

April 2013

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Recommended Citation

KUMAR, J. KISHORE and Devi, V. Lakshmi (2013) "DESIGN AND ANALYSIS OF A GRID-CONNECTED PHOTOVOLTAIC POWER SYSTEM," *International Journal of Power System Operation and Energy Management*: Vol. 2 : Iss. 2 , Article 1.

DOI: 10.47893/IJPSOEM.2013.1066

Available at: <https://www.interscience.in/ijpsoem/vol2/iss2/1>

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DESIGN AND ANALYSIS OF A GRID-CONNECTED PHOTOVOLTAIC POWER SYSTEM

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Abstract - A grid-connected photovoltaic (PV) power system with high voltage gain is proposed, and the steady-state model analysis and the control strategy of the system are presented in this paper. For a typical PV array, the output voltage is relatively low, and a high voltage gain is obligatory to realize the grid-connected function. The proposed PV system employs a ZVT-interleaved boost converter with winding-coupled inductors and active-clamp circuits as the first power-processing stage, which can boost a low voltage of the PV array up to a high dc-bus voltage. Two compensation units are added to perform in the system control loops to achieve the low total harmonic distortion and fast dynamic response of the output current. Furthermore, a simple maximum-power-point-tracking method based on power balance is applied in the PV system to reduce the system complexity and cost with a high performance. At last, a 2-kW prototype has been built and tested to verify the theoretical analysis of the paper.

Index Terms—Bidirectional power flow control, compensation units, direct current control, maximum-power-point-tracking (MPPT) method, photovoltaic (PV) system, steady-state model.

I. INTRODUCTION

Today photovoltaic (PV) power systems are becoming more and more popular, with the increase of energy demand and the concern of environmental pollution around the world. Four different system configurations are widely developed in grid-connected PV power applications: the centralized inverter system, the string inverter system, the multistring inverter system and the module-integrated inverter system. Generally three types of inverter systems except the centralized inverter system can be employed as small-scale distributed generation (DG) systems, such as residential power applications. The most important design constraint of the PV DG system is to obtain a high voltage gain. For a typical PV module, the open-circuit voltage is about 21 V and the maximum power point (MPP) voltage is about 16 V. And the utility grid is 220 or 110 Vac. Therefore, the high voltage amplification is obligatory to realize the grid-connected function and achieve the low total harmonic distortion (THD).

The conventional system requires large numbers of PV modules in series, and the normal PV array voltage is between 150 and 450 V, and the system power is more than 500 W. This system is not applicable to the module-integrated inverters, because the typical power rating of the module-integrated inverter system is below 500 W, and the modules with power ratings between 100 and 200 W are also quite common. The other method is to use a line frequency step-up transformer, and the normal PV array voltage is between 30 and 150 V. But the line frequency transformer has the disadvantages of larger size and weight. In the grid-connected PV system, power electronic inverters are needed to realize the

power conversion, grid interconnection, and control optimization. Generally, grid-connected pulse width modulation (PWM) voltage source inverters (VSIs) are widely applied in PV systems, which have two functions at least because of the unique features of PV modules. First, the dc-bus voltage of the inverter should be stabilized to a specific value because the output voltage of the PV modules varies with temperature, irradiance, and the effect of maximum power-point tracking (MPPT). Second, the energy should be fed from the PV modules into the utility grid by inverting the dc current into a sinusoidal waveform synchronized with utility grid. Therefore, it is clear that for the inverter-based PV system, the conversion power quality including the low THD, high power factor, and fast dynamic response, largely depends on the control strategy adopted by the grid-connected inverters. In this paper, a grid-connected PV power system with high voltage gain is proposed. The grid connected PV system includes two power-processing stages: a high step-up ZVT-interleaved boost converter for boosting a low voltage of PV array up to the high dc-bus voltage, which is not less than grid voltage level; and a full-bridge inverter for inverting the dc current into a sinusoidal waveform synchronized with the utility grid. Furthermore, the dc-dc converter is responsible for the MPPT and the dc-ac inverter has the capability of stabilizing the dc-bus voltage to a specific value. The grid-connected PV power system can offer a high voltage gain and guarantee the used PV array voltage is less than 50 V, while the power system interfaces the utility grid. On the one hand, the required quantity of PV modules in series is greatly reduced. And the system power can be controlled in a wide range from several hundred to thousand watts only by changing the quantity of PV module branches in parallel.

and R is the equivalent load of the converter.

The main aim of a PV system is to maximize its energy its energy yield. Issues such as low cost, reliability, long life time (20 years and longer), high (part – load) efficiency and good environmental conditions (availability of solar radiation) are hence of importance to the PV system. Other important requirements for these PV systems are the fulfillment of standards concerning power quality, electromagnetic compatibility, acoustic noise limitations as well as safety and protection requirements. The high power converters such as the multi level inverters are required for the better grid connected PV system.

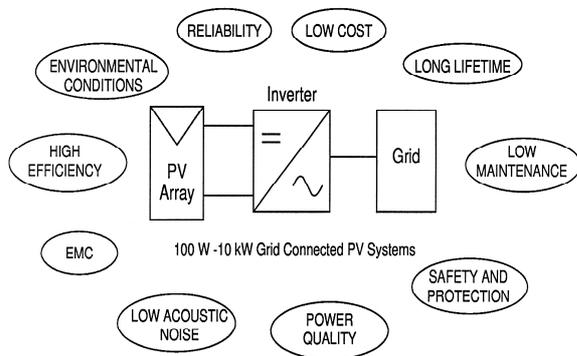


Fig. 3 Issues regarding grid connected PV systems

III MODELING OF SOLAR ARRAY

DC – DC boost convert is the combination of MOSFETs , Mutual Inductances and Diodes. The MOSFET device turns on when a positive signal is applied at the gate input ($g > 0$) whether the drain-source voltage is positive or negative. If no signal is applied at the gate input ($g=0$), only the internal diode conducts when voltage exceeds its forward voltage V_f .

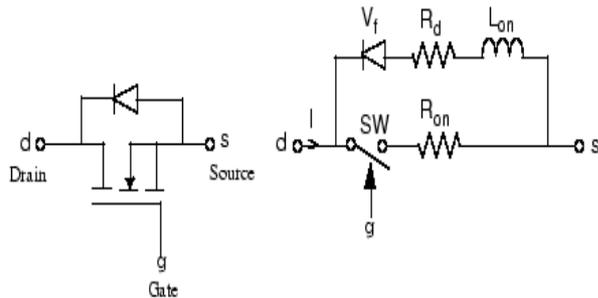


Fig 4 Internal Diagram of the MOSFET

With a positive or negative current flowing through the device, the MOSFET turns off when the gate input becomes 0. If the current I is negative and flowing in the internal diode (no gate signal or $g = 0$), the switch turns off when the current I becomes 0. The simulation block of multilevel inverter mainly consists of IGBT, the full bridge inverter. The output

of the inverter is almost sinusoidal but not a pure sinusoidal some what of non fundamental frequency content is still appears in the wave form due to this there is a chance of polluting the grid when we sychronized with the grid. So that we have to filter the harmonic content from the output of the inverter with the help of a filter. In this proposed system I used a 2nd order filter to filterout the harmonic content from the output voltage. In this project a voltage source is considered as a grid. The AC Voltage Source block implements an ideal AC voltage source. The generated voltage U is described by the following relationship:

$$(8)$$

Where

Negative values are allowed for amplitude and phase. A frequency of 0 and phase equal to 90 degrees specify a DC voltage source. Negative frequency is not allowed; otherwise the software signals an error, and the block displays a question mark in the block icon.

IV SIMULATION

To confirm the theoretical analysis in the previous sections, a 2-kW prototype of the proposed grid-connected PV power system was built. Two ZVT-interleaved boost converters of 1 kW are connected in parallel via a dc bus through a central inverter of 2 kW to the grid. The lower power dc–dc converters are connected respectively to the individual PV arrays, and the central system inverter can expand the power rate and reduce the system cost.

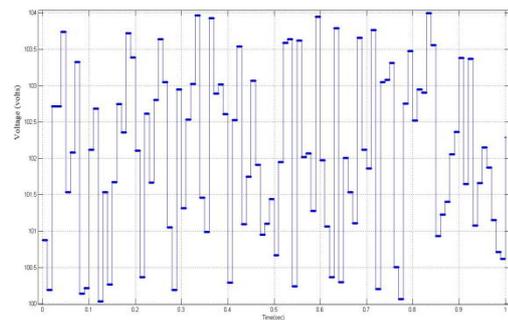


Fig 5 Output Of The Solar Unit

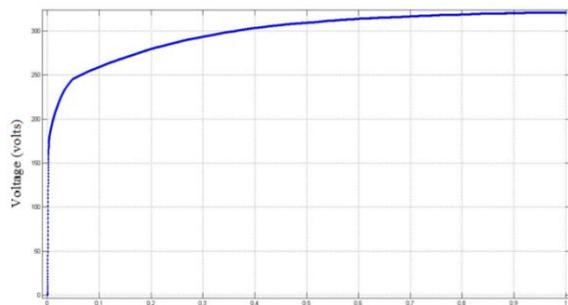


Fig 6. Output of The DC – DC Boost Converter

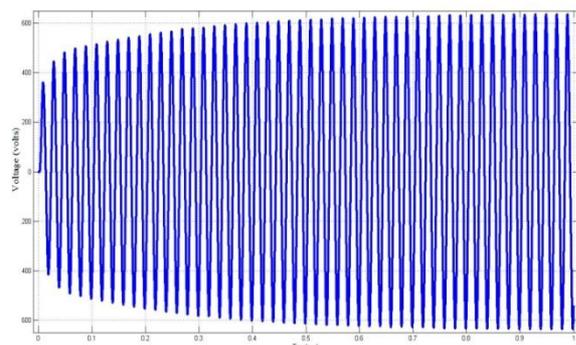


Fig 8. Output Of The cascaded System

If suppose single block is designed for 50v grid voltage is 500 we need to connect $500/50v = 10$ blocks in cascaded connection. If suppose another customer required 1000 v we need to connect 20 blocks in cascade. $1000/50$. So we need not to redesign our system for different grid voltage. From the figure 9 by selecting the Harmonic Order we can find the Total Harmonic Distortion (THD). With this proposed system the Total Harmonic Distortion (THD) has been reduced to 3.7%.

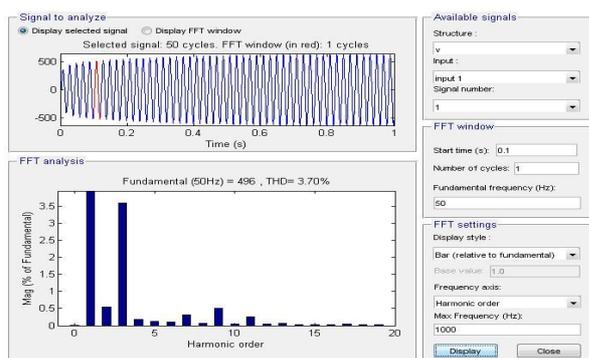


Fig 8 FFT Analysis Tool - THD

V. CONCLUSION

This paper presents a grid-connected PV power system with high voltage gain. The proposed PV system employs a high step-up ZVT-interleaved boost converter with winding-coupled inductors and active-clamp circuits as the first power-processing stage, and high voltage gain is obtained by the turns ratio selection of winding-coupled inductors. In conventional system a single PV cell is connected to a dc - dc converter and the output of the dc - dc converter is connected to the inverter finally inverter feeds the power into the grid. In this system inverter and DC - DC converter are rated for grid voltage, so the cost of the whole system is high and reliability is low. Another problem is the inverter output is not a pure AC so we need to use large size filter. The Proposed system eliminates all above disadvantages. In this system DC - DC converter and inverter are rated for lower voltage and such blocks are connected in cascade to meet the grid voltage. Since we are using low voltage components the overall cost of the

system is less and reliability is high. As by using this cascaded inverter, the requirement of high rated filter is reduced which will further reduces cost, complexity of the system and THD.

We can implement the whole by using DSP. In future we can build one single block consists of PV cell DC - DC converter and inverter rated for voltage rating V. if suppose if the grid voltage is 5v we need to cascaded 5 such a blocks.

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] M. Calais, J. Myrzik, T. Spooner, and V. G. Agelidis, "Inverters for single phase grid connected photovoltaic systems—An overview," in *Proc. IEEE PESC*, 2002, vol. 4, pp. 1995–2000.
- [4] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "Power inverter topologies for photovoltaic modules—A review," in *Proc. IEEE IAS Conf.*, 2002, pp. 782–788.
- [5] Q. Li and P. Wolfs, "A current fed two-inductor boost converter with an integrated magnetic structure and passive lossless snubbers for photovoltaic module integrated converter applications," *IEEE Trans. Power Electron.*, vol. 22, no. 1, pp. 309–321, Jan. 2007.
- [6] 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.
- [7] 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.
- [8] T. Kerekes, R. Teodorescu, and U. Borup, "Transformerless photovoltaic inverters connected to the grid," in *Proc. IEEE APEC Conf.*, 2007, pp. 1733–1737.
- [9] O. Lopez, R. Teodorescu, F. Freijedo, and J. Doval-Gandoy, "Eliminating groundcurrent in a transformerless photovoltaic application," in *Proc. IEEE PES Conf.*, 2007, pp. 1–5.
- [10] 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.
- [11] Q. Zhao and F. C. Lee, "High-efficiency, high step-up DC-DC converters," *IEEE Trans. Power Electron.*, vol. 18, no. 1, pp. 65–73, Jan. 2003.
- [12] R. J. Wai and R. Y. Duan, "High step-up converter with coupled-inductor," *IEEE Trans. Power Electron.*, vol. 20, no. 5, pp. 1025–1035, Sep. 2005.
- [13] K. C. Tseng and T. J. Liang, "Novel high-efficiency step-up converter," *IEEE Electr. Power Appl.*, vol. 151, no. 2, pp. 182–190, Mar. 2004.

