ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Three-Phase Grid Connected ZCT Inverter integrated Photovoltaic Systems

Kasukurthi Neelima
M.Tech-Power Systems and Automation,
Dept of Electrical and Electronics Engineering,
Sir C.R.R. College of Engineering, AP, India.

T.Kranthi Kiran
Assistant Professor,
Dept of Electrical and Electronics Engineering,
Sir C.R.R. College of Engineering, AP, India.

Abstract:
When ac loads are fed through inverters it required that the output voltage of desired magnitude and frequency be achieved. Low leakage current and high efficiency are two key indexes for transformer less PV grid-connected inverter. The transformer less inverter topologies have superior efficiency thanks to saving transformer, but their semiconductor devices are still on hard-switching state at present. A variable output voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. On the other hand, if the dc input voltage is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width-modulation (PWM) control within the inverter. First and foremost, a novel zero current-transition (ZCT) concepts for the three-phase full-bridge transformer less PV grid-connected inverters are presented in this paper. Second, the zero-current turn-off for high-frequency main switches of the inverters and the zero-current turn-on for auxiliary switches added are achieved by introducing two resonant tanks. Furthermore, a family of ZCT transformer less grid connected inverters with sinusoidal pulse width modulation is deduced.

I. INTRODUCTION:

This chapter presents the background and the motivation of the thesis, continuing with a short overview of grid-connected PV systems. Furthermore, it details the aims of the project, continuing with a list of the main contributions and finishing with the outline of the thesis.

TRANSFORMERLESS PV grid-connected inverters have already found widespread application in practice [1]. The higher conversion efficiency and lower leakage current are two major pushing forces in the development of the transformer-less grid-connected inverter. In order to improve the efficiency of the single-phase transformer less grid-connected inverters, two ways are developed: one is constructing multilevel circuit structures (mainly focusing on five-level topologies and the other is using new semiconductor devices, such as SiC-type or GaN-type devices. The single-phase transformer less multilevel grid-connected inverter has some merits, such as lower voltage stress for power device, smaller filter size and losses, which is beneficial to gain the efficiency [2-3]. However, the control strategy is sophisticated given the problem of voltage unbalance for the power devices and the degraded reliability of the inverter. The wide band gap (WBG) semiconductor devices will promote the development of power electronics and improve on the conversion efficiency essentially. However, at present, the fabricating technique of the new materials stays on immature still, and the rate of finished products is low. Therefore, the cost of the inverter with WBG devices would be increased significantly, which is reverse with the target of “dollar per watt” initial installation cost for PV generation system.

Grid Connected PV Systems:

As mentioned before, decentralized energy production using solar energy could be a solution for balancing continuously-increasing energy needs. Grid connected PV systems have had an enormous increase in their market share over the last decade.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

With a reasonable set of incentives, the solar photovoltaic market in the U.S. could grow more than 30% per year over the next 20 years, from 340MW of installed capacity to 9600 MW [4]. This market growth is also present in other countries worldwide.

Problem formulation:

The efficiency of commercial PV panels is around 15-20%. Therefore, it is very important that the power produced by these panels is not wasted, by using inefficient power electronics systems.

Overview of grid connected PV systems:

This chapter highlights the advantages of transformer less PV inverters compared to those with galvanic isolation. Furthermore, a summary of several transformer less PV inverter topologies is presented, followed by discussions about the parasitic capacitance of the PV array, emphasizing the safety issues regarding ground leakage currents due to varying voltages imposed over this capacitance [5]. PV systems connected to the low voltage grid have an important role in distributed generation systems. In order to keep up with the current trends regarding the increase in PV installations, PV inverters should have the following characteristics:

- Low cost
- Small weight and size, due to residential installations
- High reliability to match with that of PV panels
- High efficiency
- String inverters
- Module integrated inverters
- Multi-string inverters.

Transformer-less PV inverters:

Depending on the electrical isolation between the PV panels and utility grid, the inverter can be isolated or non-isolated. This galvanic isolation is usually realized by the means of a transformer, which has major influence on a grid-connected PV systems' DC to AC efficiency [6-9].

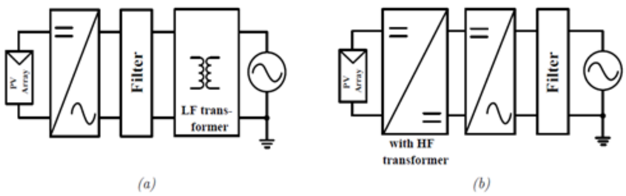

Fig 1: Grid-connected PV system using an inverter with galvanic isolation

a) Grid-side low-frequency (LF) transformer
b) DC side high-frequency (HF) transformer.

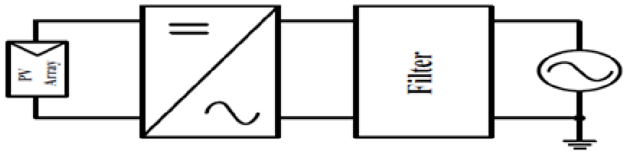

Fig 2: Grid connected PV system with transformer-less inverter.

Transformer-less inverter topologies:

Inverters, according to the levels of power conversion, can have one or more stages. A single and double stage topology for a single-phase grid connection is presented in Fig 3.

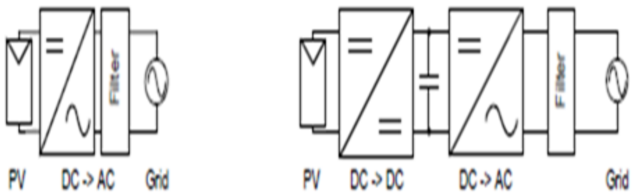

Fig 3: Grid connected PV inverters

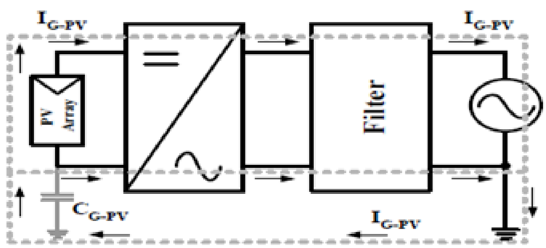

Fig 4: Transformer-less PV system showing the parasitic capacitance between the PV and the grounded frame of the array and the path of the alternating ground leakage current.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

II. Circuit Structure Of Single-Phase PV Array ZCT Converter:

Circuit Structure of ZCT-H6-I:

In order to realize the soft-switching operation for the high-frequency main switches S_5 and S_6 in the HS-H6-I topology , the resonant components C_{5a}, L_{5a}, C_{6a} , L_{6a}, the auxiliary switches S_{5a}, S_{6a} (including their antiparallel diodes or, body diodes D_{5a} and D_{6a}), and one auxiliary diode D are introduced to form two resonant tanks, as shown in Fig. 1(a), L5a= L6a=Lr, and C5a = C6a= Cr. The line-frequency full-bridge inverter consists of the switches Sr1, S2, S3, and S4; the inductors L1,L2, and capacitor C1 make up the filter connected to the grid; D7 and D8 are a couple of clamping diodes in the freewheeling period. The modulation pattern of the ZCT-H6-I is the same with the HS-H6-I topology. This section focuses on the operation principle analysis of the ZCT resonant tank.

Operation Principle Analysis:

Before the analysis, the following assumptions are given: 1) All semiconductor devices are ideal switches with antiparallel diodes, and the diodes are also ideal diodes without parasitic parameters (this assumption will ignore the reverse-recovery problem); 2) the capacitance Cdc1 and Cdc2 of the dc filter are large enough to be treated as a constant voltage sources (this assumption will ignore the dc injection problem), and the inductance L1and L2 of the ac filter are large enough to be treated as a constant current sources at the switching frequency scale. By analyzing the operation principle of the ZCT-H6-I, the characteristics of the resonant tank can be concluded as follows: During the switching transition, the shunt resonant network is activated to create a partial resonance to achieve zerocurrent turn-off for the high-frequency main switches; when the switching transition is over, the circuit simply reverts back to the familiar PWM operation mode. In this way, the inverter can achieve soft-switching while preserving the advantages of the PWM style. The ZCT concept, illustrated in the ZVT-H6-I inverter, can also be extended to other transformerless full-bridge grid-connected inverter topologies, such as Heric, H5, and H6-II.

III. Simulation Validation of 1-ϕ PV array ZCT converter:

In order to verify the operation principle and validity of the ZCT concept, a 50-kHz, 1-kW ZCT-H6-I simualtion circuit has been built in MATLAB/simulink.

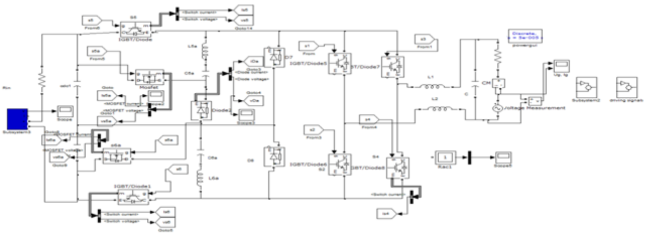

Fig 4: simuyaltion circuit of 1-ϕ PV array ZCT converter

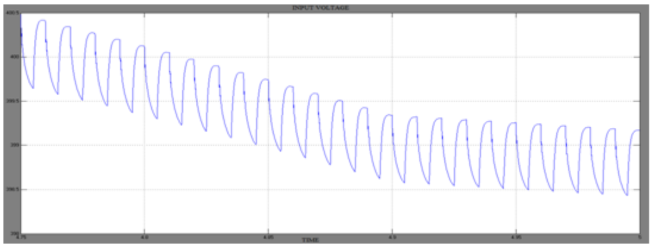

Fig 5: Input voltage of ZCT-H6-I

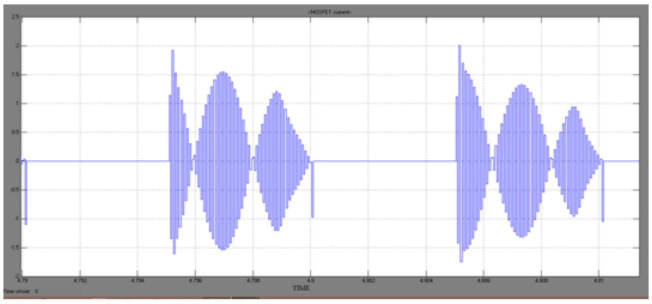

Fig 6: mosfet current of ZCT-H6-I

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

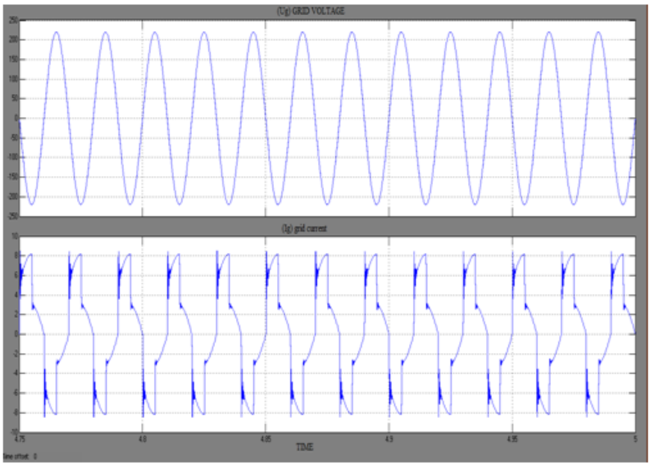

Fig 7: grid voltage and grid current of ZCT-H6-I

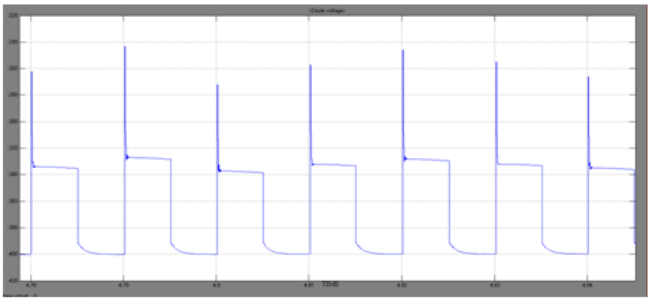

Fig 8: diode voltage of ZCT-H6-I

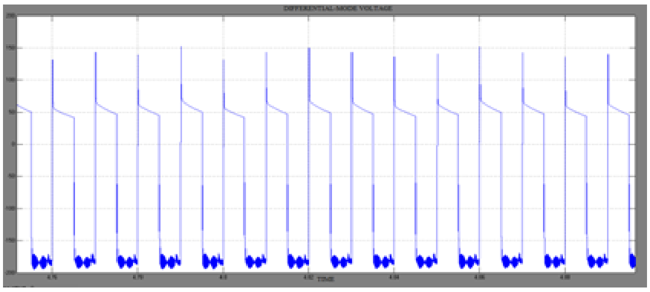

Fig 9: Differential mode voltage of ZCT-H6-I

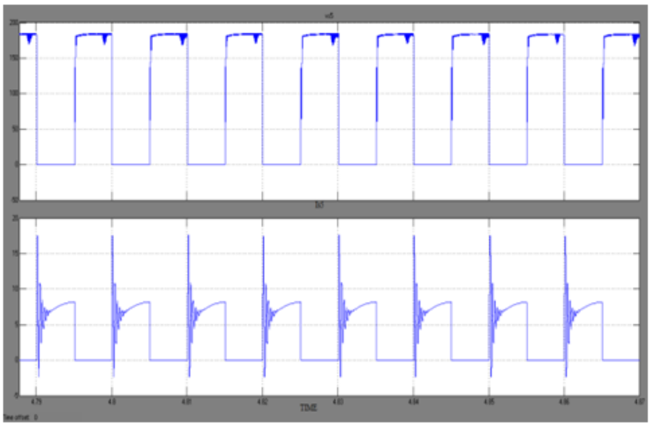

Fig 10: Simulation wave form for Vs5 and Is5

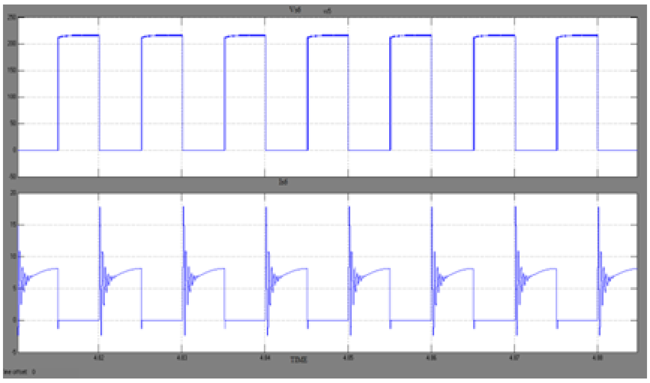

Fig 11: Simulation waveform for Vs6 and Is6

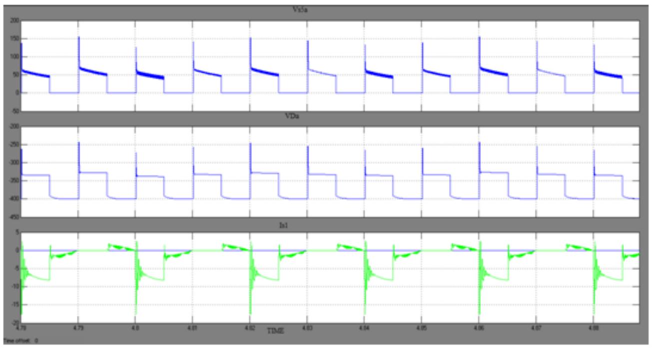

Fig 12: Simulation waveform for Vs5a and V_{Da}, Is1

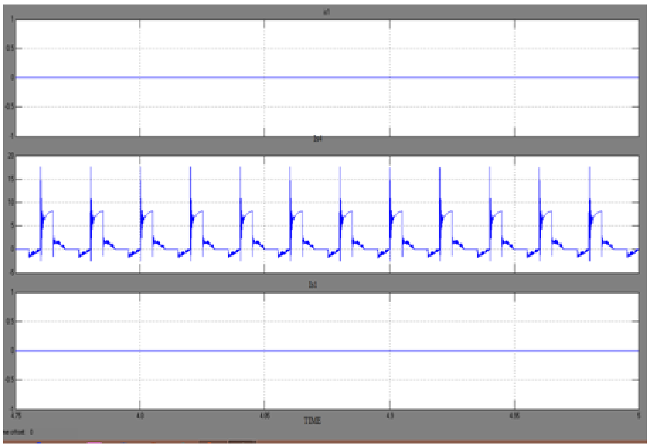

Fig 13: Simulation waveforms for is1 and Is4,Is1

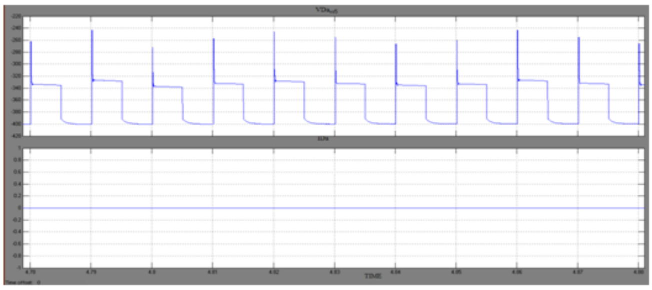

Fig 14: Simulation results for VDa and IDa

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

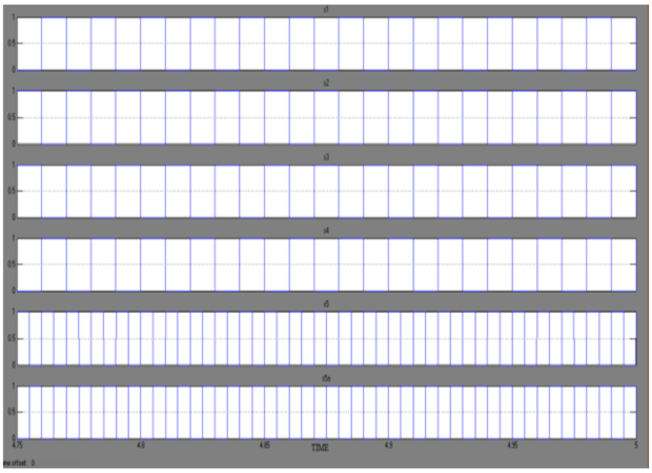

Fig 15: Switching signals of S1, S2, S3, S4, S5, S6

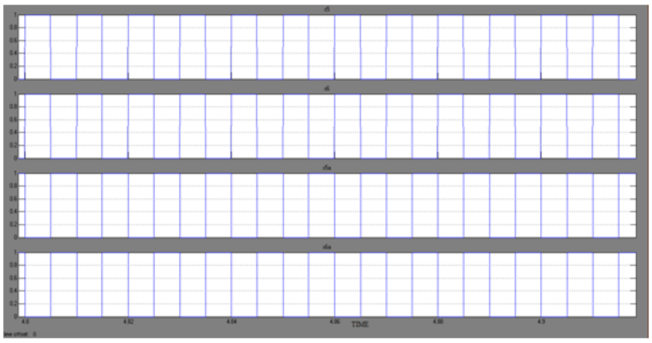

Fig 16: Simulation waveforms for S5, S6 and S5a, S6a

IV. Proposed Three-Phase ZCT Inverter

Circuit Structure:

In order to realize the soft-switching operation for the high frequency main switches S5 and S6 in the HS-H6-I topology, there sonant components C5a, L5a, C6a, L6a, the auxiliary switchesS5a, S6a (including their anti parallel diodes or, body diodesD5a and D6a), and one auxiliary diode Da are introduced to form two resonant tanks, as shown in Fig. 1(a), L5a = L6a = Lr, and C5a = C6a = Cr. The line-frequency full-bridge inverter consists of the switches S1, S2, S3, and S4 ; the inductors L1,L2 , and capacitor C1 make up the filter connected to the grid;D7 and D8 are a couple of clamping diodes in the freewheeling period. The modulation pattern of the ZCT-H6-I is the same with the HS-H6-I topology. This section focuses on the operation principle analysis of the ZCT resonant tank.

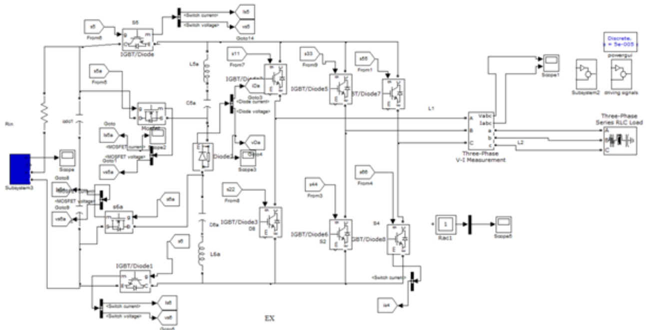

Fig 17: Simulation Circuit of the Proposed Three-phase grid tied ZCT inverter

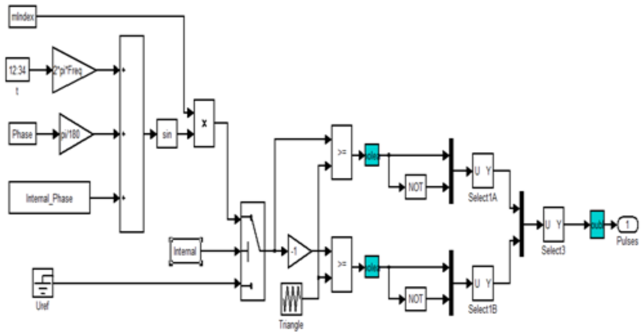

Fig 18: Circuit design of PWM technique

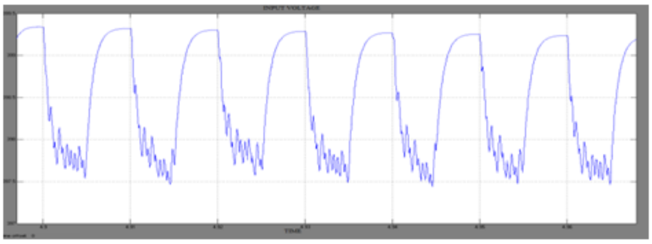

Fig 19: Waveform for grid tied ZCT inverter input voltage

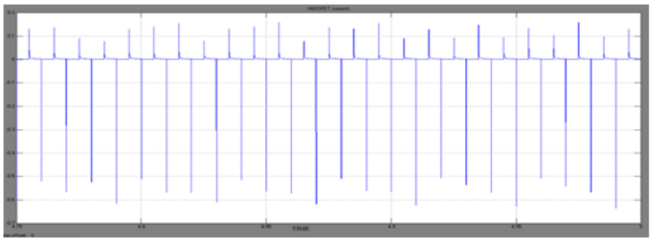

Fig 20: Waveform for grid tied ZCT inverter mosfet current

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

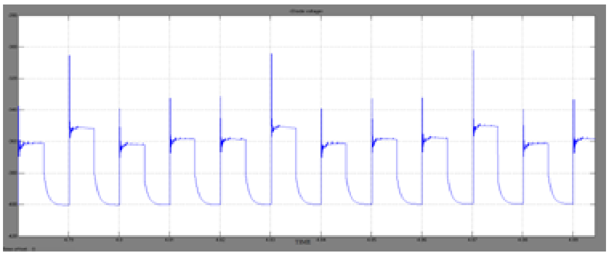

Fig 21: Waveform for grid tied ZCT inverter diode voltage

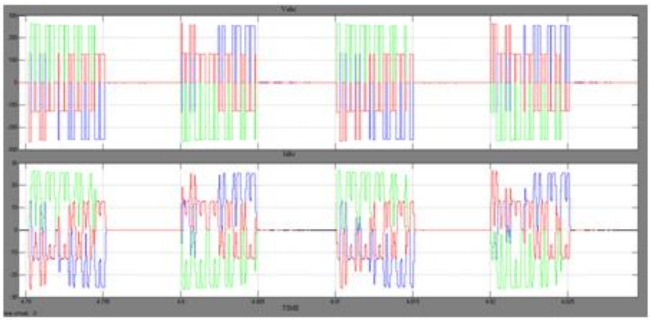

Fig 22: Three-phase grid tied ZCT inverter Vabc and Iabc

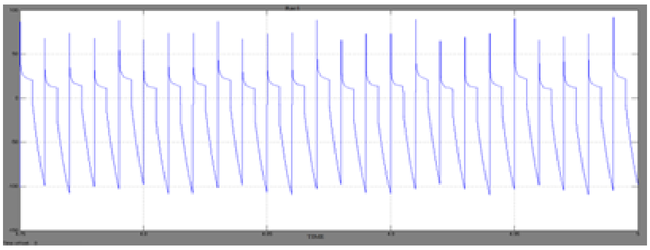

Fig 23: Three-phase grid tied ZCT inverter Rac1

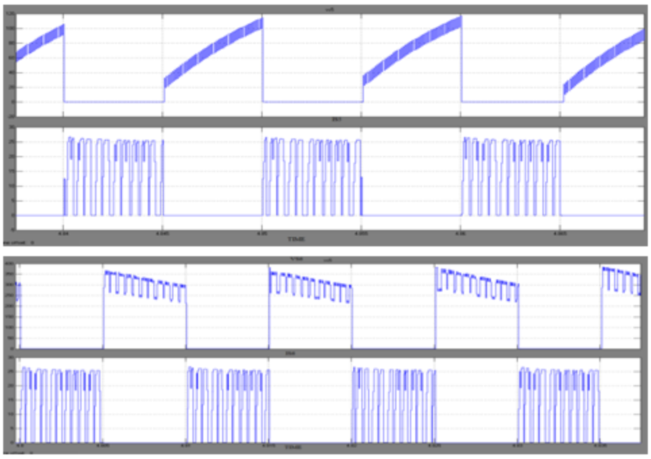

Fig 24: Grid tied ZCT inverter Vs5, Is5, Vs6 and Is6

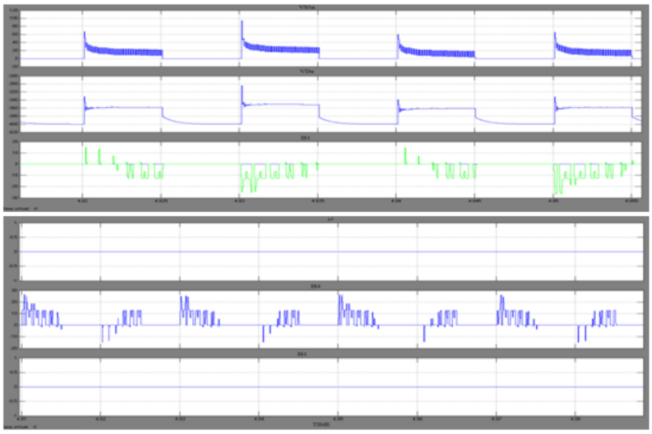

Fig 25: Waveforms of V_{s5a}, V_{Da}, I_{S1}, I_{S4} and I_{S1}

V. CONCLUSION:

The three-phase DC-DC series resonant converter switching with constant frequency keeps the structure operating with the maximum efficiency and optimized transformer utilization. The topologies chosen for the converters qualify the modified dual-stage inverter for high power operation. The transformer size can be minimized by the increase of the DC-DC converter switching frequency, which is independent of the DC-AC stage. The filter elements size is also reduced due to the low ripple of DC-DC converter input and output current. As a consequence, an insignificant capacitor was used on implementation of the PV array parallel filter. Two factors mainly contributed with this advantage: the continuous current flux with low ripple and the barrier formed by the resonant circuit to electrical perturbations on DC link that did not affect the primary side voltage bus. Besides, the Series Resonant Converter features a robust operation under unbalanced conditions. In this paper comparison has been done between single-phase and three-phase grid connected ZCT-H6 converter. From the observation of simulation results the ZCT-H6 converter is better for both single and three-phase grid applications.

REFERENCES:

[1] W. S. Yu, J.-S. Lai, H. Qian, C. Hutchens, J. H. Zhang, G. Lisi, A. Djabbari, G. Smith, and T. Hegarty, “High-efficiency inverter with H6type configuration for photovoltaic non-isolated AC module

applications," in Proc. IEEE 25th Annu. Appl. Power Electron. Conf. Expo., 2010, pp. 1056–1061.

[2] T. Kerekes, R. Teodorescu, P. Rodriguez, and G. Vazquez, "A new high-efficiency single-phase transformer less PV inverter topology," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 184–191, Jan. 2011.

[3] H. F. Xiao and S. J. Xie, "Transformer less split-inductor neutral point clamped three-level PVgrid-connected inverter," IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1799–1808, Apr. 2012.

[4] J.-M. Shen, H.-L. Jou, and J.-C. Wu, "Novel transformer less grid connected power converter with negative grounding for photovoltaic generation system," IEEE Trans. Power Electron., vol. 27, no. 4, pp. 1818–1829, Apr. 2012

[5] Y. Gu, W. Li, Y. Zhao, B. Yang, C. Li, and X. He, "Transformer less inverter with virtual DC bus concept for cost-effective grid-connected PV Power systems," IEEE Trans. Power Electron., vol. 28, no. 2, pp. 793–805, Feb. 2013

[6] B. Gu, J. Dominic, J.-S. Lai, C.-L. Chen, T. LaBella, and B. Chen, "High reliability and efficiency single-phase transformer less inverter for grid connected photovoltaic systems," IEEE Trans. Power Electron., vol. 28, no. 5, pp. 2235–2245, May 2013.

[7] X. Yuan and Y. Zhang, "Status and opportunities of photovoltaic inverters in grid-tied and micro-grid systems," in Proceedings of the 5th IEEE Power Electronics and Motion Control Conference, pp. 593–596, August 2006

[8] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz et al., "Power-electronic systems for the grid integration of renewable energy sources: a survey," IEEE Transactions on Industrial Electronics, vol. 53, no. 4, pp. 1002–1016, 2006.

[9] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "Power inverter topologies for photovoltaic modules—a review," in Proceedings of the 37th IEEE Annual Meeting and World Conference on Industrial Applications of Electrical Energy (IAS '02), pp. 782–788, October 2002.