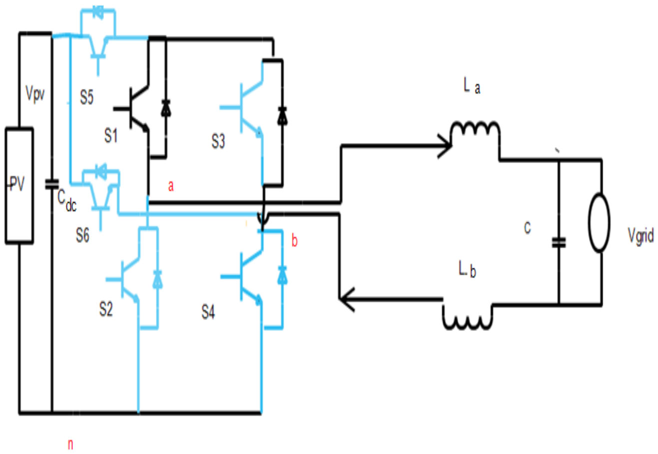

Fig -2.2: Freewheeling mode in positive half period

During freewheeling mode of positive half period, current freewheels through switch S1 and the antiparallel diode S3.All the other switches remains in off position. The common mode voltage during this period is given by VCM=Van +Vbn/2=0.5VPV

Mode 3: Active Mode

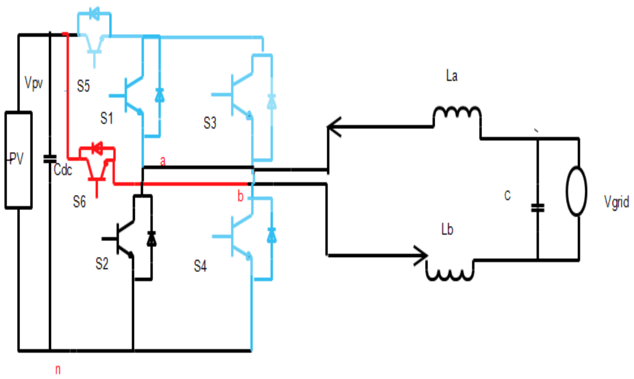

Fig -2.3: Active mode in negative half period

During active mode of negative half period switches S2, S3 and S6 will conduct and switches S1 and S4 remains in the off position. In this mode of operation although three switches are turned on, current flows through only S2 and S6 and hence the conduction losses can be reduced. The direction of current flow is indicated by the arrows. The common mode voltage VCM is given by

$$VCM = (Van + Vbn)/2 \approx 0.5VPV.$$

Mode 4: Freewheeling Mode

During freewheeling mode of negative half period, current freewheels through switch S3 and the antiparallel diode S1.All the other switches remains in off position. The common mode voltage during this period is given by VCM=Van +Vbn/2=0.5VPV.

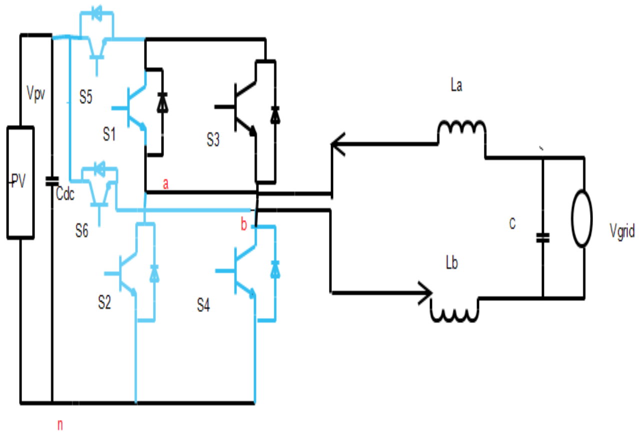

Fig -2.4: Freewheeling mode in negative half period

3. SIMULATION

3.1 Simulation Parameters

The simulation parameters used are given in table 1.

Table -2: Simulation parameters

PARAMETERS	VALUES
Rated power	57.5 W
Input PV voltage	230 V
Grid voltage	230 V
Grid frequency	50 Hz
Switching frequency	20 KHz
Filter inductors La , Lb	3 mH
DC capacitance	940 µF
Resistive Load	1000 Ω
Output capacitance	0.47 µF
Power devices	(MOSFET)
Boost converter inductance	1 m H
Boost converter capacitance	1000µF

The gate drive signals for the MOSFET switches are shown in fig 3.

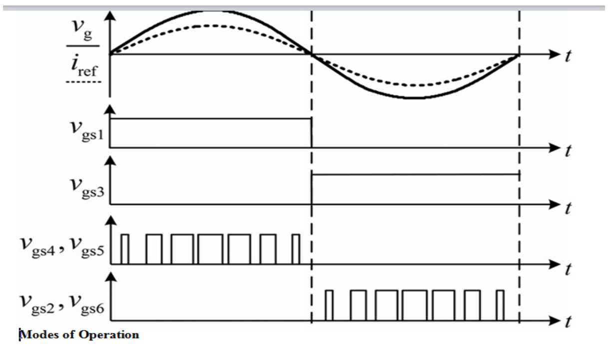

Fig - 3: Gate drive signals

The simulation diagram for the proposed H6 inverter topology connected to the grid is shown in fig 4.

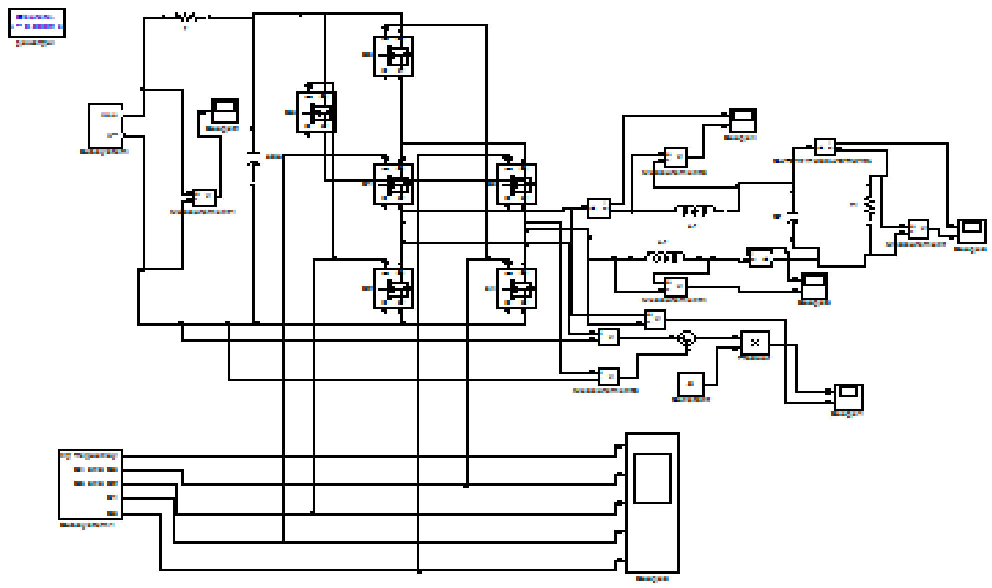

Fig - 4: Simulation diagram

The closed loop for voltage control is shown in fig, 4.1

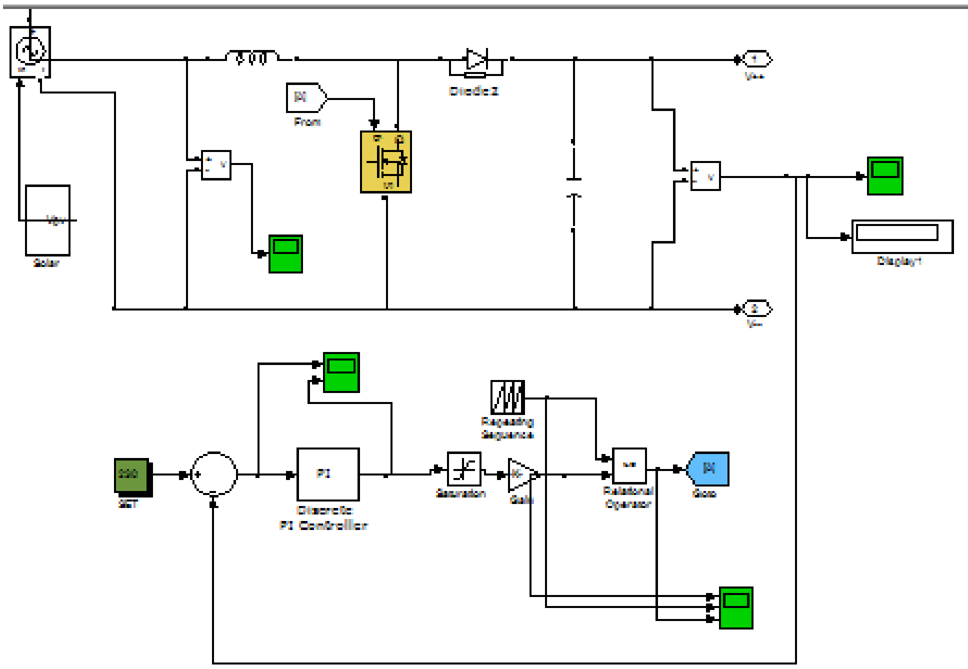

Fig – 4.1: Closed loop for voltage control

The simulation results obtained are as shown in figure 5.

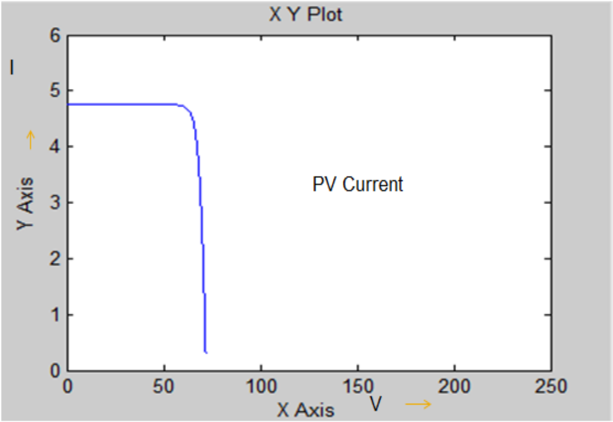

Fig - 5a: PV current

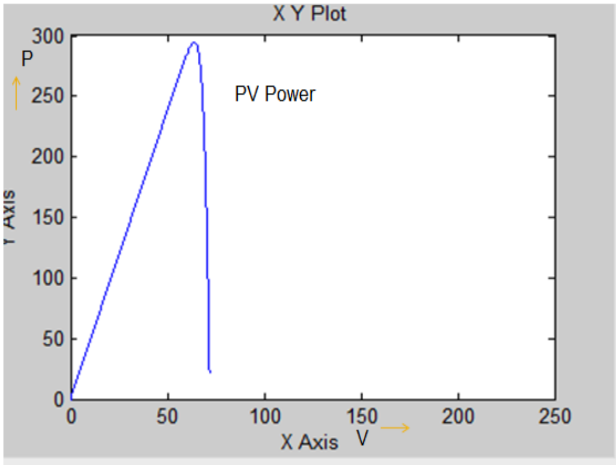

Fig – 5b: PV Power

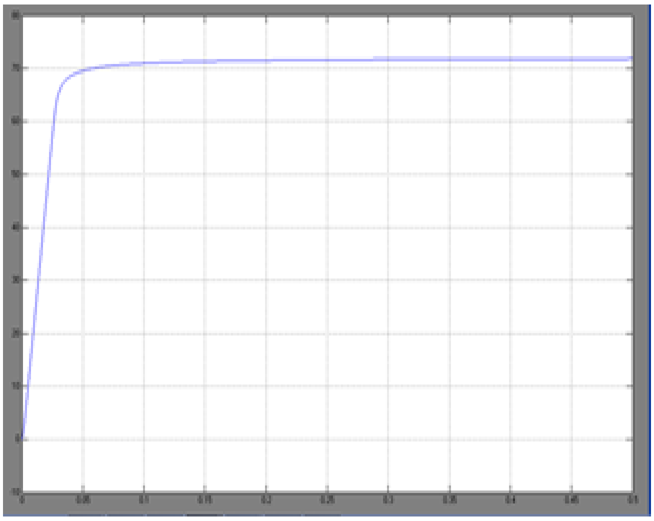

Fig – 5c: PV Voltage – before boosting

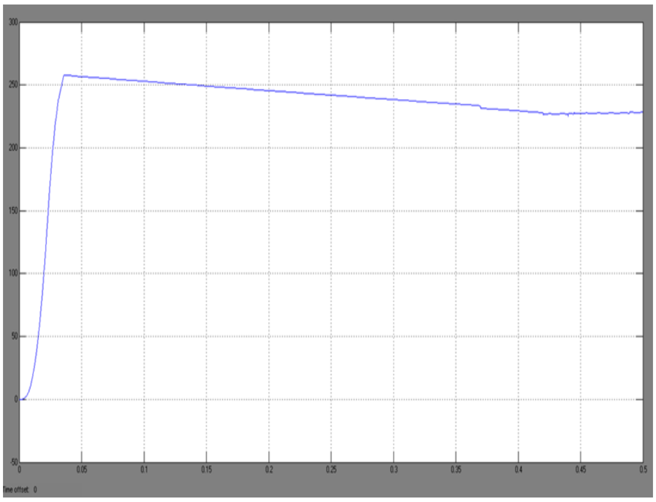

Fig – 5d: Boosted PV voltage

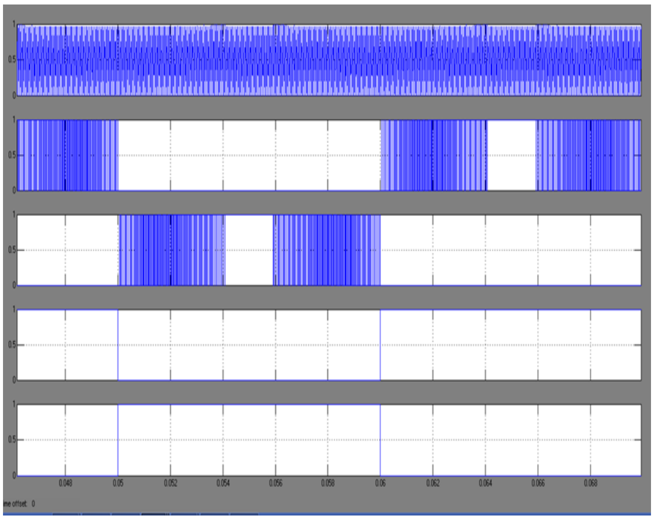

Fig – 5e: Gate drive signals for MOSFETS

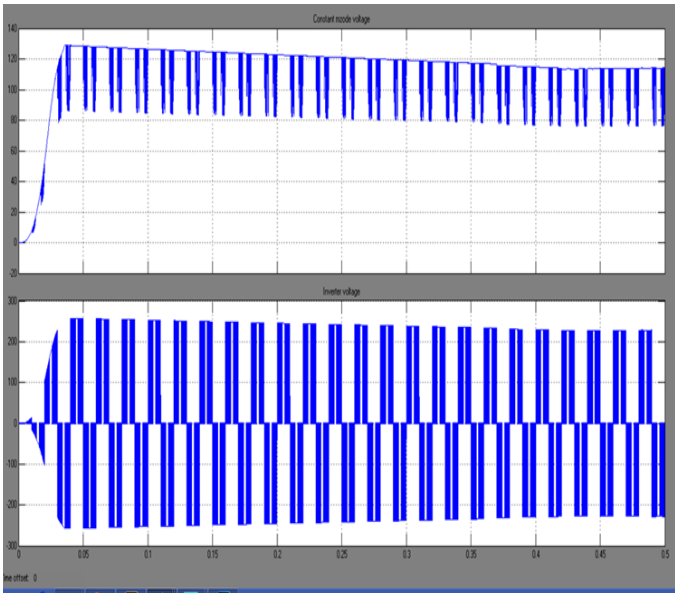

Fig – 5f: CM voltage, inverter voltage

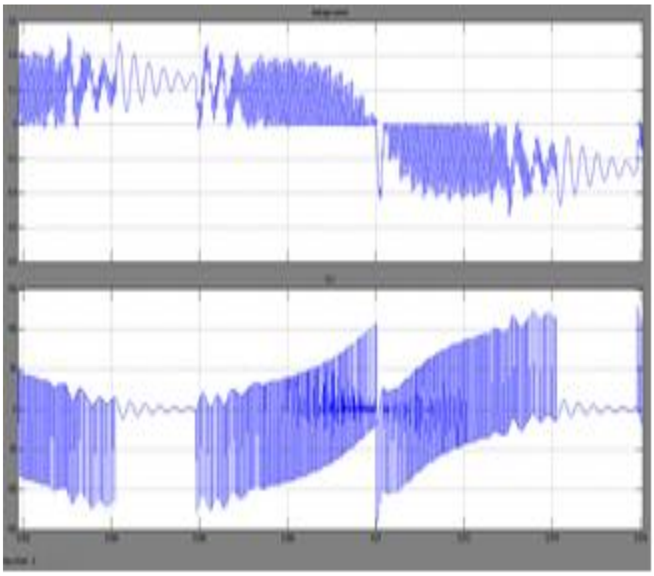

Fig – 5g: Leakage current, VLa

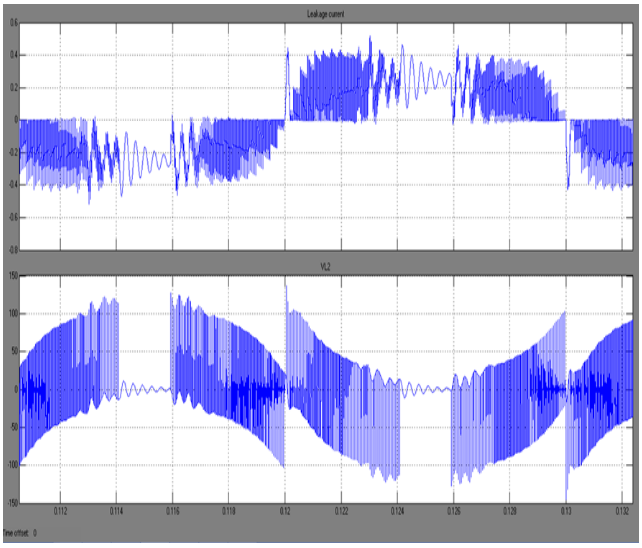

Fig – 5h: Leakage current, VLb

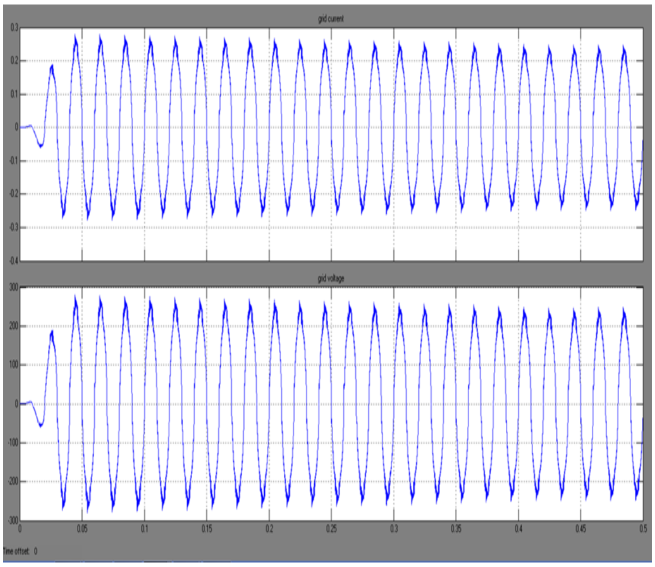

Fig – 5i: Grid current & Grid voltage

3.3 Simulation Results

The simulation results obtained are given in table 3.

Table -3: Simulation results

PARAMETERS	VALUES
PV Voltage Obtained	72 V
Boosted DC Voltage	230 V
PV Current for 72 V DC	0.25 A
Grid current	0.25 A
Grid voltage	230 V
Output Power	57.5 W

4. CONCLUSION

Tapping roof top solar power is gaining importance in order to meet shortage of electric power. The solar power is fed to the grid through an inverter. There are different topologies of inverter with and without galvanic isolation. In this work a topology, H6 topology is taken for analysis, design and simulation. An H6 topology is designed for 46 W and 230 volts, 50 Hz. Different components are selected for the design. The circuit is simulated to verify the design and to check whether the reference grid current is obtained. The leakage current is also tested through simulation. Now it is found that the design objectives are satisfied through simulations.

ACKNOWLEDGEMENTS

I wish to record my indebtedness and thankfulness to all those who helped me prepare this paper titled" Single Phase H6 Transformerless Inverter with a Simple Boost Converter for PV -Grid Tied Power Systems and present it in a satisfactory way.

REFERENCES

[1]. Li Zhang, Kai Sun, Yan Xing, and Mu Xing, "H6 Transformerless Full-Bridge PV Grid-Tied Inverters" IEEE Trans. Power Electron., vol. 29, no. 3, pp. 1229 – 1238, March 2014.

[2]. R. Gonzalez, J. Lopez, P. Sanchis, and L. Marroyo, "Transformerless inverter for single-phase photovoltaic systems," IEEE Trans. Power Electron., vol. 22, no. 2, pp. 693–697, Mar. 2007.

[3]. S. B. Kjaer, J. K. Pederson, and F. Blaabjerg, "A review of single-phase grid-connected inverters for photovoltaic modules," IEEE Trans. Ind.Appl., vol. 41, no. 5, pp. 1292–1306, Sep/Oct. 2005.

[4]. INTERNATIONAL JOURNAL OFENERGY AND ENVIRONMENT Volume 3, Issue 4, 2012 pp.639-650 Journal homepage: www.IJEE.IEEFoundation.org

[5] Advantages and Disadvantages of Grid Connected System mudassarblog.blogspot.com

BIOGRAPHIES

Aparna Das, is a PG student pursuing M.tech in Power Electronics at Vidya Academy of Science & Technology, Thrissur district Kerala. She has completed her B.Tech in Electrical & Electronics Engineering from Jyothi Engineering college, Thrissur district Kerala in the year 2012.Her current research interests include Power Converters, Renewable Energy Generation Systems and grid technologies.

Email id:**anjuammu.das@gmail.com**

Sheeja G, is a PG student pursuing M.tech in Power Electronics at Vidya Academy of Science & Technology, Thrissur district Kerala. She has completed her B.Tech in Electrical & Electronics Engineering from Annamalai University Chidambaram, in the year 2008.Her current research interests include DC-DC Converters, Renewable Energy Systems and Power Quality Problems.

Email id: **sheejaeee.in@gmail.com**