Design and Analysis of Grid Connected Single Phase Transformerless Inverter for controlling Two Solar PV Arrays

[1]D. Vinod, [2]N Mahesh Babu

[1]M.Tech Scholar, [2]Associate Professor
[1]Department of Electrical & Electronics Engineering
[1]Bheema Institute of Technology & Science, Adoni, Kurnool Dist, A.P, India.

Abstract: **Due to limited availability of natural resources and growth of usage of renewable energy sources have made the need of alternate energy source to fulfill the requirement of huge amount of energy for growing population in the world. The alternate energy source is PV based solar system and this is controlled using inverter. In this paper we propose a grid connected single phase inverter without transformer for controlling the operation of two PV arrays under different atmospheric conditions. The proposed system is designed using MATLAB SIMULINK and the performance of system is analyzed. An analysis result shows that the efficiency of proposed systems is improved and size is reduced.**

IndexTerms – **photovoltaic, PV systems, inverter, sub-arrays, grid, topologies, efficiency, transformer less .**

I. INTRODUCTION

The rapid growth of world population requires more energy consumption. But the availability of natural resources such as coal and fuel are limited. Recently, renewable energy sources are widely used for supply of energy to world. Today, renewable energy sources are becoming major contributors for supply of total reliable energy consumption in the world. The benefits provided by renewable energy sources are: their independence from limited fossil and nuclear fuels and their low impact on the environment. But as an alternate energy source known as solar power is a better option to overcome the problem of shortage of energy due to increase in population and limited availability of natural resources. Since solar energy is naturally available, it is pollution free and inexhaustible. Solar energy is generated using photovoltaic system or solar system. Photovoltaic is a method for generating electric power by using solar cells. Solar cells produce direct current electricity from sunlight which can be used to power equipment or to recharge a battery. The PV based solar system consists of photovoltaic modules (photovoltaic cells) and transformer based inverter. These photovoltaic cells to produces the higher voltages, currents and power levels. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels. The existing PV system used to generate energy from solar cell is transformer based and energy contribution of these sources is very low. But such PV system is having efficiency low and the market for PV systems is one of the most stable and fastest growing in the world. In future, the PV system will be one the wieldy used energy source and to maintain the further growth of PV systems there is need for decrease in cost, improve the efficiency and reliability of PV systems. In PV systems the valuable improvements can be made on the side of inverters. These inverters account for approximately 15..25% of the system cost and are still a bottleneck for system reliability. Therefore it seems to be a well spent effort to have a close look at the inverters, their topologies and control. One of the idea to make improvement in inverter is to make it transformer less with this the size of inverter will become compact and cost will reduce and will have flexible grounding configuration. The cost of PV panels is very high as compare to other renewable energy sources and to reduce the cost a grid connected PV inverters must be designed accurately. The benefits of design of grid connected PV inverters are low weight, high efficiency and small size [1]-[3].

The grid connected PV inverters are classified into two: one is grid connected PV inverters with transformer and another grid connected PV inverters without transformer. In PV system the purpose of transformer is to provide galvanic isolation between PV panels and grid: high frequency transformer is kept at DC side of inverter or transformer with low frequency on grid side. Low frequency transformers based inverters will make the complete system bulky and costly and high frequency based inverters will reduce the efficiency of system due to presence of several power stages [4]. In general, the grid connected power system constructed using transformer based inverter will have increase in size, increase in weight and increase in cost and efficiency of this system is reduced but the leakage current is eliminated. Thus, removing the transformer from inverter offers benefits like improvement in efficiency of overall system, reduction of system size, and system weight [5-7].

The main purpose of grid connected transformer less inverters is to eliminate the leakage current [8]-[9]. In paper [10] a modified FB has been proposed and it decreases ripple current and provides improvement in efficiency but few DC current is injected in the grid and this current restricts the inverters performance. The NPC inverter efficiency is improved as compared to FB inverter and the output filter volume is reduced because of three level of output voltage. But, the requirement of this topology is doubled DC voltage input as compare to FB topologies. The inverters like H5, H6 and HERIC will operate strategy known as unipolar SPVM and requires two filter inductors which rises the size system and cost system [11]. In the multi-level neutral point clamped inverters, the DC link capacitor midpoint is joined to the grid neutral line in order to reduce leakage current. Such inverters provide higher efficiency as compare to FB inverters but require DC bus voltage very high for feeding the grid and this limits the input DC sources voltage range [12- 13]. In addition, with the aid of incentives provided by government and reduce in prices of PV system module a grid connected PV systems plays a key role in generation of distributed power. The development of grid connected PV systems is due to its cost reduction, advances in power electronics technology and from government incentives [1]. The grid connected PV systems can be designed to be having smaller size, low cost and higher efficiency with the usage of transformer less inverter. But, there will be flow of unsafe leakage current between PV array and grid because of existence of stray capacitance. The leakage current introduces conducted and radiated electromagnetic interference, total harmonic distortion and losses. Furthermore, the injection of DC current to the grid will saturate the distribution transformer along the grid.

To provide solutions to these issues, various conversion topologies have been invented. A novel transformer less inverter topology is invented to remove the leakage current of grid connected PV systems with the use of MPC technique. This inverter topology can be realized using minimum number of active and passive components as compare to conventional topologies

Another way to effectively elimination of leakage current is by directly connection of grid neutral point and negative polarity of the PV. Further such inverter topology will improve the power quality and reduces the filter requirements. The remaining paper is organized as follows section II gives the details of literature review of PV systems, topologies and a grid connected inverter with and without transformer , section II describes about schematic diagram of stand-alone and the grid-connected photovoltaic system and proposed inverter system. Finally the section III presents about the simulation results in terms of screen shoots and discussion and also conclusion, future work and references

II. Literature review

In paper [1] [2] the authors have proposed a novel high efficiency PV inverter topology without transformer for single phase. The designed system is having increased operating efficiency, reduced size, volume and weight.

In Paper [3]-[5], the authors have proposed the PV system with interconnection of large modules in series. The power yield from proposed design of array gets considerably reduced when the modules exposed to varied environmental conditions: shading.

In paper [6]- [12] the authors have been invented various topologies based on H-bridge inverter and inverter topologies based presented in [13], [14] uses single PV source and the inputs of this topologies are prone to this mismatched operating problem due more number of series connected modules.

In papers [15]- [19] the authors have proposed various topologies for PV system which are obtained from NPC(neutral point clamped) based inverter. These topologies requires magnitude of PV voltage is double as compare to conventional H-bridge based inverter topologies and if this is not provided then there is a severe problem of mismatch. So as to conquer the previously mentioned issue endeavors have been made to digest most extreme accessible power from every one of the PV modules while they are presented to mismatched operating conditions. Schemes along with generation control circuit [4], [5] will achieve it with re-distribution of power taken form sub arrays between themselves in order to operate all sub-arrays at their respective maximum power point (MPP)s. these schemes are realized using two stage configuration and having control algorithms which is complex and low operating efficiency. Because the efficiency of schemes are extremely dependent on shading level for which every subarrays are exposed.

In paper [2] the authors have designed the schemes using module integrated converters (MIC) and many input string inverter to control each PV module of array. But, these schemes need the involvement of dc to dc converter stage before the dc to ac inverter stage. This stage increases the number of components, reduces the system efficiency and reliability [20], [21]. In paper [22] [23]the authors describes the solution to overcome the issues in MIC and multi input string inverters with the use of switched based PV system and use of voltage injection based system. But this method also has issues of increase in number of active component, decreased efficiency of system and its reliability.

In voltage injection based techniques the modules which are shaded are bypassed.

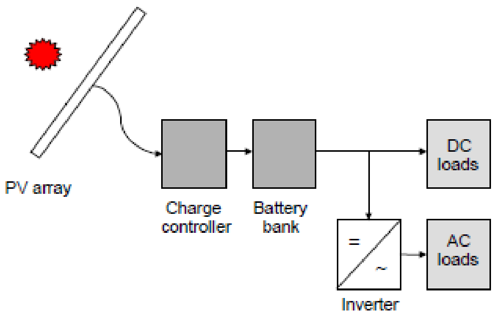
So to attain adequate DC bus voltage under the condition of shaded more number of modules are included in sub-arrays as compare to the techniques and this increases the systems cost. In turn to reduce the need of number of components and make control simple efforts are carried out to design sub-array with desired number of PV modules connected in series according to the input voltage requirement of the system. Such type of two sub arrays are then connected in series and each sub arrays are controlled for operating at respective MPPs [20], [24]- [28]. By isolating the modules in two sub arrays and consequently working the two sequentially associated sub arrays at their particular MPPs, the yield of intensity during non uniform natural condition is improved without expanding the quantity of intensity preparing stages.

In paper [24][25][29] authors presented the schemes which operates with the concept of isolation of modules in two arrays and working two PV sub arrays at their MPPs for limiting DC current magnitude within allowable range. In paper [26, 27, 29, 30] authors discuss about T-type power circuit configuration for single and three phase applications. The T-type based single phase half bridge configurations needs double the number of serially connected PV modules (in a sub array) in comparison with full-bridge configuration thus making scheme efficiency useless at the time of mismatched operating conditions. In additional, single phase full bridge T-type configuration has a issue of increase in magnitude of leakage current beyond set limit.

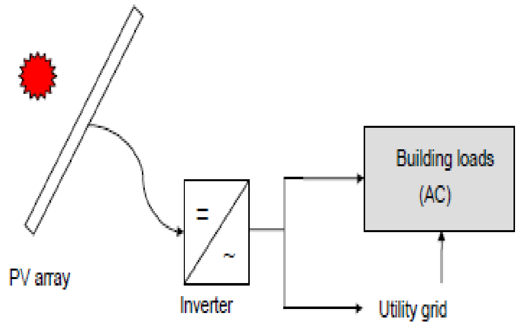
In papers [26][27] it has been presented about T-type 3-phase solar PV based grid connected, systems for more than 10kW power and this scheme cannot applicable for power level is about around 5 kW [20], single phase grid connected application. In paper [20] the scheme makes two stages of power processing and overall efficiency improvement of system depends on mismatch extension. The paper [28] presents a scheme that uses single stage of power processing and this scheme has poor overall efficiency because the dc to ac inverter based on buck boost has been designed to work in DCM (discontinuous mode of conduction).

III. Proposed system

We propose the grid connected single phase transformer less inverter for controlling of PV system. A novel inverter topology is obtained by combining two half bridge inverters along with their respective ac bypass is used to control two serially connected sub arrays individually. The proposed system can be implemented and simulated using MATLAB-SIMULINK tool. After this the analysis of proposed system design is carried out to study the performance in terms of efficiency, losses cost and size. Figure 1(a) and (b) shows the schematic diagram of stand-alone photovoltaic system and grid-connected photovoltaic system. Figure 1 (b) depicts single phase transformer less inverter is designed to control two Solar PV arrays. The PV arrays are operating under different atmospheric conditions.



(a)



(b)

Figure 1 Schematic diagram of (a) stand-alone photovoltaic system, (b) grid-connected photovoltaic system[26]

The Figure 2.shows the schematic circuit of combined half bridge inverter with AC bypass (CHBIAB) without transformer is used to control the PV arrays to improve efficiency and reduce the size of system.

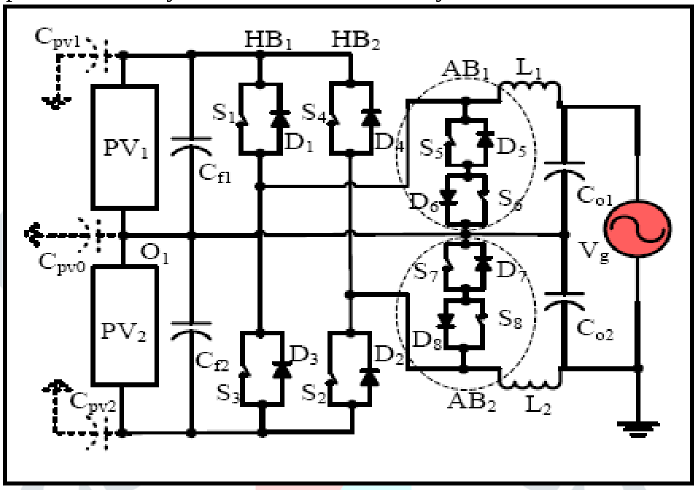


Figure 2.Proposed combined half bridge inverter with AC Bypass (CHBIAB)

Inverter consists of two components one is half bridge (HB1) and another half bridge (HB2). Also there are two PV array called PV1 and PV2 two sub-arrays where consider for control through inverter. The AC by(AB1) and (AB2) are constructed using S5, D5 and S6, D6. L1, Co1 and S7, D7 and S8, D8. L2, Co2 will serve as output filter elements. The S1, D1 , S3, D3 and S2, D2, S4, D4 are the switches. The proposed inverter shown in figure 2 is implemented and simulated in MATLAB SIMULINK tool and results are analyzed to know the performance of the system in terms of efficiency and size.

IV. SIMULATION RESULTS AND DISCUSSIONS

The results are shown in terms of snapshots and snapshots are self-explanatory. The snapshot makes the user understand easily the working operations in the proposed system. Below are snapshots of execution results of designed proposed system

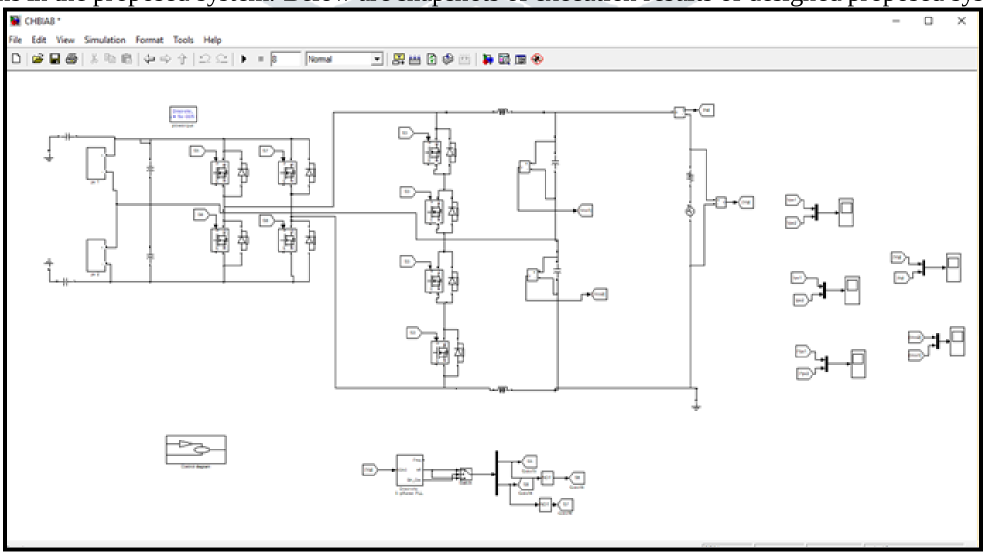


Figure 3.Simulink design of proposed inverter

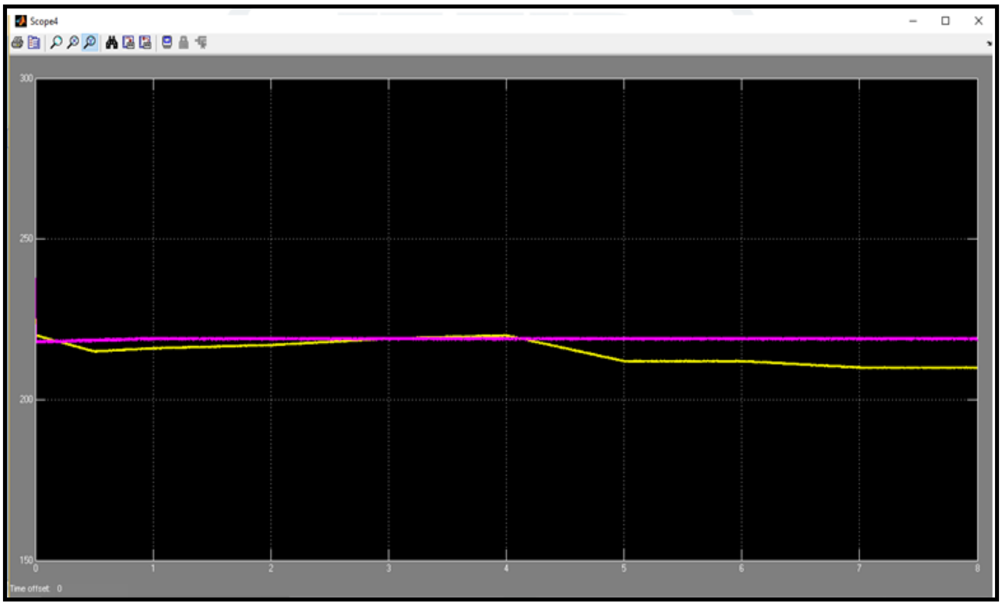


Figure 4 Simulated performances: Power output from *PV*1 and *PV*2

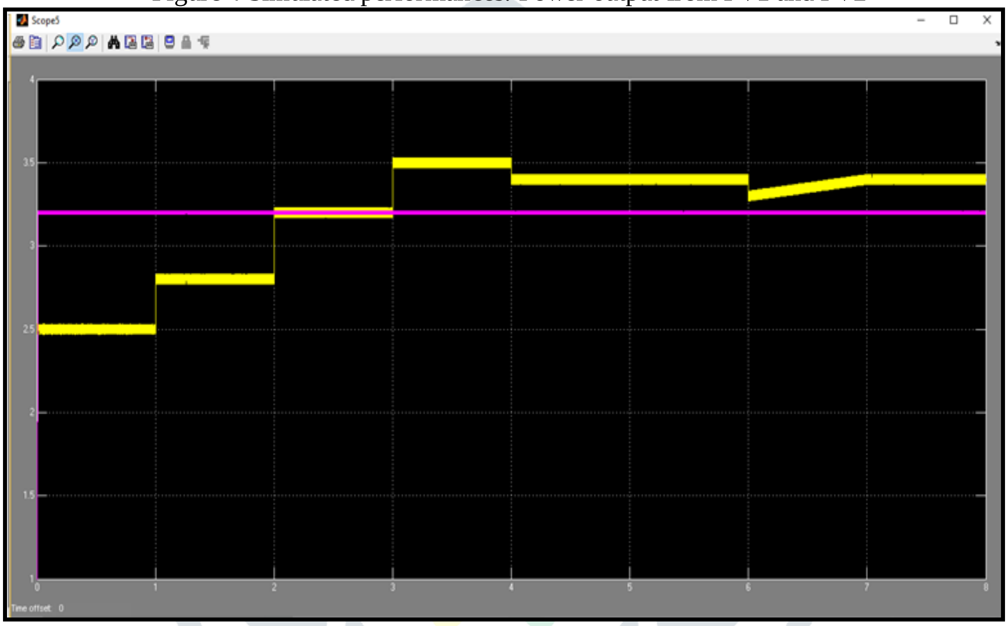


Figure 5 Simulated performances: Voltage output of *PV*1 and *PV*2

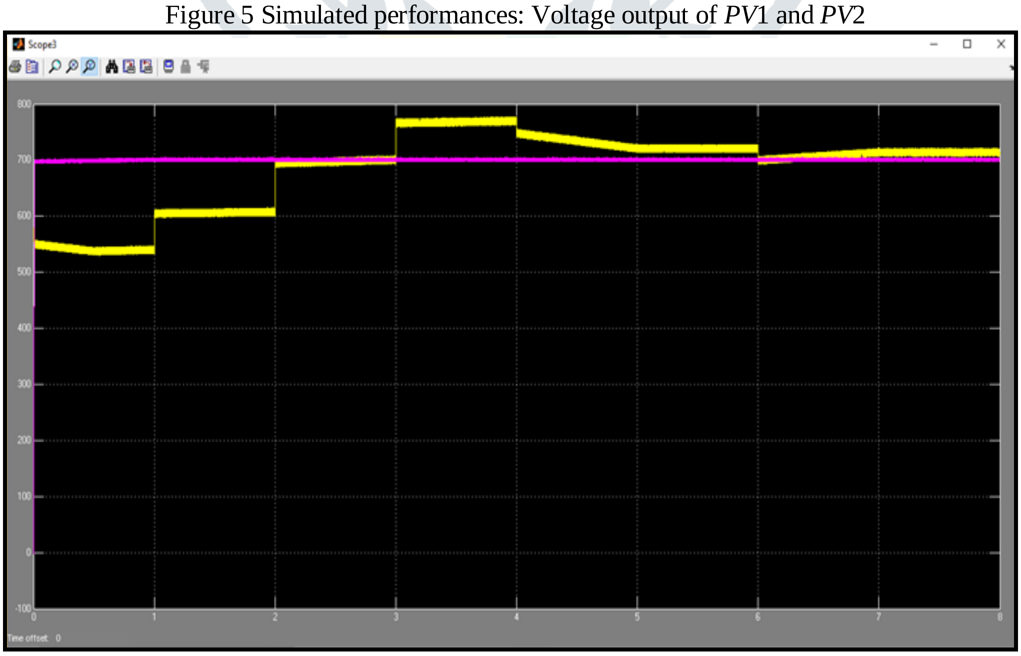


Figure 6 Simulated performances: Output current of *PV*1 and *PV*2

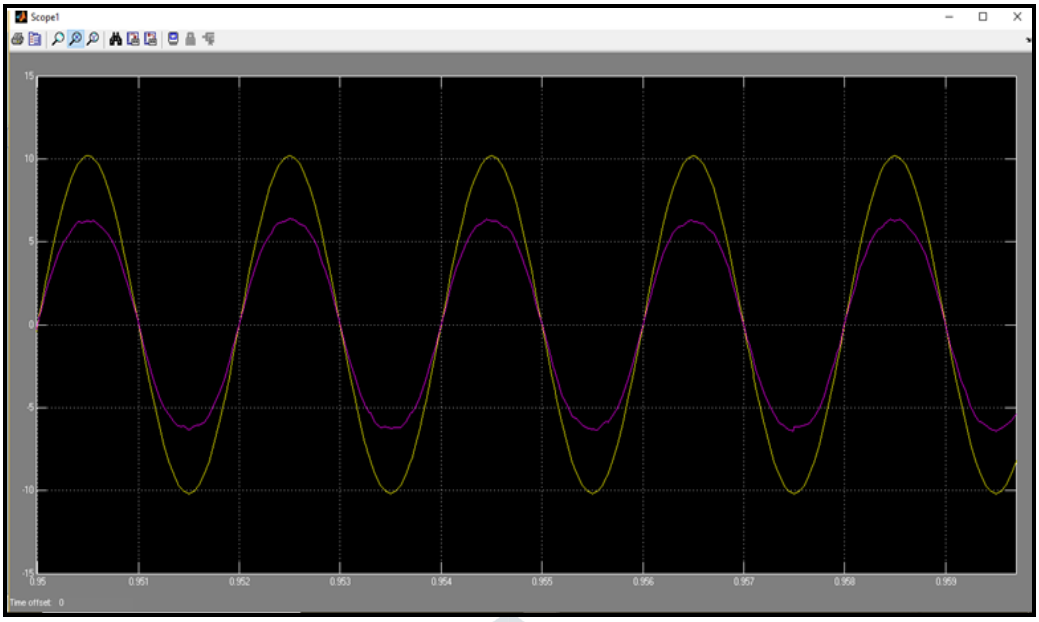


Figure 7 Simulated performances: Grid current along with their magnified version

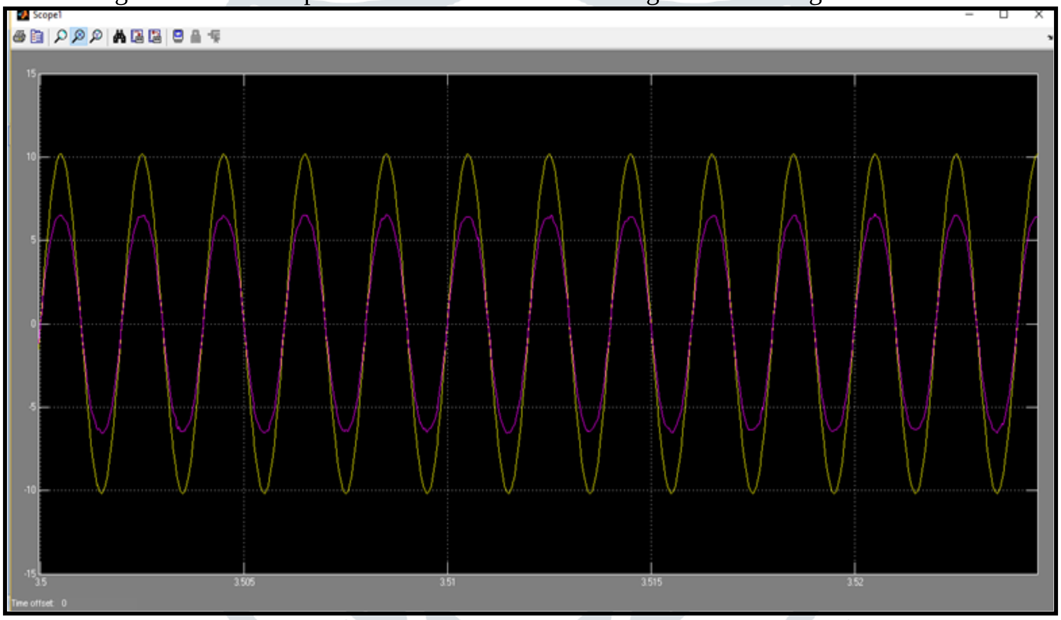


Figure 8 Simulated performances: grid voltage along with their magnified version

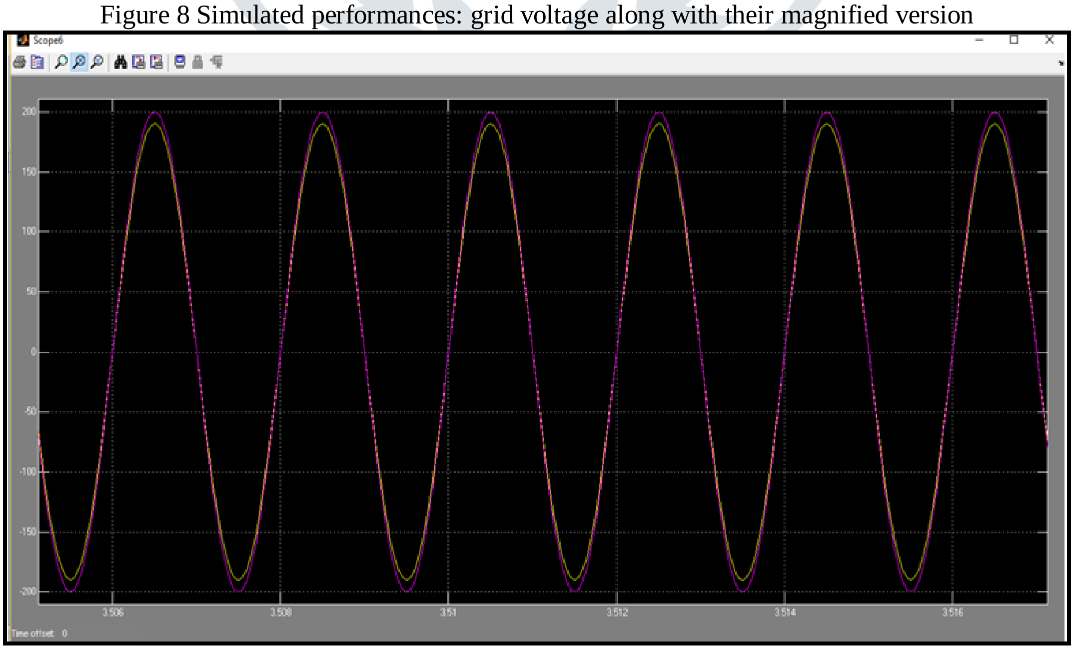


Fig. 10. Simulated performance: Output capacitor voltages along with their magnified versions

V. CONCLUSION AND FUTURE WORK

We have successfully designed and implemented the grid connected single phase inverter without transformer called combined half bridge inverter with AC Bypass (CHBIAB) using SIMULINK. Also we have carried out the performance analysis and the results shows that the efficiency is increased and size of system is reduced.

In future, we will design and simulate the proposed system using VHDL and Xilinx tool. Also we verify the hardware implementation using FPGA.

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