RESEARCH ARTICLE OPEN ACCESS

Integrated Converter Topologies Implementation to Photovoltaic Modules Connected to Grid

Hans Manoj R, Mahamuni N. N., Dr. Vivekkant Jogi.
Research Scholar MSE&IT, MATS University Raipur, India
Lecturer STES's Sou. Venutai Chavan Polytechnic, Pune, India.
Associate Professor, MSE&IT, MATS University Raipur, India

ABSTRACT
The development of photovoltaic (PV) module generation is increasing at almost an exponential rate. A PV based power system with high voltage gain and the steady-state analysis are presented in this paper. For a conventional photovoltaic cell, the output voltage is comparatively low, and for grid connection it requires high voltage gain. Hence the proposed topology uses interleaved converter coupled with inductor coil and PWM technique as a primary conversion stage which moderate the voltage to a high dc bus voltage. In second stage a bridge inverter with bidirectional power flow strategy which interconnect grid. In addition to this for power balancing a Maximum Power Point Tracking (MPPT) system is applied gives high performance with minimum cost and comparatively high dynamic response.

Keywords: *Photovoltaic module, Interleaved converter, PWM technique, Maximum power point tracking (MPPT) system, Inverter topologies, Electrical grid.*

Date of Submission: 28 -05-2017 Date of acceptance: 05-08-2017

I. INTRODUCTION

As the world's power demand is increasing, growth of generation from renewable sources also needs to increase and PV arrays are most feasible source, but photovoltaic (PV) power supplied to the utility grid is gaining more and more importance [1]. For connecting PV power to the grid there are four different configurations are developed (i) The string inverter system (ii) The centralized inverter system, (iii) The multi string inverter system, (iv) Module-integrated inverter system[1]–[4].

The PV system connection to grid includes two conversion stages including a step-up Zero voltage Transformer (ZVT) interleaved boost converter for increasing a voltage of PV module to the high dc-bus voltage, which is equal to grid voltage rating; bridge inverter for converting the dc current into ac waveform synchronized with the utility grid. The interleaved boost converter is responsible for the MPPT and the bridge inverter has the capability of stabilizing the ac-bus voltage to a grid value.

The output voltage of PV arrays is normally ranges between 150V to 450V. Therefore in conventional system large number of PV models are connected in series and total power is always greater than 500 W. The average rating of integrated inverter module is less than 500 W, normally power rating of inverter module is between 100 to 200 W. Another method is by using high frequency state up transformer but it has disadvantages of large weight and size [3] [4].

In this paper, a PV module is connected to utility grid system with increased voltage gain is presented. Fig. 1 shows the block diagram of proposed PV module connected to utility grid system. As in that first it boost up the voltage to grid voltage level and then inverter stage with MPPT tracking system for steady state sinusoidal voltage.

II. EVOLUTION OF PHOTOVOLTAIC INVERTERS

An overview of existing power converter topologies for the AC-Module is given.

A. The Past: Centralized Inverters

In the past centralize inverter modules are connected in series and parallel to achieve high voltage and power level. The power

Losses in series and parallel modules are overcome by Generation Control which also the possibilities of hot spots.

B. The Present: String Inverters and AC-Modules

The Recent string inverter technology uses single string of modules, to obtain a high input voltage to the inverter. Though it overcome the losses generated by the string diodes and an individual MPPT but suffered with host spot risks.

The AC-Module removes the hot spot risks to some extends as well as it also minimized losses due to mismatch between modules and inverter, as well as it supports optimal adjustment between the module and the inverter.

C. The Future: AC-Modules and AC-Cells

The future AC modules are integration of one great PV-cell and the inverter. To amplify the cell' inherent very low voltage up to an appropriate level for the grid-connected inverter and at the same time to reach a high efficiency is key challenges with this technology. Therefore the new converter technologies are need to be proposed.

III. GRID-CONNECTED PHOTOVOLTAIC POWER SYSTEM

The grid-connected PV power system offers a high voltage gain as well as maintains the used of PV array voltage. The proposed PV system is based on two power processing stages (i) high step-up ZVT-interleaved boost converter (ii) full-bridge inverter. The ZVT interleaved boost converter amplifies low voltage of PV array up to the high dc-bus voltage. On the other hand boost converter inverts the dc current into a sinusoidal waveform synchronized with the utility grid. It also controlled the system power in wide range from several hundred to thousand watts only by changing the quantity of PV module branches in parallel.

The Proposed grid-connected PV power system is shown in Figure 1. The proposed system can be applied to the string or multistring inverter system, as well as to the module-integrated inverter system in low power applications. The non-isolation PV systems such as highly efficient reliable inverter concept (HERIC), neutral-point-clamped (NPC) topology, H5 topology, etc. are of great importance worldwide especially in especially in Europe. Though the transformer systems with floating and non-earth-connected PV dc bus need more protections but it has several advantages such as high efficiency, lightweight. Therefore ZVT-interleaved boost converter have been employed in PV systems which maintain the PV array voltage below 50V required range as well as ensures the personnel safety in high power applications.

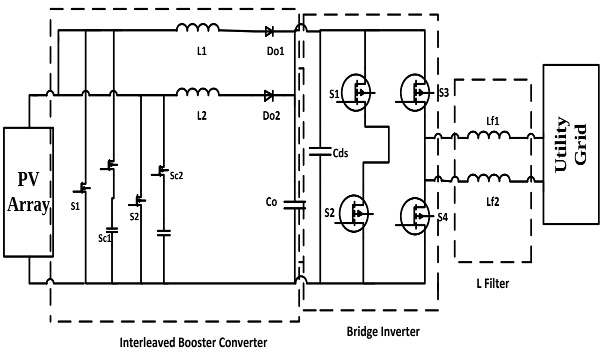

Fig. 1 Proposed grid-connected PV power system.

IV. STEADY-STATE MODEL OF HIGH STEP-UP ZVT-INTERLEAVED BOOST CONVERTER

The ZVT-interleaved boost converter with winding-coupled inductors and active-clamp circuits offer the voltage-gain extension. The active clamp circuits are responsible for commutation of main switches and the auxiliary switches. The Fig. 2(a) and Fig. 2(b) below shows the High step-up ZVT-interleaved boost converter and its equivalent circuit respectively.

The equivalent circuit model is demonstrated in Fig. 2(b), where Lm_1 and Lm_2 are the magnetizing inductors; L_{lk1} and L_{lk2} are the leakage inductors including the reflected leakage inductors of the second and third windings of the coupled inductors; Cs_1 and Cs_2 are the parallel capacitors, including the parasitic capacitors of the switches; Cc_1 and Cc_2 are the clamp capacitors; N is the turns ratio n2 /n1.

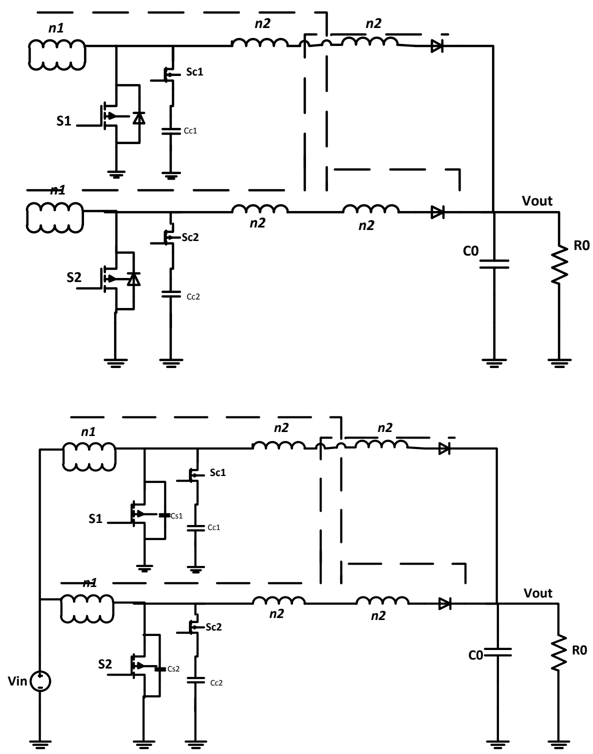

Fig.2. High step-up ZVT-interleaved boost converter and its equivalent circuit. (a) ZVT-interleaved boost converter. (b) Equivalent circuit.

The different converters such as resonant converters LLC, LCC can provide the high voltage gain. However they induced some inherent problems such as electromagnetic interference (EMI) due to variable frequency operations and low conversion efficiency because of circulating energy generation. Therefore, the design of the transformer is difficult and the converter's efficiency is impacted. The working principles and waveforms for high step-up

ZVT-interleaved boost converter analyzed in this paper. Moreover the full-bridge dc–dc converter is also employed commonly as a similar first stage in the PV system.

The three main advantages of ZVT-interleaved boost converter are as follows:

1. With increase in turns ratio it extends the voltage gain given by,

$$M = \frac{Vout}{Vin} = \frac{N+1}{D-1}$$

2. Reduce the conduction and switching losses therefore able to recover the leakage energy with reduced Voltage stress of the main switches given by

$$V_{ds} = \frac{Vout}{N+1}$$

3. Achievs ZVT soft switching for both main and auxillary switches during the whole swithcing transistions which reduces the Diode reverse-recovery loss.

The leakage inductor affects the voltage gain (1) of steady-state model and causes errors to the design of circuit parameters. The fallowing assumptions are considered to simply the calculations

a. To ignore the voltage ripple on the main switches the clamp capacitance is assumed large enough
b. The magnetizing current I_{Lm} is considered constant in one period to keep the magnetizing inductance greater than leakage inductance.
c. The main switches and auxiliary switches are ignored for their deadlines.
d. A strict symmetry is provided for interleaved and intercoupled boost converter cells.

V. CONTROL STRATEGY OF FULL-BRIDGE INVERTER WITH BIDIRECTIONAL POWER FLOW

The Fig. 1 full bridge inverter acts as a voltage-source PWM (VS-PWM) converter which implements the bidirectional flow. Therefore the direct current control strategies have been employed to achieve the synchronization with the utility grid voltage as well as high power factor, the low total harmonic distortion (THD) and the fast dynamic response. Figure 3 below shows the Control block of two-stage grid-connected PV system.

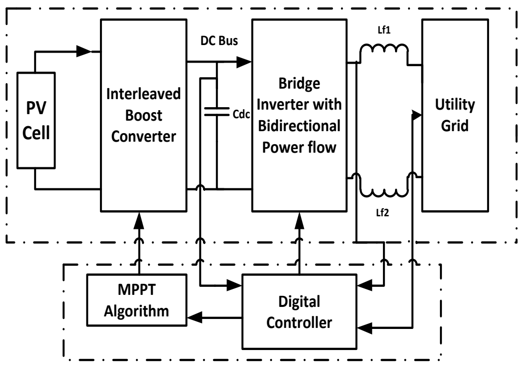

Fig. 3. Control block of two-stage grid-connected PV system.

The control block of the full-bridge inverter with bidirectional power flow is shown in figure 4. The bidirectional flow of power facilitates and compensation of the dc-bus and the ac-side voltage variations, improves the stability of overall system.

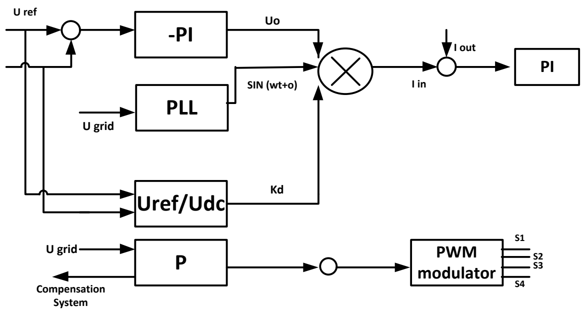

Fig. 4. Control block of full-bridge inverter with bidirectional power flow.

With the direct current flow strategy the VS-PWM converter can force the instantaneous load current to accurately follow the sinusoidal reference which stabilizes the synchronization.

A. Control of the Bidirectional Power Flow

As shown in figure 4, the voltage-feedback control loop keep the dc bus voltage to constant value U_{ref} with zero error so that the dc-bus voltage U_{dc} is always controlled. The output of negative PI regulator decides the direction and magnitude of VS-PWM converter's output current and power. The VS-PWM converter acts as an inverter when If $U_{dc} > U_{ref}$ with increasing Ue and acts as PWM rectifier, when If $U_{dc} < U_{ref}$ where Ue is decreasing. Based on the conditions of the ZVT-interleaved Boost converter will work in an open-circuit state.

B. Direct Current Control With Compensation Units

The error signal generated from i_{out} and i_{ref}, processed in current-feedback control loop by PI regulator. The current control loop kept at higher bandwidth 2-5 Khz than voltage loop bandwidth of 200–500 Hz to ensure stability of the proposed inverter control with two PI regulators. The system gives low harmonics to reduce losses in steady state, the fast response to provide high dynamic performances, and the peak current protection to reject overload. Compensation coefficient K_d represents a negative fluctuating feature with the frequency 2ω *and defined as*

$$K_d = \frac{Uref}{Udc}$$

The utility grid voltage u_{grid} synchronization between the frequency ω and phase φ of current reference i_{ref} is achieved by using phase-locked-loop (PLL) in this system.

VI. SIMPLE MPPT SOLUTION BASED ON POWER BALANCE

The various cost effective and complex MPPT algorithms are implemented in recent years for power optimization of PV modules. The proposed MPPT algorithm can be implemented by controlling output U_e of the negative PI controller in the voltage loop rather than considering the integral multiple of voltage and current thus reduces the whole system losses. Perturb and observe (P&O) algorithms value for controlling the magnitude of U_e are described in Table –I below.

The MPPT solutions eliminates the nonlinearity of the whole system losses and long-term fluctuation of the utility grid voltage, thus transferred the maximum power to the utility grid, but not the output power from PV array.

Table-I
P&O ALGORITHM EMPLOYING U_e

Perturbation in *D*	Change in U_e	Next Perturbation in *D*
Positive	Positive	Positive
Positive	Negative	Negative
Negative	Positive	Negative
Negative	Negative	Positive

Proposed system implementation modules-

The Matlab Simulink is used to implement the module of proposed Grid-Connected Photovoltaic Module Integrated Converter. The voltage parameters are kept in stabilize ranges so that no active power can be consumed except for the IGBT losses. The PV arrays are connected to utility grid with high voltage gain. This is shown by simulation result as PV voltage is 80 V, and grid voltage is about 340 V, by MPPT it stabilized voltage and bidirectional inverter gives power flow control Figure below shows the simulations waveforms. It can be seen that the output current is highly sinusoidal synchronized with the grid voltage.

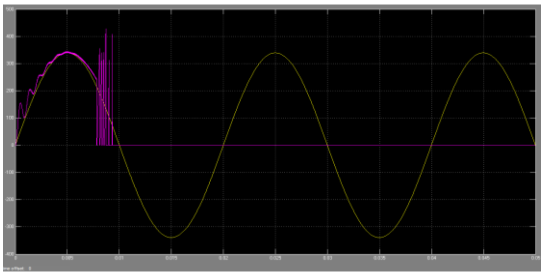

Fig 5. Voltage Across Utility Grid interconnected by PV module.

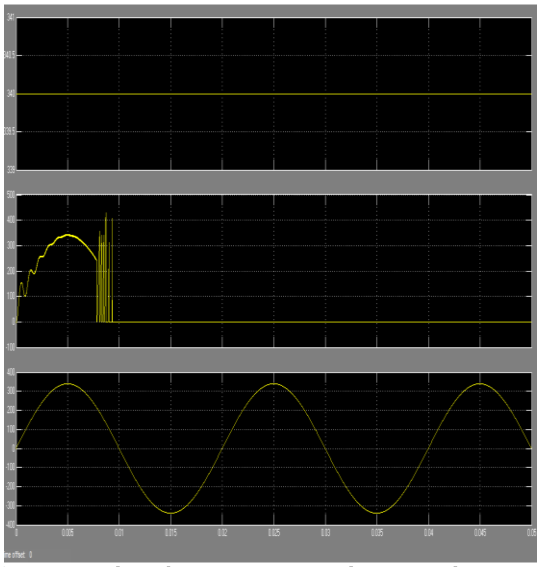

Fig 6. A. Interleaved Boost Converter Voltage; B. Voltage across Filtering Capacitor; C. Voltage across MPPT while connecting to grid.

Simulation results indicate that the PV module successfully connected to grid through ZVT interleaved converter which boost up the voltage level and MPPT technique which trace out maximum power to the utility grid from PV module.

VII. CONCLUSION

In this paper the grid-connected PV power system with high voltage gain is studied. The proposed PV system employed in two stages, first high step-up ZVT-interleaved boost converter with winding-coupled inductors and active-clamp circuits. By selecting the accurate turn's ratio of winding-coupled inductors high voltage gain can be achieved. The proposed work also exhibit and verified the steady-state model of the converter. The output current and dc bus voltage is maintained by using full-bridge inverter with bidirectional power flow in the second stage. The MPPT method improves the performance of the system. The current work shows implementation of one of the module of proposed Grid-Connected Photovoltaic Module Integrated Converter. The simulations waveforms validate the implementation work.

REFERENCES

[1] S. B. Kjaer, J. K. Pedersen, 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.

[2] Q. Li and P.Wolfs, “A review of the single phase photovoltaic module integrated converter topologies with three different DC link configurations,” IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1320–1333, May 2008.

[3] H. M. Kojabadi, B. Yu, I. A. Gadoura, L. Chang, and M. Ghribi, “A novel DSP-based current-controlled PWM strategy for single phase grid connected inverters,” IEEE Trans. Power Electron., vol. 21, no. 4, pp. 985–993, Jul. 2006..

[4] 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.

[5] T. Kerekes, R. Teodorescu, and U. Borup, “Transformerless photovoltaic inverters connected to the grid,” in Proc. IEEE APEC Conf., 2007, pp. 1733–1737.

[6] O. Lopez, R. Teodorescu, F. Freijedo, and J. Doval-Gandoy, “Eliminating ground current in a transformerless photovoltaic applictation,” in Proc. IEEE PES Conf., 2007, pp. 1–5.

[7] R. Gonzalez, E. Gubia, J. Lopez, and L.Marroyo, “Transformerless singlephase multilevel-based photovoltaic inverter,” IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2694–2702, Jul. 2008.

[8] W. Li and X. He, “ZVT interleaved boost converters for high-efficiency, high step-up DC/DC conversion,” IET Electr. Power Appl., vol. 1, no. 2, pp. 284–290, Mar. 2007.

[9] Soeren Baekhoej Kjaer, John K. Pedersen, Frede Blaabjerg, “A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules,” ieee transactions on industry applications, vol. 41, no. 5, september/october 2005.

[10] Quan Li, Peter Wolfs, “A Review of the Single Phase Photovoltaic Module Integrated Converter Topologies With Three Different DC Link Configurations”, Ieee Transactions On Power Electronics, Vol. 23, No. 3, May 2008.

[11] Soeren Baekhoej Kjaer, John K. Pedersen, Frede Blaabjerg,” Power Inverter Topologies for Photovoltaic Modules – A Review”, Industry Applications Conference, 2002.

International Journal of Engineering Research and Applications (IJERA) is **UGC approved** Journal with Sl. No. 4525, Journal no. 47088. Indexed in Cross Ref, Index Copernicus (ICV 80.82), NASA, Ads, Researcher Id Thomson Reuters, DOAJ.

Hans Manoj R " Integrated Converter Topologies Implementation to Photovoltaic Modules Connected to Grid" International Journal of Engineering Research and Applications (IJERA) 7.8 (2017): 61-65.