International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(22s) 2026 pp. 1816-1825
https://doi.org/10.70917/ijcisim-2026-4430
Article

Single Phase Photovoltaic Inverter with Grid Synchronization Using Dual Stage DC-DC Boost Converter

Harsh Vaghela[1], Bhavesh Patel[2], Nitin Adroja[3], Vishal Rathod[4], Hardik Bhatia[5], and Shivam Kapoor[6]

[1, 2, 3,4]Electrical Engineering Department, Government Engineering College Bhuj, Gujarat Technological University, Gujarat, India.
[5, 6]Environment Engineering Department, Government Engineering College Bhuj, Gujarat Technological University, Gujarat, India
[1]http://orcid.org/0009-0001-6301-0076 , [2]http://orcid.org/0009-0007-5867-1594 [3]http://orcid.org/0009-0007-9182-9322 , [4]https://orcid.org/0009-0000-4522-0603 , [5]http://orcid.org/0009-0003-9718-778X [6]https://orcid.org/0000-0001-5036-5858

Abstract: Now a days, transformer less inverter for grid connected photovoltaic system getting more attractive because of the benefits like lower cost, smaller in size as well as higher efficiency as compared with the transformer based inverter. However, once a transformer is removed, there is no any kind of galvanic isolation between photovoltaic arrays and grid. There is one another technical problem is the leakage current issue which needs to be escaped carefully. A new H6- type transformer less inverter for grid connected photovoltaic system is proposed that can reduce the problem of galvanic isolation by operating H6 inverter in freewheeling mode. It can also remove the leakage current by maintaining the common mode voltage constant at safe level as per the international standard and also operate with high frequency. In this system, a dual stage DC-DC boost converter is used to reduce the number of series connected PV panel and the effect of partial shading. It can also reduce the cost of full system. Sinusoidal pulse width modulation is used as control strategy to get good quality of voltage at the output of H6 inverter.
Keywords: PV Inverter; multistage converter; MPPT; Inverter;

1. Introduction

As per the world energy petition increasing at an exponential rate, the reliant on the fossil fuels is no longer a luxury. Although the fossil fuels gives a temporary solution to this energy crisis, they produce the emission of carbon dioxide and other harmful gases, which affect the environment. This has paved the way for research on renewable energy technology and other studies in the fields of power electronics. Hence, the cost of utilizing the renewable energy is at an ever falling rate [1]. One such source of renewable energy, the Sun, offers unlimited energy. From this solar energy, photovoltaic systems consisting of photovoltaic modules, generates environmental friendly power and it gain more and more recognised with each passing days. The photovoltaic modules comprise of several solar cells, which transform the energy of the sunlight straight into electricity, and it converts into desired levels of DC voltage and current. They produce electricity due to a quantum mechanical process known as the photovoltaic effect. The major drawback with these photovoltaic systems is that their cost is much high as compared to the conventional sources and their efficiency are also quite low. Modern power electronics signify as heart for the semiconductor device which is comprehensively used to turn ON or OFF the switches. To convert AC to AC, DC to DC, DC to AC and AC to DC are basic transformation function among which inverter is one of them which will convert DC to AC [2].

Copyright: © 2026 by the authors

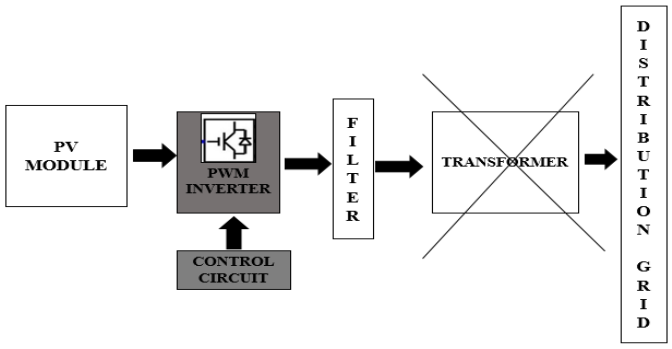


Fig. 1 Transformer Based Inverter System

Whatever the power generated by the photovoltaic system is maintain at maximum level by using the proper control strategy for the DC to DC converter which is used at the output of photovoltaic system. PWM inverter is used to convert the DC voltage generated by the photovoltaic system into AC voltage. This AC voltage is then step-up by using power transformer which is shown in fig. 1 and it is feed to the grid with proper synchronization of frequency, phase and the amplitude of the voltage. The system which used the power transformer to feed the power from photovoltaic system have higher cost and the large space requirement. So to reduce the problems associates with the power transformer, a transformer less grid connected PV inverter topology is proposed based on the conventional full bridge inverter with two supplementary power switches, which ensures the DC decoupling at the freewheeling mode [11].

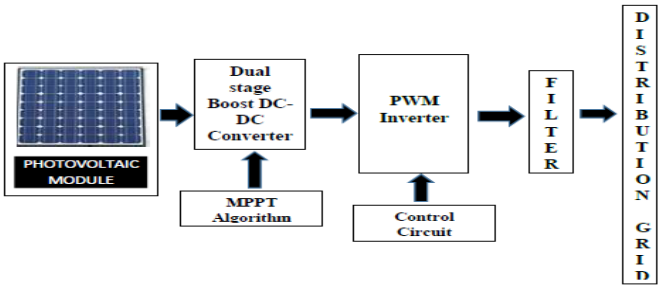


Fig. 2 Transformer less Inverter System

2. Photovoltaic module

A PV module is combination of numerous PV solar cells. A one small PV cell is having a capacity of producing 1 watt or 2 watt of power and it is depends on the type of material used [8]. As per the high demanding of power one or more photovoltaic cells are connecting together and made a high power module. Now as per demand or capacity of the power plant or generating capacity, the number of photovoltaic modules are connecting with each other in the arrangement of an array.

2.1 Design of PV module

At first, under Standard Test Condition (STC) sun array S6B2609 panel with 210W maximum output power is being tested. At STC condition of 25-degree temperature and irradiance of 1000 W/m2 the panel is simulated which output voltage is 52V and is shown in Fig.3 [2]. Table-I shows the system parameters of photovoltaic module.

TABLE-I SYSTEM PARAMETERS OF PHOTOVOLTAIC MODULE

Parameter	Value
Manufacturer	Sun array

Solar Panel Model	S6B2609
Isc	8.51A
Voc	33.50V
Imp	7.84A
Vmp	26.63V
Pmax	210W
Characteristic constant	0.007

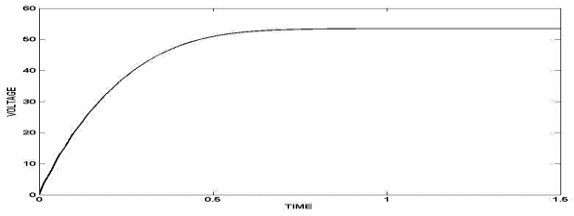


Fig. 3 Output Voltage of PV Array

Fig.3 is indicating the voltage after performing MPPT and connect the PV module in series and parallel as per power and current requirement. Incremental and Conductance MPPT algorithm is used in this system.

3. Dual Stage Boost Converter

Dual stage is nothing but converting 52V to 325V in two stage (52V to 130V and 130V to 325V) because of one limitation of the simple one stage boost converter. Dual stage boost converter is shown in fig.4. This limitation is that single-stage boost converter would be large duty ratio (for 52V to 325V Duty ratio is 0.84 it is above 80%), for this voltage conversion which is not convenient for MOSFET switching (practically) because it lead to increase stress on MOSFET [2]. That is the main reason behind to use dual stage boost converter for this conversion.

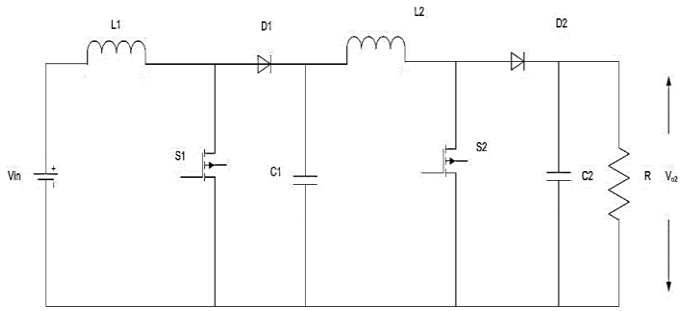


Fig.4 Circuit Diagram of Dual Stage Boost Converter

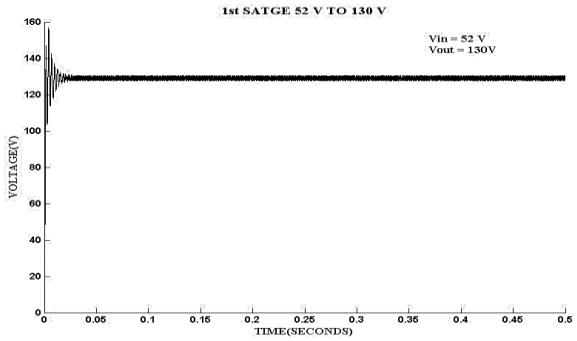
Design parameter of dual stage boost converter is given in table-II. Wave form of both stage is shown in fig.5.

TABLE-II DESIGN PARAMETER OF DUAL STAGE BOOST CONVERTER

Parameter	**Stage 1**	**Stage 2**
Vin	52 V	130 V
Vout	130 V	325 V
Frequency	20 kHz	21 kHz
ΔVo	6.5 V	16.25 V

ΔIo	2.4 A	0.865 A

3.1 1st Stage of DC-DC Boost Converter



2nd Stage of DC-DC Boost Converter

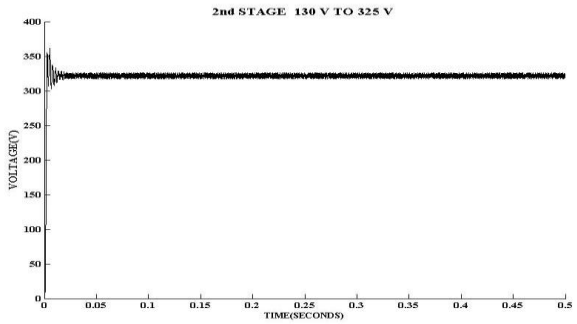


Fig.5 Output Waveform DC-DC Boost Converter

4. Single Phase H6 Inverter

Transformer less inverter having a three big issues like galvanic isolation, leakage problem, and common-mode voltage. And H-bridge single phase inverter is fails to solve this three problem and also conventional inverter having more harmonic distortion, so solve these problems uses a new H6 single phase inverter which shown in fig.

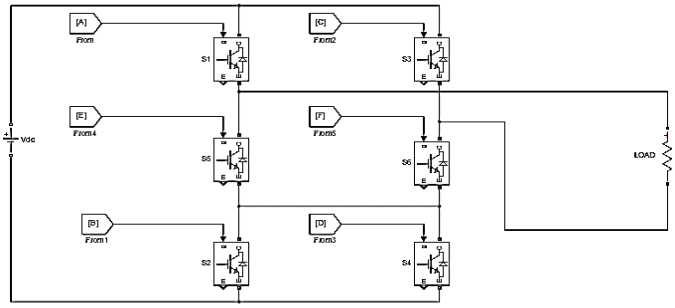


Fig.6 H9 Inverter Topology

A H6 type photovoltaic inverter's gate drive signal and simulink model of are shown in fig.7 and fig.8. Gate drive signal of H6 inverter is indicate that when phase shift is ensued in between the current and voltage, the current of grid ig rests in negative, in the beginning of the positive half period and vice versa. So, this H6 inverter enforced to operate in mode 6 and mode 3 which is generally known as freewheeling mode. Output of H6 inverter is shown in fig 9.

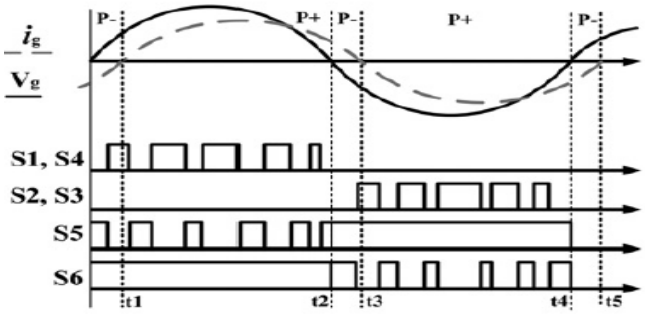


Fig.7 Control signal of H6 inverter

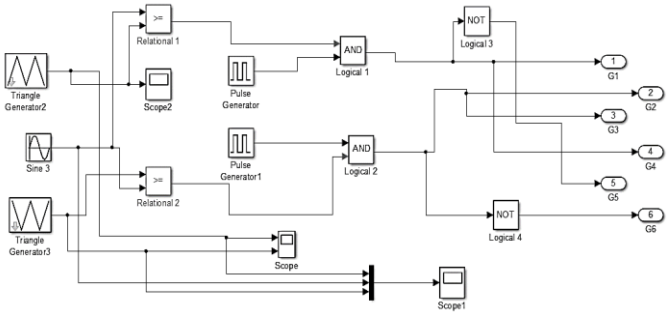


Fig.8. Switching Scheme of H6 Inverter

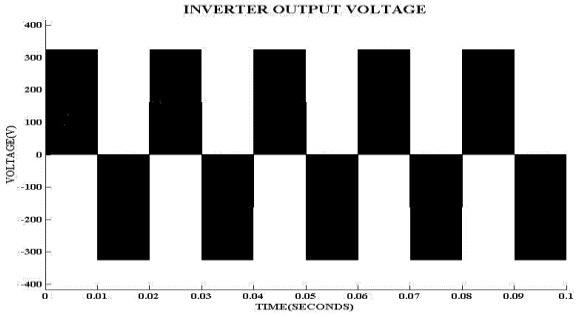


Fig 9. Output Voltage Waveform of H6 Inverter

5. Grid shynchronizing & Filter

5.1 Grid Shynchronizing

The control block of inverter is shown in fig.10. First stage is the DC-DC converter with MPPT controller extract maximum power from PV array and second stage is DC-DC converter provide constant DC link voltage. DC side power is transferred to the AC side with the help of inverter. Control circuit of the inverter maintain power balance between DC side and AC side with the help of current control loop. Synchronous PLL is used to synchronise injected voltage with the grid. PI controller ensure proper quality of injected current.

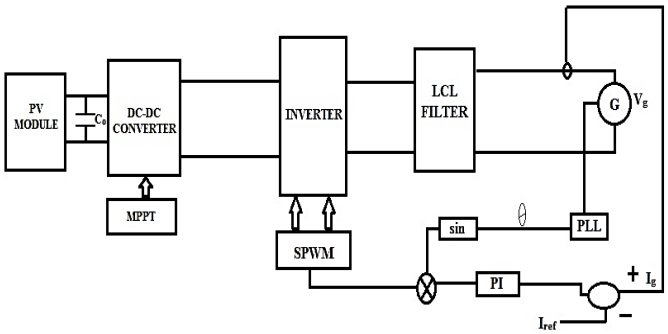


Fig.10 Grid Synchronising Method General Block Diagram

Current is injected in phase with the grid voltage to ensure zero reactive power. Synchronised grid current and reference current will be compared and error will be generate and this error goes into the PI controller to reduce this error. Output of this PI controller multiply with the sine wave which is comes from PLL and generate the reference signal for the SPWM technique. By comparing the reference signal with the triangle carrier waveform, gate pulse is generated for the H6 inverter.

5.2 LCL-Filter

For altering the amplitude of a signal with respect to frequency an electrical network is used, which is defined as filter [13].The main function of filter is to remove the unwanted harmonics and will not add further any frequency.

Here in this proposed system LCL filter is used, LCL filters, which are particularly popular in the renewable energy industry today, are an efficient and economical way of ensuring and improving the quality of power fed from the energy source to the grid [13]. Their purpose is to filter the unwanted signal frequencies from the inverter output.

The LCL filter will be very weak to oscillations and it will magnify frequencies nearby its cut-off frequency [14]. The simplest way is to add damping resistor. In general there are four possible places where the resistor can be placed series/parallel to the inverter side inductor or series/parallel to filter capacitor.

a) Calculations of La, Lb. & C

$$Z_b = \frac{V^2}{p}$$

Here V = grid voltage, p = output power

$$L_a , L_b = \frac{Z_b}{2\pi f}$$

La, Lb = Inverter Side Grid Side Inductor, f = Grid frequency

$$C = \frac{1}{2 * \pi * f * Z_b}$$

C = Filter Capacitance

$$R_{cd} = \frac{1}{3 * 2 * \pi * f * C}$$

Rcd = Damping resistor

6. Results & Discussion

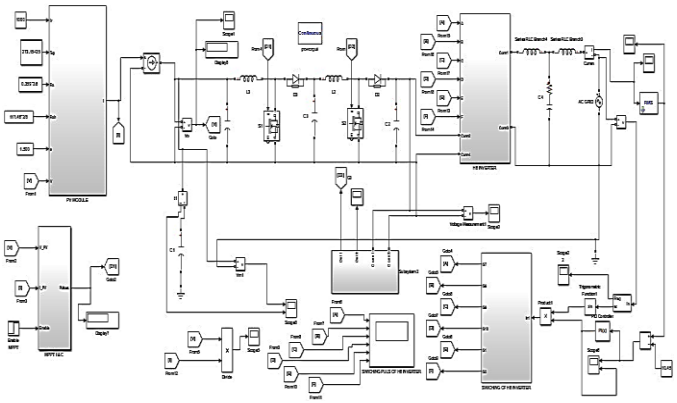


Fig.11 Simulink Model of Proposed System

Fig 11. is indicate the full system simulation circuit diagram of the transformer less PV inverter. In this diagram dual stage boost converter, H6 single phase inverter and filter circuit are connected with the 2.4 kW, 230 V AC Grid. Output grid current, grid voltage, grid power shown in below fig 12 and 13.

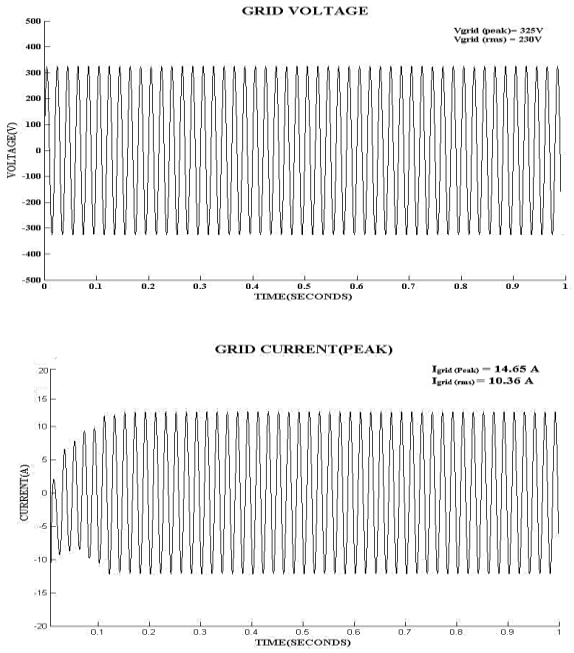


Fig 12 Output Grid Voltage and Grid Current Waveform

In fig 12 indicate the grid voltage, grid current and accordingly power is indicate into the fig 13. As per the grid synchronizing method used in this network is PLL (Phase Locked Loop) voltage and current are in the phase and it is clearly indicating in the above results.

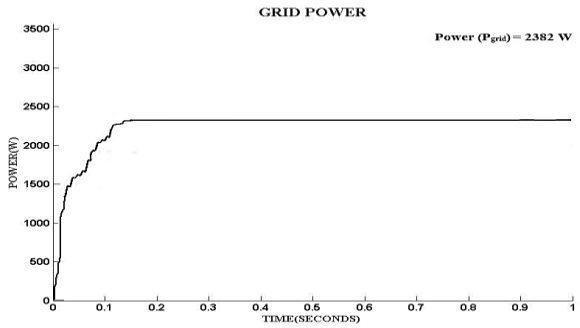


Fig 13 Grid Output Power

Advantage of this proposed system is that common mode voltage is continuously constant in the four working stage of the grid, so from the constant common mode voltage leakage current reduction is possible. Here doing comparison for the H-Bridge inverter and H6 inverter in terms of %THD and leakage current. For both inverter wave form of the leakage current are indicate in the fig.14 and fig.16. Common mode voltage is also indicate for the H6 inverter is in fig.17. Now comes on the %THD analysis in H-Bridge inverter it is coming around 3.93% and for the H6 inverter it is coming 1.43% it is much lower than IEEE519 standard. Analysis of %THD for both is indicate in fig.15and 9.8.

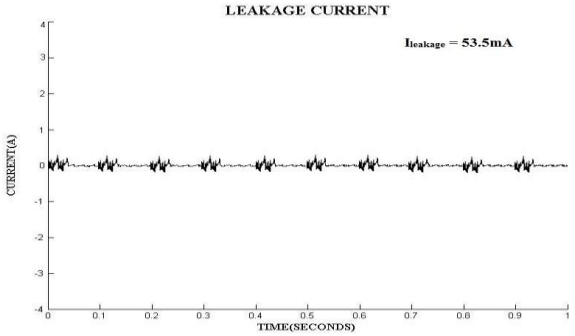


Fig 14. Leakage Current of H-Bridge Inverter

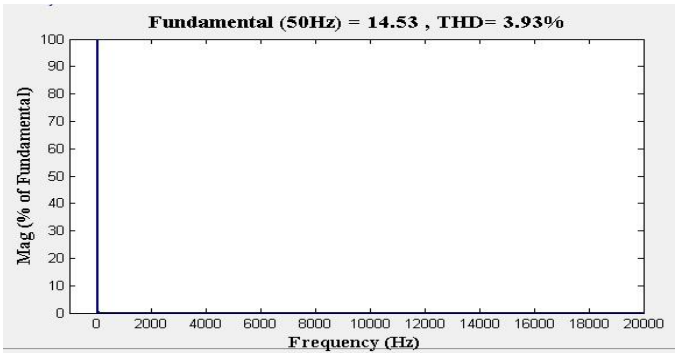


Fig 15. %THD Analysis Output Current of H-Bridge Inverter

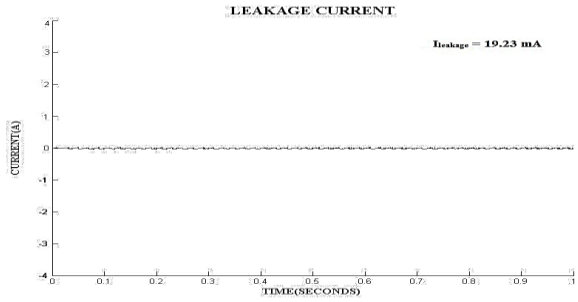


Fig.16 Leakage Current of H6 Inverter

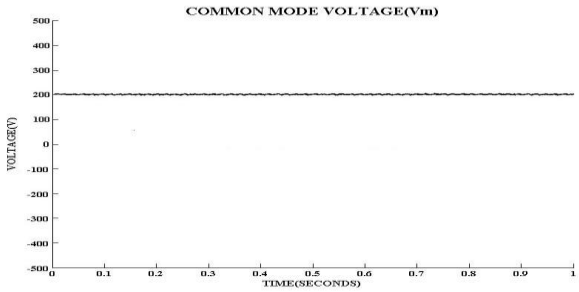


Fig.17 Common Mode Voltage of H6 Inverter

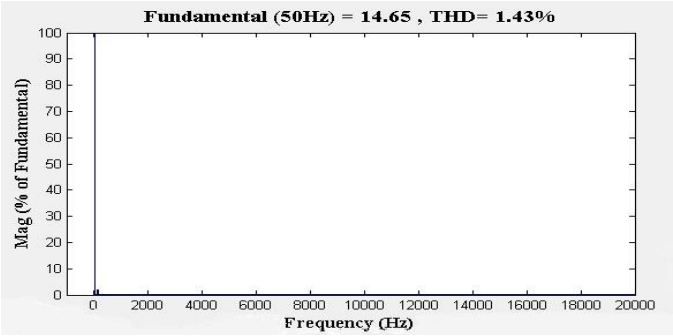


Fig.18 %THD Analysis of Output Current of H6 Inverter

The simulations are carried out to analysis and compare the overall performance of the H-Bridge and H6 topologies using MTLAB software. The parameter used in simulation are same for both the topologies. From the above results of the H-Bridge and H6 inverter it is clearly seen that H6 topology is far better than H-Bridge inverter for transformer less topology. In table III compared the result of both inverter in terms of %THD and leakage current.

TABLE-III RESULT COMPARISON OF H-BRIDGE AND H6 INVERTER

Parameter	H-Bridge Inverter	H6 - Inverter
%THD	3.93%	1.43%
I leakage	53.5mA	19.23mA

7. Conclusion

The simulation of the transformer less grid connected inverter was performed and compared with the conventional H-Bridge inverter for the same rating system by software and as a result pure sinusoidal waveform was obtained with the reduced of %THD up to the 1.43% in H6 inverter which is less than 1.5% which is much lower than the IEEE519 standard. Also leakage current is analysed for both H6 inverter and H-Bridge inverter so after comparison

of the leakage current it is clear that in H6 inverter leakage current is much lower (19.23 mA) than H-Bridge inverter (53.5 mA). The simulation and its results conclude that the H6 inverter topology for transformer less grid connected inverter is more suitable than H-Bridge topology and it is compact in size for being transformer-less, and it is appropriate for supplying constant current with dynamic load with LCL filter.

Refersnces

1. Ahmed Abdalrahman, Abdalhalim Zekry, and Ahme Alshazly, "Simulation and Implementation of Grid-connected Inverters", *International Journal of Computer Applications (0975 – 8887)* Volume 60– No.4, December 2012.
2. Sajib Chakraborty, Wahidul Hasan, S.M. Baque Billah, "Design and Analysis of a Transformer-Less Single- Phase Grid-Tie Photovoltaic Inverter Using Boost Converter with Immittance Conversion Topology" *International Conference on Electrical Engineering and Information & Communication Technology (ICEEICT) 2014.*
3. Tan Kheng Suan Freddy, Nasrudin A. Rahim*, Senior Member, IEEE*, Wooi-Ping Hew*, Member, IEEE*, and Hang Seng Che, "Comparison and Analysis of Single-Phase Transformerless Grid-Connected PV Inverters" *IEEE TRANSACTIONS ON POWER ELECTRONICS,* VOL. 29, NO. 10, OCTOBER 2014.
4. Aparna Das, Sheeja G, "Single-phase h6 transformer-less inverter with a simple boost converter for pv-grid tied power systems*" IJRET: International Journal of Research in Engineering and Technology* Volume: 04 Issue: 06 | June-2015, Available.
5. Bader N. Alajmi, Khaled H. Ahmed*, Senior Member, IEEE*, Grain Philip Adam, and Barry W. Williams, "Single-Phase Single-Stage Transformer less Grid-Connected PV System" *IEEE TRANSACTIONS ON POWER ELECTRONICS*, VOL. 28, NO. 6, JUNE 2013.
6. Nimrod Vázquez, *Senior Member*, IEEE, Marco Rosas, Claudia Hernández, *Member*, IEEE, Eslí Vázquez, and Francisco Perez-Pinal, *Member*, IEEE, "A New Common-Mode Transformer-less Photovoltaic Inverter", *Citation information: DOI 10.1109/TIE.2015.2426146*, IEEE Transactions on Industrial Electronics.
7. Monirul Islam, S. Mekhilef, *Senior Member, IEEE, "*High Efficiency Transformer less MOSFET Inverter for Grid-tied Photovoltaic System", *2014 IEEE*
8. *http://www.springer.com/978-3-319-14940-0*
9. Muhammad H. Rashid, "*Power Electronics, Circuits, Devices, and Applications*", *Third Edition, Pearson Education, Inc., 2004*.
10. Monirul Islam, Saad Mekhilef, "H6-type transformer-less single-phase inverter for grid-tied photovoltaic system*", IET Power Electron., 2015,* Vol. 8, Iss. 4, pp. 636–644, the Institution of Engineering and Technology 2015.
11. "Review of Distributed Generation Interconnection Standards*", EEA Conference & Exhibition 2014*, 18 – 20 June, Auckland
12. Oscar Lopez, Remus Teodorescu, Francisco Freijedo, Jesus Doval Gandoy "Leakage current evaluation of a single phase transformer less PV inverter connected to the grid" *2007 IEEE.*
13. Hyosung Kim, Kyoung-Hwan Kim "Filter Design For Grid Connected PV Inverters" *ICSET 2008,*IEEE 2008
14. A.E.W.H. Kahlane , L. Hassaine and M. Kherchi , "LCL filter design for photovoltaic grid connected systems" *Revue des Energies Renouvelables SIENR'14* Ghardaïa (2014) 227 – 232
15. Soeren Baekhoej Kjaer, Member, IEEE, John K. Pedersen, Senior Member, IEEE, and Frede Blaabjerg, Fellow, IEEE *"*A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules" *IEEE Transactions On Industry Applications,* VOL. 41, NO. 5, SEPTEMBER/OCTOBER 2005
16. Hiren Patel and Vivek Agarwal, Senior Member, IEEE "A Single-Stage Single-Phase Transformer-Less Doubly Grounded Grid-Connected PV Interface" *IEEE TRANSACTIONS ON ENERGY CONVERSION,* VOL. 24, NO. 1, MARCH 2009
17. Pratapsinh G. Parmar, Urvashi D. Patel "A Review on DC-DC converters for
18. Photovoltaic system" *International Journal Of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering,* Vol. 3, Issue 12, December 2015.
19. Ahmed Sony Kamal Chowdhury, M. Abdur Razzak "Single Phase Grid-Connected Photovoltaic Inverter for Residential Application with Maximum Power Point Tracking"*978-1-4799-0400-6/13*, 2013 IEEE