International Journal of Applied Research 2016; 2(12): 05-11

ISSN Print: 2394-7500
ISSN Online: 2394-5869
Impact Factor: 5.2
IJAR 2016; 2(12): 05-11
www.allresearchjournal.com
Received: 02-10-2016
Accepted: 03-11-2016

Sundaram A
Wolkite University,
Department of Electrical and Computer Engineering,
Wolkite, Ethiopia

Kibru Mesfin Germamo
Wolkite University,
Department of Electrical and Computer Engineering,
Wolkite, Ethiopia

Ashnafi Paulo's Forsido
Wolkite University,
Department of Electrical and Computer Engineering,
Wolkite, Ethiopia

Correspondence
Sundaram A
Wolkite University,
Department of Electrical and Computer Engineering,
Wolkite, Ethiopia

MPPT based power management system for parallel connected PV arrays using integrating buck-boost converter with single phase inverter

Sundaram A, Kibru Mesfin Germamo and Ashnafi Paulo's Forsido

Abstract
The increase in power demand is one of the major concerns in the power sector area. In the day to day operations it is difficult to meet out the power demands with the available resources using the conventional energy sources. In this aspect the demand has increased for renewable sources of energy to be utilized along with conventional systems to meet out the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid. Thus it can be used to power rural areas and provide portable operations where the availability of grids is very low. In order to tackle the present energy crisis one has to develop an efficient manner in which power has to be extracted from the incoming solar radiation. The power conversion mechanisms have been greatly reduced in size in the past few years. The objective of the paper is to develop a MPPT based power management system for parallel connected PV arrays by integrating buck-boost dc-dc converter with single phase inverter. This paper proposes a new method for the MPPT control of PV systems. This method uses perturb processes in search of the maximum PV output. In this technique, the controller adjusts the output voltage of the PV cell based on its instantaneous output power. The incremental conductance algorithm uses the slope of the power-voltage curve of the PV cell to determine the voltage reference. The derivative of the cell output power with respect to the cell output voltage at the MPP is zero. This method requires more computations relative to the P&O but may reach the MPP faster.

Keywords: Power management system, photovoltaic (PV array), maximum power point tracking, buck-boost converter

1. Introduction

Photovoltaic (PV) offers an environment friendly source of renewable energy. This way of power generation is relatively cost effective. The success of a PV application depends on the power electronics device that can extract sufficiently high power from the PV arrays to obtain the overall output power per unit at a low cost. The maximum power point tracking (MPPT) of the PV becomes a key control in the device operation for successful PV applications. Under different sunshine conditions it is difficult to determine the maximum amount of solar energy to be observed by the PV array. Hence it gives non-linear current voltage characteristics. The voltages of a solar cell primarily depend on the cell temperature and not on the solar irradiance. The connection of solar cells in series allows operating at different voltages.

The nonlinear current-voltage characteristic of PV cells is characterized with a unique MPPT, which is highly dependent on weather and load conditions. MPPT controllers are integrated with solar power systems to maximize the output power extracted from PV generator. Various MPPT techniques have been proposed including, perturbation and observation (P&O), incremental conductance, fractional open-circuit voltage, fractional short-circuit current, fuzzy logic controller, neural network, ripple correlation control, and dc link capacitor droop control.

2. Existing System

Many types of renewable energy, such as photovoltaic (PV), wind, tidal, and geothermal energy, have attracted a lot of attention over the past decade. The PV renewable energy is found to be more suitable and appropriate system for low-voltage dc-distribution with merits of clean, quiet, pollution free, and abundant. Fig.1 indicates a dc-distribution network with a power system, including renewable distributed generators (DGs), dc loads (lighting, air conditioner, and electric vehicle), and a bidirectional inverter in which two PV arrays with two maximum power point trackers (MPPTs) are implemented.

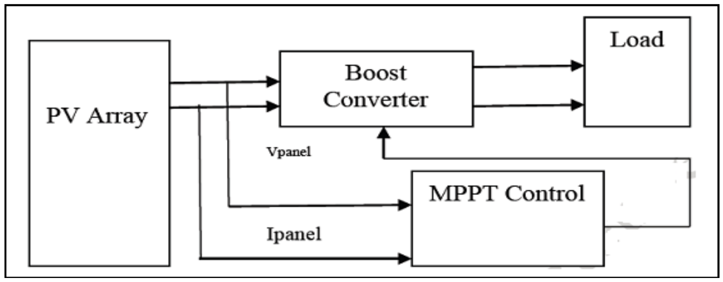

Fig 1: block diagram of MMPT

However, the i–v characteristics of the PV arrays are nonlinear, and they require MPPTs to draw the maximum power from each PV array. Moreover, the bidirectional inverter has to fulfil grid connection (sell power) and rectification (buy power)with power-factor correction (PFC) to control the power flow between dc bus and ac grid, and to regulate the dc bus to a certain range of voltages, such as 380 ± 10 V. Nowadays, a conventional two-stage configuration is usually adopted in the PV inverter systems. Each MPPT is realized with a boost converter to step up the PV-array voltage close to the specified dc-link voltage, as shown in Fig. 2

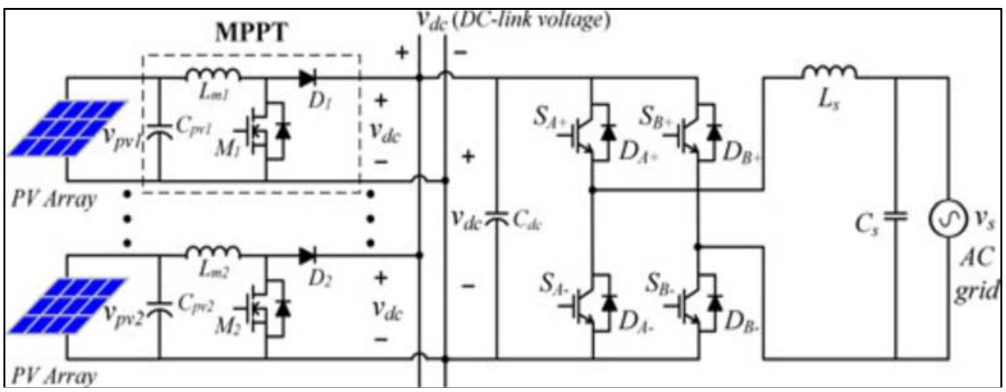

Fig 2: Conventional two-stage PV inverter system with boost-type MPPTs.

When the PV-array voltage is higher than the dc-link voltage, the boost converter is operated in by-pass mode, under this condition the inverter will function as an MPPT. Since the characteristics of PV arrays are different from each other, the inverter operated in by-pass mode cannot track each individual maximum power point accurately. More over the inverter suffers from as high-voltage stress, poor efficiency, increased complexity and low conversion efficiency.

3. Proposed System

An MPPT based power management system for parallel connected PV arrays by integrating buck-boost dc-dc converter with single phase inverter is shown in Fig.3. In the proposed system the output voltage of two PV arrays are individually boosted/bucked to a high voltage dc and interfaced to a dc bus. When the PV array voltage is less than the bus voltage, the boost operation is performed and when it is greater buck operation is performed.

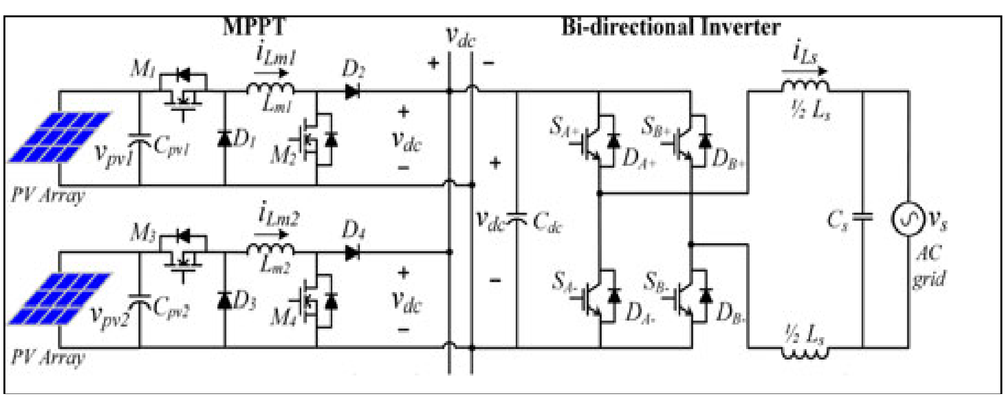

Fig 3: Configuration of the studied PV inverter system with the buck/boost MPPTs.

During boost operation, the LC-circuit with high quality factor (Q-factor) is employed to amplify the dc input voltage to the required high voltage level. The MOSFET power switch is used to make and break the high current pulse through the inductance. When current is made to flow through inductance, energy is stored and during break the stored energy is transferred to capacitance, which results in a high voltage across the capacitor. This is filtered and fed to dc-bus. During buck operation, the high voltage dc is chopped using a MOSFET that acts as a power switch which is connected in series with the source. The output results in a pulsating dc, is then filtered and fed to dc-bus. A bidirectional inverter is interfaced to the dc bus to transfer energy from dc bus to ac grid and vice versa.

3.1 Operation and analysis of the proposed buck/boost MPPT

The MMPT topology is formed with a buck/boost converter which is depicted in Fig. 4. The shared inductor is provided with wide PV array voltage from 0 to 600V. To obtain different performance the two MPPTS may be connected separately or in parallel. The MPPT senses PV voltage v_{PV}, dc-bus voltage vdc, and inductor current i_{Lm} to determine operational mode and duty ratio for tracking the maximum power point accurately.

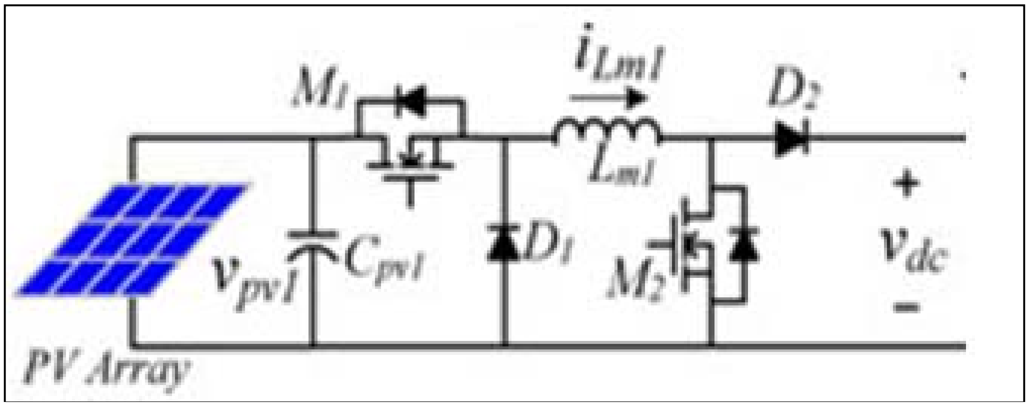

Fig 4: MPPT Buck Boost Converter

When voltage v_{PV} is higher than vdc, the MPPT is operated in buck mode, and switch M1 is turned ON to magnetize the inductor Lm and thus increase the inductor current i_{Lm}. While switch M1 is turned OFF, inductor Lm releases its stored energy through diodes D1 and D2.when voltage v_{PV} is lower than v_{dc}, the MPPT is operated in boost mode, and switches M1 and M2 are turned ON to magnetize the inductor Lm. While switch M2 is turned OFF, inductor Lm releases its stored energy through diode D2. Thus, the control laws can be expressed as follows:

$$d_{buck} = \frac{v_{dc}}{v_{PV}} (for\ buck\ mode) \quad (1)$$

$$d_{boost} = \frac{v_{dc} - v_{PV}}{v_{pv}} (for\ boost\ mode) \quad (2)$$

To draw maximum power from PV arrays, a perturbation and observation control algorithm for tracking maximum power points is adopted.

3.2 Introduction to perturb-and-observe (P&O) method

This is a common MPPT algorithm used in almost all the commercial PV product. The concept involves in the increased reference value to the inverter output and then detects the actual output power. If the actual output power is found to be increased then the reference value also increases until the actual output starts to decrease. To maintain a minimum power variation the perturb size is kept small. The PI controller used then moves the operating point to the particular voltage level. P&O flowchart is shown in Fig. 5.

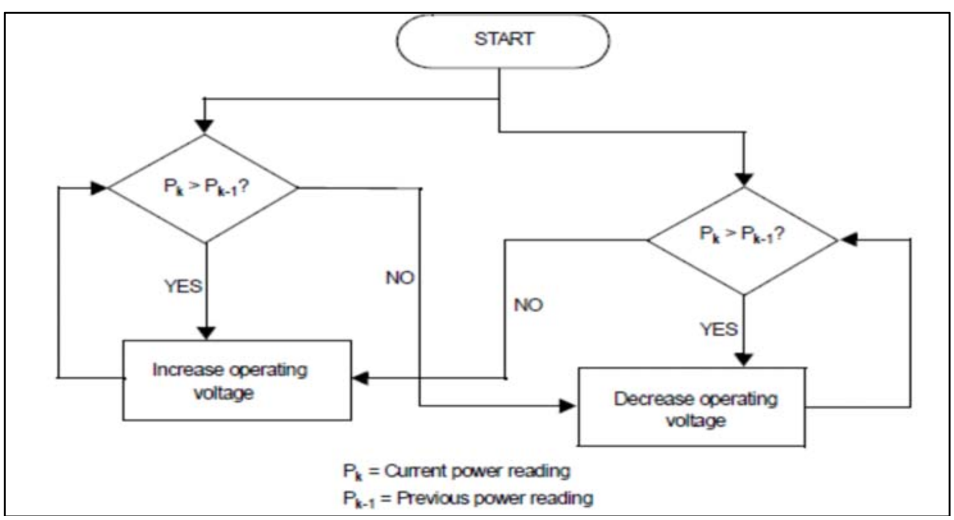

Fig 5: P & O Algorithm

3.3 Principle of P&O method

Perturb-and-observe (P&O) method is dominantly used in practical PV systems for the MPPT control due to its simple implementation, high reliability, and tracking efficiency. It shows the flow chart of the P&O method. The present power *P(k)* is calculated with the present values of PV voltage *V(k)* and current *I(k)*, and is compared with the previous power P(k-1). If the power is found to be increased then the next voltage change is to be in the same direction else in the opposite direction as shown in Fig. 6

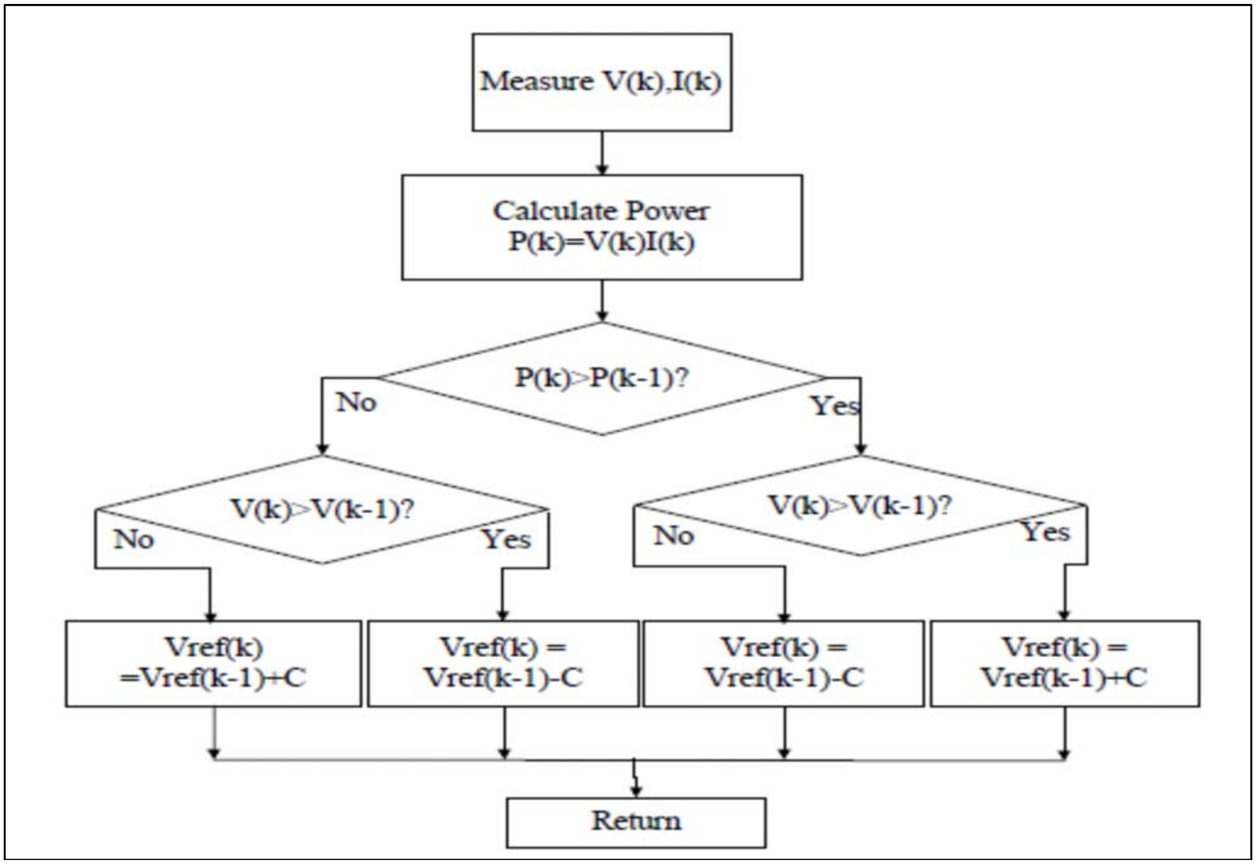

Fig 6: Principle method of P & O Algorithm

3.4 Perturbation and observation tracking method

In this study, based on the perturbation and observation tracking method the MPPT controller tracks the maximum output power from the PV array. The controller is authorised to determine the operation mode of the proposed MPPT. When the MPPT is operated in boost mode, inductor current iLm is equal to output current iPV of the PV array; thus, the output power of the PV array can be expressed as follows:

$$PPV\_boost(n) = v_{PV}(n) \times i_{Lm} \quad (3)$$

When the proposed MPPT is operated in buck mode, inductor current i_{Lm} is equal to output current; thus, the output power of the PV array can be expressed as follows:

$$PPV\_buck(n) = v_{dc}(n) \times i_{Lm}(n) \quad (4)$$

To track the peak power the controller used in the algorithm increases or decreases the duty cycle ratio. The controller will also update the duty ratio of the MPPT power stage every ten line cycles at the zero crossing of the line voltage. There is a shared auxiliary power supply for the MPPTs and the inverter for the shown PV inverter system. Since the switching frequencies of the MPPT (25 kHz) and the inverter (20 kHz) are different, it causes switching noise which might affect the accuracy of the voltage and current. To avoid noise interference, the MPPTs are synchronized with the inverter. When the output power of the PV arrays is determined accurately, the proposed controller can track the maximum power point precisely.

3.5 Buck–boost mode transition

Since the operation range of the dc-bus voltage is limited within 380 ± 20 V (including ripple voltage) in the dc distribution system, operational-mode transition between the buck and boost modes will be critical to control and also to accommodate a wide PV input voltage variation (0–600 V). When the proposed MPPT is operated in boost mode, the voltage Vpv is close to vdc, switch M2 is turned OFF and the duty ratio of switch M1 starts to decrease (–Δd) from 100%. With this control scheme, current iPV of the PV array will charge the input capacitor Cpv. To prevent mode fluctuation problems, the voltage vPV can be raised up to a higher level.

When the switch M1 is continuously turned ON, the duty ratio of switch M2 starts to increase (+Δd) from 0%, when vPV drops toward vdc during buck mode, the MPPT can achieve smooth mode transition by tuning the duty ratios of the active switches. A flowchart of the buck/boost mode transition scheme is shown in Fig. 7.

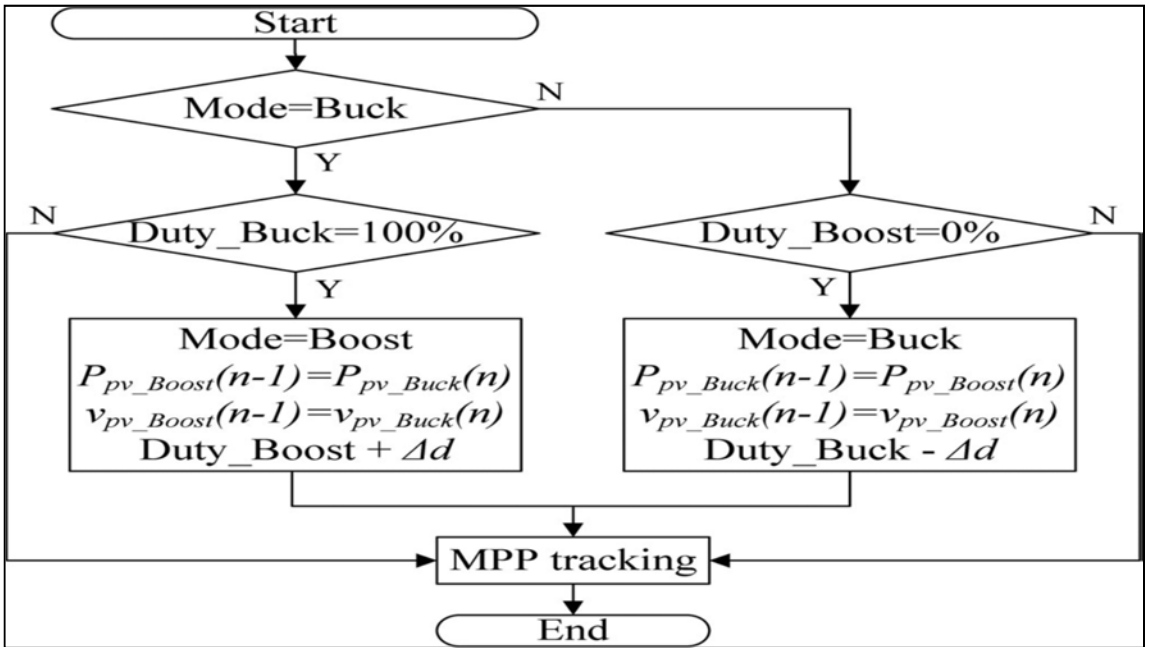

Fig 7: Flowchart of the buck/boost mode transition algorithm

3.6 Proposed PV inverter system

Functional Block diagram of an MPPT based power management system for parallel connected PV arrays by integrating buck-boost dc-dc converter with single phase inverter is shown in Fig 8. The V-I characteristic of PV array is nonlinear in which the voltage decreases with increase in current. The decrease in voltage is less until a peak point and after the peak point voltage decreases drastically. A considerable amount of output power is possible until the peak point and after then the power output is very low.

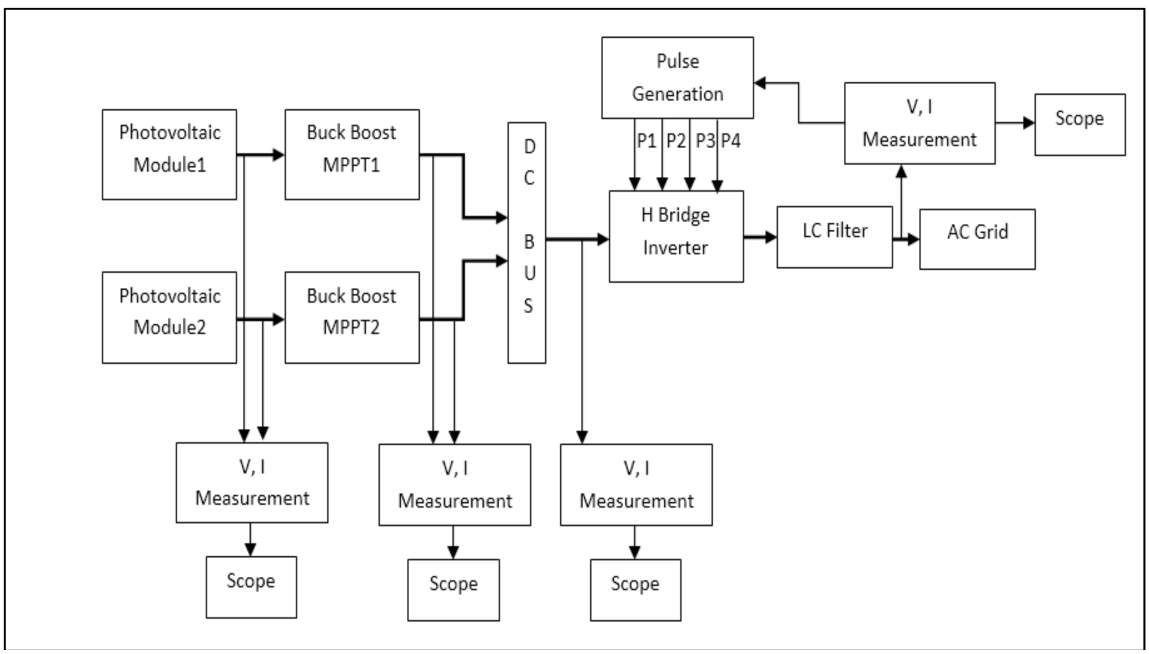

Fig 8: Proposed PV inverter system with the buck/boost MPPTs.

4. Simulation Results

In order to draw maximum power from PV panels a number of MPPT (Maximum Power Point Tracking) algorithms are developed, in which the power is drawn as long as the voltage is above peak value. When the voltage goes below peak value the PV array is disconnected for a small duration. Then the system is reconnected when the voltage is raised and attains a specific value which is above the peak value. In the proposed system the output voltage of two PV arrays are individually boosted/bucked to a high dc voltage and interfaced to a dc bus. When the PV array voltage is less than the bus voltage, boost operation is performed and when it is greater buck operation is performed.

During boost operation, a LC-circuit with high quality factor (Q-factor) is used to amplify the dc input voltage to a required high voltage level. Here, a MOSFET power switch is employed to make and break a high current pulse through the inductance. When current is made to flow through inductance, energy is stored in inductance and when this current is cut the stored energy in inductance is transferred to capacitance, which results in a high voltage across capacitor and this high voltage is filtered and fed to dc-bus.

During buck operation, the high dc voltage is chopped by using a MOSFET power switch connected in series with a source and then the resultant pulsating dc is filtered and fed to dc-bus.

A bidirectional inverter is also interfaced to dc bus which is used for energy transfer from dc bus to ac grid and vice versa. When the dc power is excess, the inverter is used to convert excess dc power to ac power and inject to grid, and when there is deficiency in dc power the inverter is used to convert ac power to dc power and supply to dc bus. The gate pulses, inverter voltages and currents are shown in Fig. 9 and Fig. 10

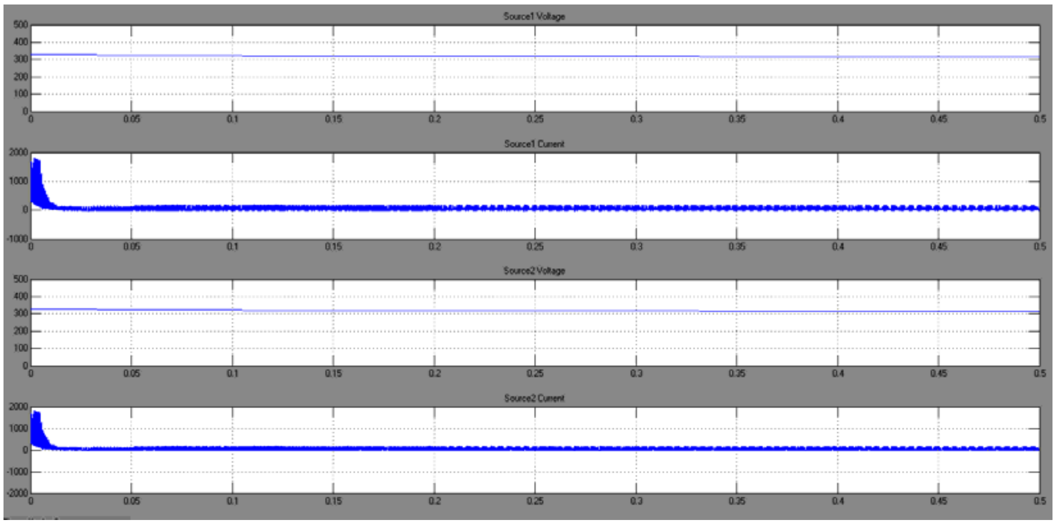

Fig 9: Gate pulses of photovoltaic buck boot converter

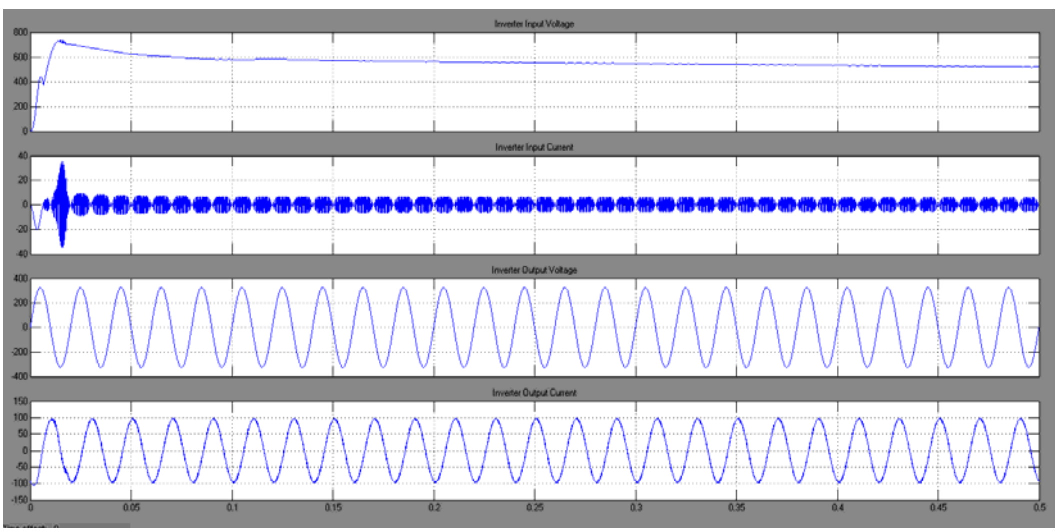

Fig 10: Inverter voltage and current

5. Conclusion

In the proposed work, a single-phase bidirectional inverter with two buck/boost MPPTs has been designed and implemented. The inverter controls the power flow between dc bus and ac grid, and regulates the dc bus to a certain range of voltages. A droop regulation mechanism according to the inductor current levels has been proposed to balance the power flow and accommodate load variation. Since the PV-array voltage can vary from 0 to 600 V, the MPPT topology is formed with buck and boost converters to operate at the dc-bus voltage around 400 V, reducing the voltage stress of its followed inverter. Integration and operation of the overall inverter system have been discussed in detail, which contributes to dc-distribution applications significantly. Simulation results are obtained from a single-phase bidirectional inverter with the two MPPTs.

6. References

1. Carrasco JM, Franquelo LG, Bialasiewicz JT, Galvan E, Guisado RCP, Ma AM *et al*. Power-electronic systems for the grid integration of renewable energy sources: a survey, IEEE Trans. Ind. Electron., 2006; 53(4):1002-1016,
2. Khanh LN, Seo JJ, Kim TS, Won DJ. Power-management strategies for a grid-connected PV-FC hybrid system, IEEE Trans. Power Deliv. 2010; 25(3):1874-1882.

3. Tan YK, Panda SK. Optimized wind energy harvesting system using resistance emulator and active rectifier for wireless sensor nodes, IEEE Trans. Power Electron., 2011; 26(1):38-50.
4. Kwon JM, Nam KH, Kwon BH. Photovoltaic power conditioning system with line connection, IEEE Trans. Ind. Electron., 2006; 53(4):1048-1054.
5. Selvaraj J, Rahim NA. Multilevel inverter for grid-connected PV system employing digital PI controller, IEEE Trans. Ind. Electron., 2009; 56(1):149-158.
6. Gao F, Li D, Loh PC, Tang Y, Wang P. Indirect dc-link voltage control of two-stage single-phase PV inverter," in Proc. 2009 IEEE ECCE, 2009, 1166-1172.
7. Nami A, Zare F, Ghosh A, Blaabjerg F. A hybrid cascade converter topology with series-connected symmetrical and asymmetrical diode clamped H-Bridge cells, IEEE Trans. Power Electron., 2011; 26(1):51-65.
8. Dwari S, Parsa L. An efficient high-step-up interleaved dc–dc converter with a common active clamp, IEEE Trans. Power Electron., 2011; 26(1):66-78.
9. Shen JM, Jou HL, Wu JC. Novel transformer less grid connected power converter with negative grounding for photovoltaic generation system, IEEE Trans. Power Electron., 2012; 27(4):1818-1829.
10. Kerekes TR, Teodorescu P, Rodriguez G, Vazquez, Aldabas E. A new high-efficiency single-phase transformerless PV inverter topology, IEEE Trans. Ind. Electron., 2011; 58(1):184-191.
11. Araujo SV, Zacharias P, Mallwitz R. Highly efficient single-phase transformerless inverters for grid-connected photovoltaic systems, IEEE Trans. Ind. Electron., 2010; 57(9):3118-3128.
12. Park JS, Choi JH, Gu BG, Jung IS, Lee EC, Ahn KS. "Robust dc-link voltage control scheme for photovoltaic power generation system PCS, in Proc. 31st Int. Telecommun. Energy Conf., 2009, 1-4.
13. Salomonsson D, Soder L, Sannino A. An adaptive control system for a dc microgrid for data centers, IEEE Trans. Ind. Appl., 2008; 44(6):1910-1917.
14. Azzouz MA, Elshafei AL. An adaptive fuzzy regulation of the dc-bus voltage in wind energy conversion systems, in Proc. IEEE Int. Conf. CCA, 2010, 1193-1198.
15. Kakigano H, Nishino A, Miura Y, Ise T. Distribution voltage control for dc microgrid by converters of energy storages considering the stored energy, in Proc. IEEE ECCE, 2010, 2851-2856.
16. Hur N, Jung J, Nam K, A fast dynamic dc-link power-balancing scheme for a PWMconverter-inverter system, IEEE Trans. Ind. Electron, 2001; 48(4):794-1803.
17. Yao J, Li H, Liao Y, Chen Z. An improved control strategy of limiting the dc-link voltage fluctuation for a doubly fed induction wind generator, IEEE Trans. Power Electron., 2008; 23(3):1205-1213.
18. Wu TF, Sun KH, Kuo CL, Chang CH. Predictive current controlled 5 kW single-phase bi-directional inverter with wide inductance variation for DC-microgrid applications, IEEE Trans. Power Electron., 2010; 25(12):3076-3084.
19. Middlebrook RD. Small-signal modeling of pulse-width modulated switched-mode power converters, in Proc. IEEE. 1988; 76(4):343-354.
20. Zhang MT. Powering Intel Pentium 4 Generation Processors, in Proc. Intel Technol. Symp. 2001, 215-218.