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Simulation of a PWM Single Phase Grid Connected or Stand-Alone Solar Inverter Topology with Microcontroller Based MPPT

[1]M. Nazrul Islam, [1]A.K.M.S. Islam Bhuian,
[1]Masud Kamal, [2]Kh. Asaduzzaman and [2]Mahbubul Hoq
[1]Radioactivity Testing and Monitoring Laboratory, Bangladesh Atomic Energy Commission,
P.O. Box No. 1352, Chittagong, Bangladesh
[2]Institute of Electronics, Atomic Energy Research Establishment,
Bangladesh Atomic Energy Commission, G.P.O. Box 3787, Savar, Dhaka, Bangladesh

Abstract: Solar inverter topology for single phase grid connected or stand alone applications along with microcontroller based Maximum Power Point Tracking (MPPT) has been presented in this study. The PV array consists of only 12 V cell arrangement for the topology. About 1 V 50 Hz signal has been superimposed with the carrier frequency of 1080 Hz in the discrete PWM generator which is suffice for the desired output/grid voltage. This topology has been designed with modern switching devices of IGBT-Diode, 3-winding ideal transformer and a suitable harmonic filter that gives the CTHD of only 2.26%. The microcontroller based MPPT scheme adorned with Constant Voltage (CV) or open voltage ratio method algorithm to control the operation of the topology. The whole process has been performed by MATLAB/Simulink and simulation results have been presented.

Key words: PV array, PWM, IGBT-D, CTHD, MPPT, CV algorithm and microcontroller

INTRODUCTION

The most diffused application of power electronic devices is to invert the DC generated from some dispersed energy resources (e.g., photo voltaic, fuel cells, micro turbines and battery storages) to existing 50/60 Hz AC. For getting better performance on the inverter or the total system in which many switching arms and higher frequency PWM switching are included, the advent of more advanced simulation tools will be desired (Arai *et al*., 2008).

In this regard, a high performance, single-stage inverter topology for grid connected PV systems with MPPT has been presented (Jain and Agarwal, 2007) claim the current THD of 9.13%, 325V (peak), 300 W. In (Irwanto *et al*., 2012), a new topology of three-level transformer-less Photovoltaic (PV) inverter shows that the lowest CTHD of 15.448%, 240 V, 50 W. Circuit analysis of a single phase micro-photovoltaic inverter can deal hundreds of watts of energy simulation based on MATLAB/Simulink (Cai *et al*., 2012). A Matlab/Simulink model propose an adaptation in one of the available multi-level inverters techniques to allow a lower logic communication network between inverters and the central controller without loss of performance and considering the photovoltaic panel's characteristics (Oliveira and Correa, 2012). A good number of literatures (Jain and Agarwal, 2007; Irwanto *et al*., 2012; Cai *et al*., 2012; Oliveira and Correa, 2012) with different stages describe power handling capability ranging from few watts to some hundreds. The proposed topology had some required characteristics, such as optimum use of the cell energy, reduced switching, compact size, the lower possible CTHD of 2.26% and increased loads and drives of 600 VA towards some KVS. The design process of the proposed single stage inverter topology was analytical and simulation based on MATLAB/Simulink. A Constant Voltage (CV) or open circuit voltage ratio method Maximum Power Point Tracking (MPPT) has been used to control the efficiency of the PV array. Microcontroller based control algorithm has been employed with the proposed MPPT.

MATERIALSAND METHODS

Arrangement of PV array: There is a wide flexibility for the arrangement of PV array starting from 12 V to upper. And the most modern switching devices that can handle upto 50 A load, enhance the power handling capability of 600 VA towards some KVs. In this prototype simulation, 12 V PV array gives the grid voltage of 500 V (peak) shown in Fig. 1.

Corresponding Author: M. Nazrul Islam, Radioactivity Testing and Monitoring Laboratory,
Bangladesh Atomic Energy Commission, P.O. Box No. 1352, Chittagong, Bangladesh

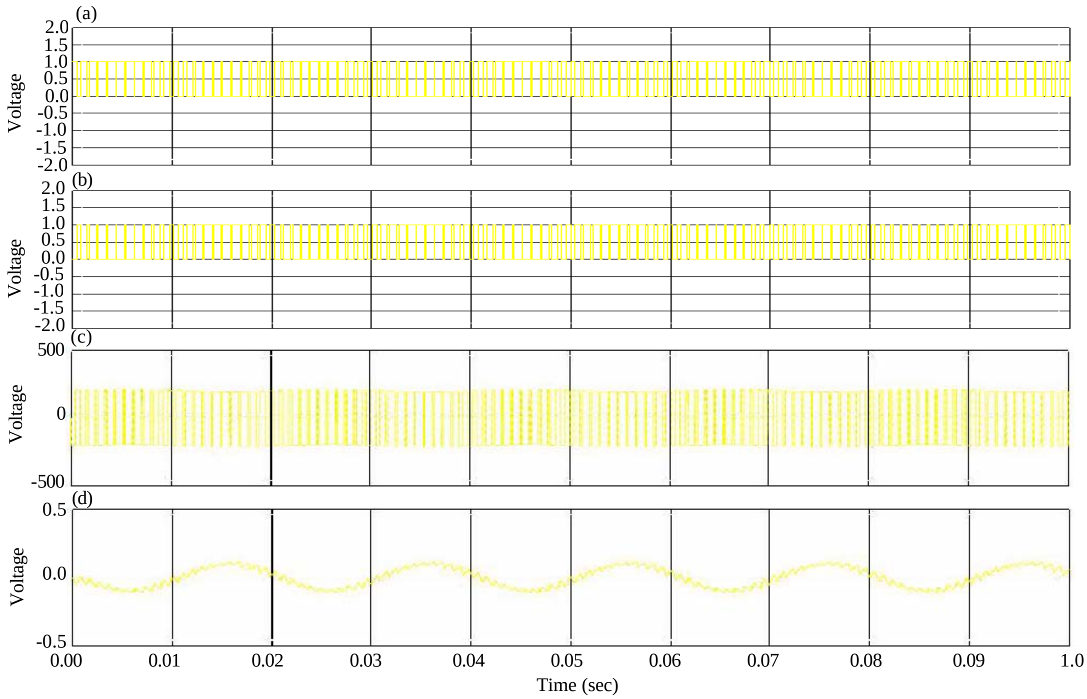

Fig. 1: The oscilloscope view for the measured quantities in Matalab. From top: a) Ch1; signal one (1 V); b) Ch2; signal two (1 V); c) Ch3; output voltage (500 V) and Ch4; d) Output current shows very small ripple

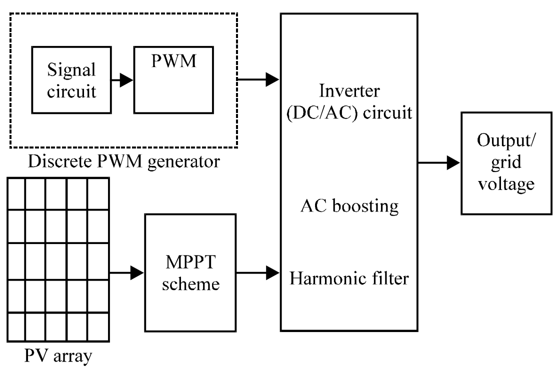

Fig. 2: The block shows elements of the proposed inverter topology

Block diagram of the proposed topology: The block diagram shown in Fig. 2, comprises of discrete PWM generator, inverter (DC/AC) circuit, AC boosting, harmonic filter, PV array and CV MPPT.

Schematic diagram of the proposed topology: The discrete PWM generator supply PWM pulses to switch the inverter circuit very rapidly and increase the AC voltage to a desired level. While the IGBT-D is ON; IGBT-D1 is OFF in positive half cycle. In the negative half cycle, IGBT-D is OFF; IGBT-D1 is ON and vice-versa. Therefore, after completion of the final AC boosting using 3-winding ideal transformer, a L-C harmonic filter eliminates the harmonic content shown in Fig. 3 and 4. Figure 1 shows the oscilloscope view for the input signals e1 and e2 (equal and opposite) and the measured quantities from top Ch1: Signal one (e1) 1 V for first switching device (IGBT-D); Ch2: Signal two (e2) 1 V for second switching device (IGBT-D1); Ch3: Output voltage 500 V (peak) and Ch4: Output current shows very small ripple.

Maximum Power Point Tracking (MPPT): Maximum Power Point Tracking (MPPT) is a widely used control technique to extract maximum power available from the solar cells in a photovoltaic system (Tung *et al.*, 2006). According to Fig. 5 on a clear day, if the solar irradiance is sufficient, then the PV array gives proper DC voltage to Constant Voltage (CV) method microcontroller (P16f676) employed algorithm MPPT scheme. This scheme always checks for the proper DC voltage from PV array whether it would present or not. On a cloudy day or at night when the solar irradiance is insufficient the scheme maintains off or performs temporary load shedding operation depending on the stoage battery.

The constant voltage algorithm Voc is the open circuit voltage of the PV panel. Voc depends on the property of the solar cells. A commonly used Voc/Vmpp value is 76% (Tung *et al.*, 2006; Hohm and Ropp, 2003). This relationship can be described by Eq. 1 as:

$$\text{Vmpp} = \text{k} \times \text{Voc} \quad \text{where}\, \text{k} = 0.76 \text{ to } \geq 1 \tag{1}$$

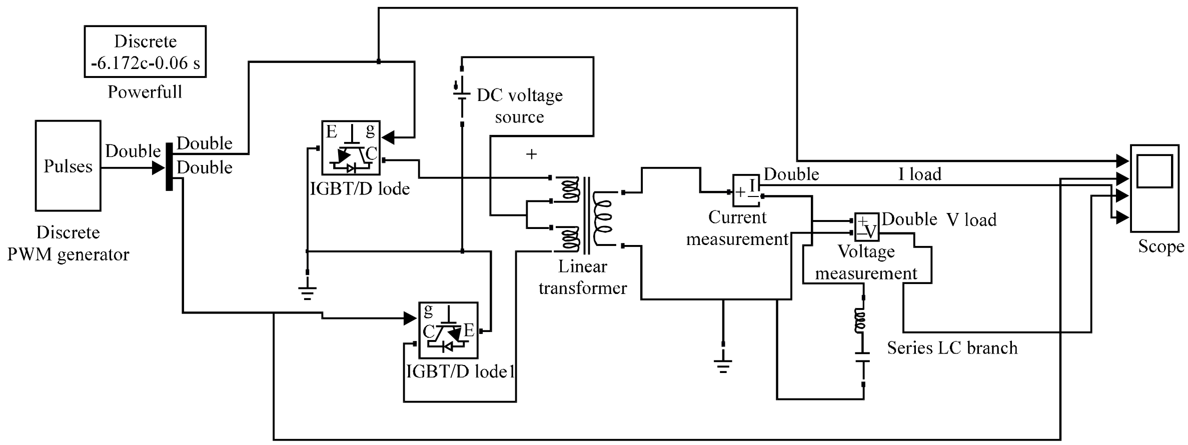

Fig. 3: Simulation model of the proposed inverter topology in Matlab

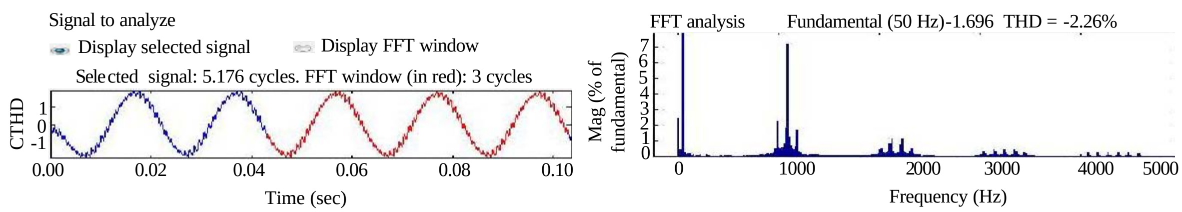

Fig. 4: The total harmonic distortion for current (CTHD) of the proposed topology

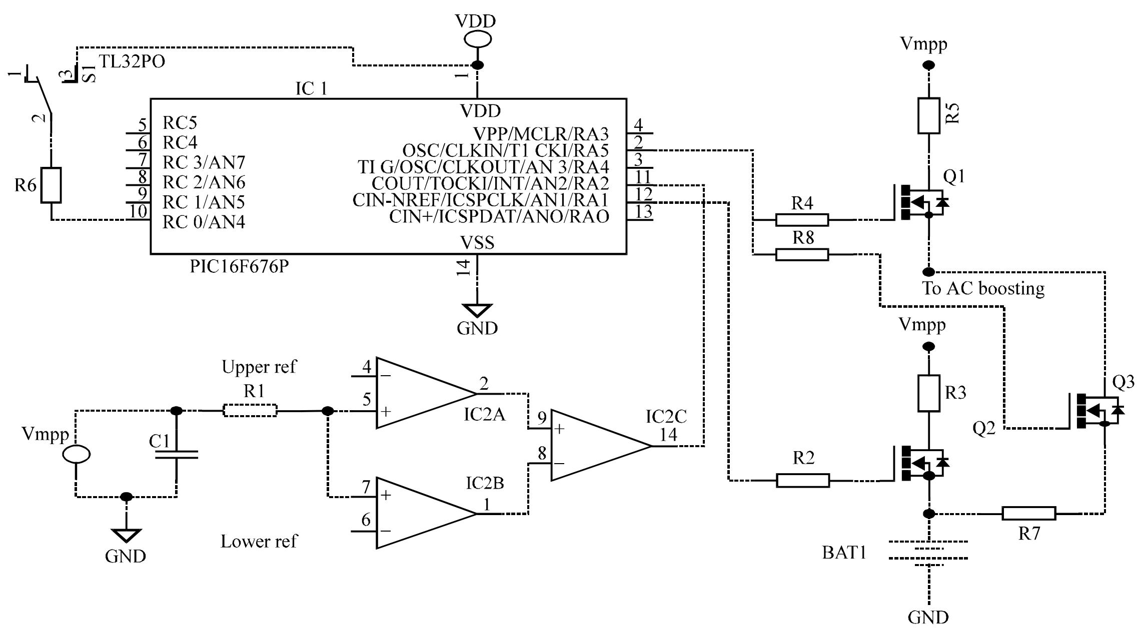

Fig. 5: Asheme of the proposed Maximum Power Point Tracking (MPPT)

RESULTS AND DISCUSSION

Inverter, DC-AC is very essential for most of the precise and sophisticated instruments and electrical and electronic systems to prevent a shutdown or damage or operation in case of power failure. Therefore, a single phase grid connected/standalone solar inverter topology has been proposed. The main goals of present study are as follows:

The chosen inverter topology comprises of push-pull action that eliminates the even harmonics. DC components of magnetomotive force acting on the output transformer core will cancel and core saturation will be eliminated the centre-tap transformer allow equal and opposite input voltages (Ryder, 1976). The use of increased loads and drives of 600 VA towards some KVS. The lower possible total harmonic distortion for the current (CTHD) recorded as 2.26% shown in Fig. 4. Introduction of most modern switching devices viz. Insulated Gate Bipolar Transistor (IGBT) with diode and modulation index 0.8. In this prototype simulation 12 V PV array gives the grid voltage of 500 V (peak). The topology would be suitable for any possible applications like Grid Connected/Standalone Solar System, IPS (Instant Power Supply) or UPS (Uninterrupted Power Supply). Constant Voltage (CV) Method based Maximum Power Point Tracking (MPPT) with microcontroller employed control algorithm.

CONCLUSION

Now-a-days, inverter topology is a very important research area in power electronics. In this context, a PWM based single phase Grid Connected/Standalone Solar inverter topology has been proposed. In this research:

- The design process was analytical and simulation
- Discrete PWM generator with internal 50 Hz signal and switching devices followed by a centre-tap transformer
- In PWM generator, a 1 V amplitude 50 Hz signal has been superimposed with the carrier frequency of 1080 Hz
- Thereafter these pulses are then applied to form variable-width pulses for gating action in the inverter (DC/AC) circuit
- A suitable L-C filter has been used to eliminate the harmonic content especially odd harmonics
- Performing Total Harmonic Distortion (CTHD) for output current is 2.26% (Fig. 4)
- The complete design has been analyzed and studied by Matlab/Simulink
- Microcontroller (PIC 16f676) based control algorithm has been employed with the Constant Voltage (CV) or Open Circuit Voltage Ratio method Maximum Power Point Tracking (MPPT)

REFERENCES

Arai, J., K. Iba, T. Funabashi, Y. Nakanishi, K. Koyanagi and R. Yokoyama, 2008. Power electronics and its application to renewable energy in Japan. IEEE Circ. Syst. Magaz., 8: 52-66.

Cai Y., Y. Jia and Y. Li, 2012. Circuit analysis of a single phase micro-photovoltaic inverter. Proceedings of the Asia-Pacific Power and Energy Engineering Conference, March 27-29, 2012, Shanghai, pp: 1-4.

Hohm, D.P. and M.E. Ropp, 2003. Comparative study of maximum power point tracking algorithms. Prog. Photovolt: Res. Appl., 11: 47-62.

Irwanto, M., Y.M. Irwan, G.N. Shasidharan, A.N. Syafawati and S.P. Hadi, 2012. Maximum voltage angle optimization of uninterruptible power supply on three-level transformer-less photovoltaic inverter. Proceedings of the International Conference on Innovation Management and Technology Research, May 21-22, 2012, Malacca, pp: 357-361.

Jain, S. and V. Agarwal, 2007. A single-stage grid connected inverter topology for solar PV systems with maximum power point tracking. IEEE Trans. Power Electron., 22: 1928-1940.

Oliveira, M.A.P. and M.B.R. Correa, 2012. Analysis of grid-tied single phase multilevel inverters powered by photovoltaic panels under partial shading conditions. Proceedings of the 3rd IEEE International Symposium on Power Electronics for Distributed Generation Systems, June 25-28, 2012, Aalborg, pp: 483-486.

Ryder, J.D., 1976. Engineering Electronics. 2nd Edn., McGraw-Hill, Kogakusha Ltd., Tokyo, Pages: 341.

Tung, Y.J.M., A.P. Hu and N.K. Nair, 2006. Evaluation of micro controller based maximum power point tracking methods using dSPACE platform. Proceedings of the Australian University Power Engineering Conference, December 10-13, 2006, Melbourne, Australia, pp: 1-5.