International Journal of Latest Engineering and Management Research (IJLEMR)
ISSN: 2455-4847
www.ijlemr.com || REETA-2K16 ǁ PP. 499-507

High-Performance of Stand-Alone Solar PV System with Implementation of High-Gain Dc-Dc Converters

K.Shobharani[1],A.Haritha[2]
[1]*(M.TECH (P.E),VEMU Institute of Engineering and Technology / JNTU A, INDIA*
[2]*(Assistant Professor, Department of EEE, VEMU Institute of Engineering and Technology / JNTU A, INDIA)*

ABSTRACT *:* This paper proposes a novel 3φ stand-alone solar photovoltaic (PV) system configuration that uses high-gain high efficiency (≈96%) dc–dc converters both in the forward power stage and the bidirectional battery interface. The high-voltage gain converters enable the use of low-voltage PV and battery sources. This results in minimization of partial shading and parasitic capacitance effects on the PV source. Series connection of a large number of battery modules is obviated, preventing the overcharging and deep discharging issues that reduce the battery life. In addition, the proposed configuration facilitates "required power tracking (RPT)" of the PV source as per the load requirements; eliminating the use of expensive and "difficult to manage" dump loads. High-performance inverter operation is achieved through abc to dq reference frame transformation, which helps in generating precise information about the load's active power component for RPT, regulation of ac output voltage, and minimization of control complexity. Inverter output voltage is regulated by controlling the modulation index of sinusoidal pulse width modulation, resulting in a stable and reliable system operation. The active power demand is controlled by regulating the dc link voltage. All the analytical, simulation with fuzzy analysis results of this work is presented.

KeyWords: Energy conversion, high-gain dc–dc converter, inverters, maximum power point tracking (MPPT), photovoltaic (PV) cells

I.INTRODUCTION

In the use of nonconventional energy Sources, photovoltaic (PV) installations are being increasingly employed in several applications, such as distributed Power generation and stand-alone systems. However, a major Challenge in using a PV source is to tackle its nonlinear output Characteristics, which vary with temperature and solar Insolation. The characteristics get more complicated if the entire Array does not receive uniform Insolation, as in partially cloudy (shaded) conditions, resulting in multiple peaks. The presence of multiple peaks reduces the effectiveness of the existing maximum Power point tracking (MPPT) schemes [1]–[3] due to their inability to discriminate between the local and global peaks. Nevertheless, it is very important to understand and predict the PV characteristics in order to use a PV installation effectively, under all conditions.

Photovoltaic systems have become an energy generator for a wide range of applications. The applications could be standalone PV systems or grid connected PV systems. A standalone PV system is used in isolated applications where PV is connected directly to the load and storage system. With a standalone photovoltaic, when the PV source of energy is very large, having energy storage is beneficial. Where as a PV system that is connected through a grid is used when a PV system injects the current directly into the grid itself. The advantage of the grid-connected system is the ability to sell excess of energy.

Now a day the population was increasing day by day, at the same way the industries are also increasing. So the demand for power is also increasing. As the conventional sources of energy are depleting and the cost of energy was rising day by day. In order to minimize the cost and to generate the power the alternative sources of energy are non conventional energy sources. Among the various sources of non conventional energy sources, PV is a promising source [1]. Since the power from sun is depends on the irradiation and weather conditions. So MPPT plays an important role in the PV system [1]–[3] and the generated maximum power is deliver to the grid through an inverter [4]–[6]. The output power of PV units is not constant during a day; it varies with changes in atmospheric conditions so robustness is essential.

In a grid connected PV System the control objectives are met by using PWM technique. It consists of two cascaded control loops [7]. The inner current control loop is used to maintain the power quality, to control the duty ratio for the generation of sinusoidal output current and the outer control loop is voltage control loop which is used to track the MPP. Normally current controllers are used in tracking method. Normally to operate the PV systems at MPP nonlinear controllers are used [8]–[13]; but they do not account for the uncertainties in the PV system. But there is more development in the field of control theory and robust linear controllers for linear systems in the presence of uncertainties through the control scheme which is often obtained from linear matrix inequality (LMI) methods [14], [15] from the last few years. A feed forward approach is proposed to control the dc-link voltage and current, and the robustness is achieved by modal analysis [16]. The controller design methods as presented in [8]–[13] and [16]–[17] are based on linearized models of nonlinear PV systems. Normally, PV systems are time varying in nature.

A nonlinear proportional-integral (PI) controller is presented in [19] to overcome the drawbacks of linear controllers, where improved performance is reported. A Lyapunov-based control scheme for a grid connected PV inverter is presented in [20] where an adaption law is included to improve the robustness. However, it is well known that the adaption technique is useful for systems with slow parameter variations which are not the case for PV systems as the changes occur rapidly. A sliding mode controller for a nonlinear grid-connected PV system is proposed in [21] and [22] along with a new MPPT technique for providing robust tracking against uncertainties and unknown disturbances within the system. The performance of the sliding mode controller is confined to the sliding surface which is constructed from a linear combination of output injected errors.

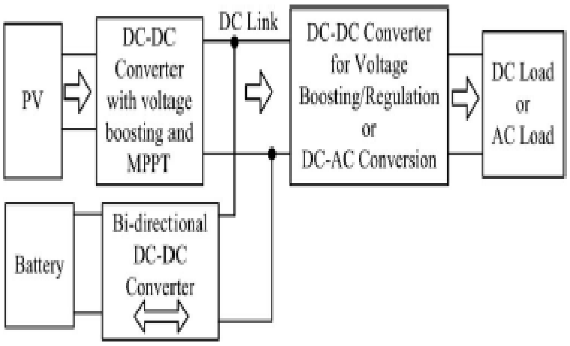


Fig.1. Simplified block diagram of a two-stage stand-alone PV system

Fig. 1 shows a typical power conversion configuration for a stand-alone PV system [1]–[3]. The forward power path from solar PV source to the load typically consists of two stages, as shown. The battery backup is interfaced with the dc link through a bidirectional dc–dc converter. Although such systems have been used extensively, they suffer from the following shortcomings.

1) Large voltage PV source poses problems such as follows.

a) There are safety issues (e.g., high dc voltage arcing) [4] and parasitic capacitance issues.

b) The mismatch and partial shading effects become more pronounced when long PV module strings are used [5].As the required load voltage is usually much higher (e.g., 230 and 440 V), the PV voltage must be boosted substantially. The conventional dc–dc converters (e.g., boost and buck–boost) offer high voltage gain at the cost of reduced efficiency.

2) Another major issue with stand-alone solar PV systems arises due to the dependence of PV source on solar irradiance. Not only that the solar radiation is not available during the nights, but passing clouds can also block it during the daytime. In order to maintain an uninterruptible power supply to stand-alone loads [6], use of battery energy storage system (BESS) is essential for stand-alone applications. A PV system, along with battery backup [7], becomes a reliable source that can maintain continuous supply to the load. Another major challenge with PV systems is the tracking of maximum power point (MPP) on the PV characteristics. In stand-alone systems, maximum power point tracking (MPPT) is possible only if battery backup is present.

A battery is needed to store the excess energy generated through MPPT, which the stand-alone load is unable to consume. Although batteries help, as described earlier, they themselves raise some problems as follows.

a) Batteries need regular maintenance.

b) For realizing high battery voltage, many battery units must be connected in series. This may cause overcharge and deep discharge problems leading to shedding of active material or sulphation of the battery, reducing the battery life [8]–[14]. The number of operating cycles decreases with increasing depth of discharge (DOD). The relationship between “capacity” and “number of cycles” for a lead acid battery with different values of DOD is shown in the plots given in Fig. 2(a). The number of cycles versus DOD is plotted and in Fig. 2(b) and clearly highlights reduction in battery life with higher DOD.

c) To prevent battery overcharging due to MPPT, installation of dump loads may be necessary. However, dump loads cause wastage of energy, and their regulation may get quite complex

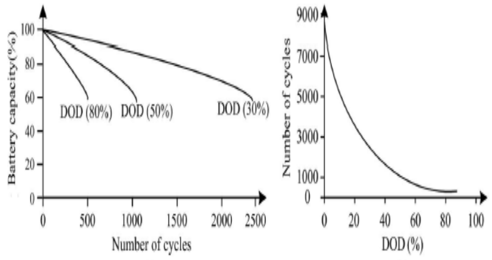


Fig.2. Effects of different parameters on battery.
2(a) Battery capacity versus number of cycles with DOD as parameter
2(b) Number of cycles versus DOD.

3) Most of the existing stand-alone ac systems do not give sufficient importance to the control and performance of the load-side inverter. They rely on simple ac voltage regulation. These controllers suffer from poor dynamic response during load variation and are, in general, not robust. Designing controllers for the control of ac quantities has several issues [17] and increases the controller complexity. Due to this reason, it is imperative to implement *abc* to *dq* transformation that results in dc quantity control [18]. Furthermore, it is also easier to handle load imbalance in the *dq* frame.

II. PROPOSED SYSTEM

Fig. 3 shows the proposed power conditioning unit considered for this work. It consists of a high-gain high-efficiency dc–dc converter, followed by a voltage source inverter in the main power stage. Battery storage is interfaced with the dc link through a high-gain high-efficiency bidirectional dc–dc converter. A 3φ H-bridge inverter feeds power into the standalone ac load. The flow of desired active power is sustained by maintaining the dc link voltage constant through the battery.

Tracking is the most important part performed by a coordinated control system in the power smoothing process.

RPT or Required Power Tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature. Hence the amount of solar power radiation requires to track is essential which is not too much lower or higher.

RPT acts as a controller with suitable voltage regulation. A RPT solar charge controller is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module.RPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery. A BESS is interfaced through another high-gain high efficiency bidirectional converter. In conjunction with RPT, the battery charge is strictly regulated to ensure its life. The control strategy proposed in this paper ensures fast transient response, low harmonics, and small steady-state errors with a simple and compact control.

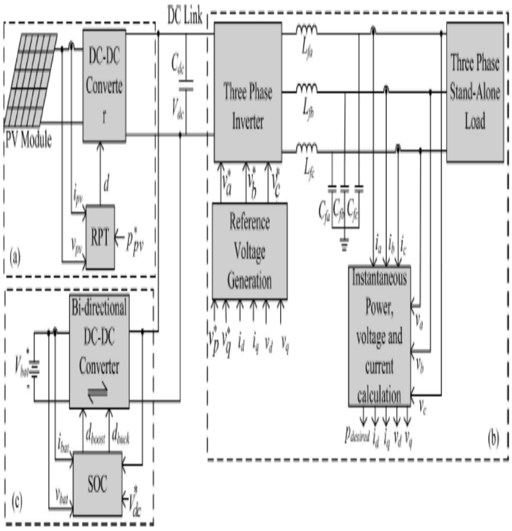


Fig. 3 .Block diagram showing the complete system and the control signals.

The two control techniques that are used in grid connected system are voltage control and current control. PV inverters inject energy directly into the grid and are controlled as power sources i.e. the PV inverters inject a "constant" power into the grid at a power factor nearer to unity. The control system constantly monitors power extracted from the PV array and adjusts the magnitude and phase of the ac voltage (in voltage control mode) or current (in current control mode) to export the power extracted from the PV array.

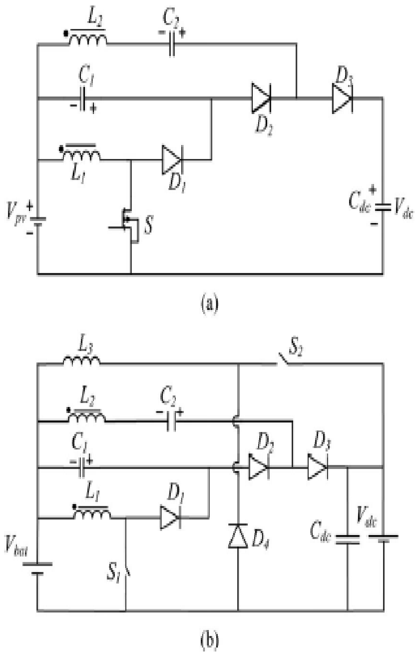
Voltage control

A voltage controlled inverter produces a sinusoidal voltage at the output. It can be used in standalone operation supplying a local load. If non-linear loads are connected within the rating of the inverter, the inverter's output voltage remains sinusoidal and supplies non sinusoidal current as demanded by the load. Since it is a voltage controlled source it cannot be directly connected to the grid and therefore it is connected via an inductance. With respect to grid voltage the voltage of inverter are controlled in magnitude and in phase. The inverter voltage is usually controlled by controlling the modulation index and this controls the reactive power. The phase angle of the inverter may be controlled with respect to the grid which controls the active power.

Current control

A current controlled inverter produces a sinusoidal current at output. It is only used for injection into the grid and not for standalone applications. The output is generated using a sinusoidal reference which is phase locked to the grid voltage. The output stage is switched so that the output current follows the generated sinusoidal reference. The reference waveform may be varied in amplitude and phase with respect to the grid and the output current automatically follows the reference.

The output current waveform is ideally not influenced by the grid voltage waveform quality and always produces a sinusoidal current. The current controlled inverter is inherently current-limited because the current is tightly controlled even if the output is short circuited.



(a)

(b)

Fig.4. (a) High-gain high-efficiency dc–dc converter
(b) High-gain High-efficiency bidirectional converter

A system that accepts input from any dc source (PV, battery, etc.) to convert into high-voltage ac output has been proposed by Ray *et al.* [23]. It consists of a bidirectional quadratic boost converter-based voltage source inverter. However, the system is silent on the management of excess PV power vis-à-vis battery life due to overcharging and discharging. Amirabadi *et al.* [24] have proposed a stand-alone PV system based on a multiport high-frequency ac link inverter. The high-frequency ac link reduces the harmonics in the ac output current of the inverter. A drawback of the system is the use of relatively high PV and battery voltage. Another stand-alone PV system with battery backup, based on a novel three-port dc–dc converter has been proposed by Chen *et al.* [25] for dc loads. The advantage of this system is that low-voltage PV and battery can be used, integrated through the same high-gain converter. However, the control flexibility is low because of the complexity of the converter. Caracas *et al.* [26] have proposed a battery less standalone solar PV system for water pumping application using a high-voltage-gain dc–dc converter stage in the system. In accordance with the ongoing discussion, this paper presents a novel configuration that overcomes the stand-alone PV systems' drawbacks described in the preceding paragraphs.

The proposed two-stage PV power conversion system for standalone ac loads has the following features.

1) It has a novel front-end dc–dc power conversion stage with high voltage gain capability. In spite of the required high voltage gain (40–400 V, i.e., a gain of ≈ 10), the efficiency (≈ 96%) is not compromised. A conventional dc–dc converter would give much lower efficiency for this kind of gain.

2) The front-end dc–dc stage is capable of performing both electrical MPPT and the required power tracking (RPT) of the PV source depending on the load requirement and the battery state of charge (SOC). RPT capability obviates the dump load requirement.

3) A BESS is interfaced through another high-gain high efficiency bidirectional converter. In conjunction with RPT, the battery charge is strictly regulated to ensure its life.

4) The control strategy proposed in this paper ensures fast transient response, low harmonics, and small steady-state errors with a simple and compact control.

5) This system can be easily upgraded to higher power rating by interfacing additional renewable energy sources with the dc link.

In Fig: 4. It consists of a coupled inductor$(L_1 \parallel L_2)$, a passive clamp network (C_1,D_1), and an intermediate energy storage capacitor (C_2), which helps to increase voltage gain without the need for an exorbitantly high duty cycle. The high voltage at the dc link (V_{dc} in Fig. 4.2) is achieved by the voltage step-up property of the coupled inductor $(L_1 \parallel L_2)$. The leakage energy of the coupled inductor is recovered by the passive clamp network (C_1,D_1). The voltages of the coupled inductor and the clamp capacitor are added to charge the intermediate energy storage capacitor (C_2), which results in a significant increase of the output voltage (i.e., high voltage gain).The voltage gain expression for this converter is derived by applying volt-second balance across $L1$ as follows:

$$V_{L1(ON)}d + V_{L1(OFF)}(1-d) = 0.$$

The expression for the voltage gain of this converter is given by

$$m = \frac{V_{dc}}{V_{PV}} = \frac{n+1}{1-d}$$

Where V_{dc} is the output voltage of the high-gain converter, V_{PV} is the input voltage to the converter (= PV output voltage),n is the number of turns in the coupled inductor, and d is the duty cycle of the converter switch. The voltage across the clamp capacitor C_1 (due to recycled energy from the leakage inductor) and the voltage across the switch (S) can be derived as follows:

$$V_{C1} = \frac{d}{1-d}V_i$$

$$V_{DS} = \frac{V_i}{1-d}$$

The high efficiency in the converter is achieved due to the following:

1) Low losses in the switch (low conduction loss, low switching loss due to zero voltage switching),

2) Energy recovery from leakage inductance,

3) Operating the converter at nominal duty cycle. The efficiency of the converter is around 96%, which increases the overall efficiency of the stand-alone system.

The RPT of the PV source is implemented by varying the duty cycle of the switch (S) of the converter as per the RPT algorithm described in the next section. RPT also contributes to the increased efficiency of the system. The circuit schematic of the bidirectional converter used in the battery interface is shown in Fig. 4.2(b). This high-gain high efficiency bidirectional converter is an extension of the high gain converter in Fig. 4.2(a). Bidirectional property is achieved by incorporating the buck feature by adding an inductor (L_3), a switch (S_2), and a diode (D_4).The block diagram of the battery interface with the dc link through this bidirectional converter is shown in Fig.3.This converter can conduct power in both directions. While supplying power from the battery to the dc link (i.e., battery discharge), it works in boost mode. On the other hand, during the charging of the battery, i.e., flow of power from the dc link toward the battery, it works as a buck converter. The duty cycles of the converter during the buck and boost modes are denoted by d_{buck} and d_{boost}, respectively.

The control scheme of the bidirectional dc–dc converter maintains the SOC level of the battery between SOC_{min} < SOC <SOC_{max} based on the reference load power and the PV generated power. The expression for voltage gain of this converter, when the battery supplies power to the dc link, is given by

$$\frac{V_{dc}}{V_{bat}} = \frac{n+1}{1-d_{boost}}$$

Where V_{bat} denotes the battery voltage. During charging of the battery, the voltage gain of the converter is given by

$$\frac{V_{bat}}{V_{dc}} = d_{buck}$$

The efficiency in the boost mode is observed to be around 96%, where as in the buck mode, it is around 94%.

III.SIMULATION ANALYSIS

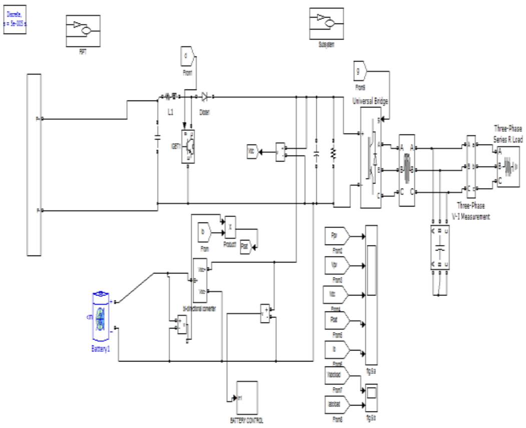
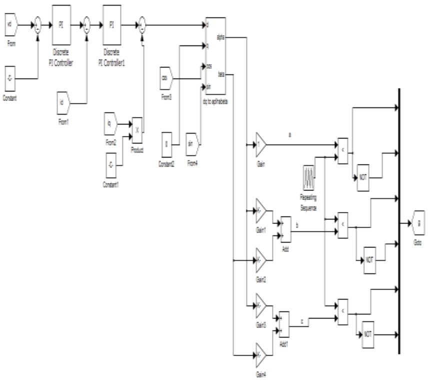


Fig. 5 .Block diagram showing the complete system and the control signals.



I.
Fig.6 .simulation subsystem showing the complete system and the control signals.

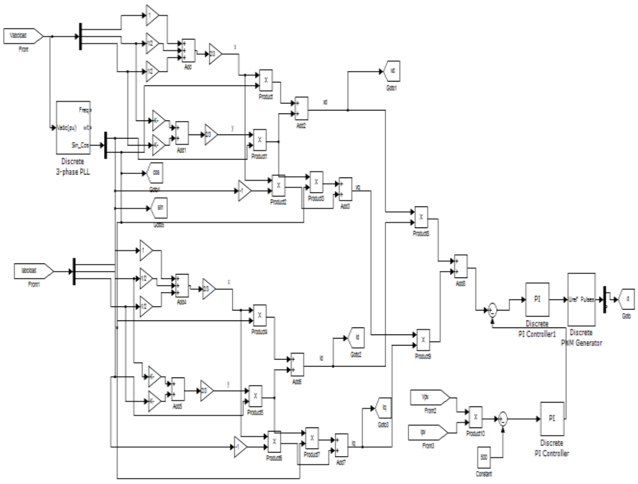


Fig. 7 .simulation RPT showing the complete control system.

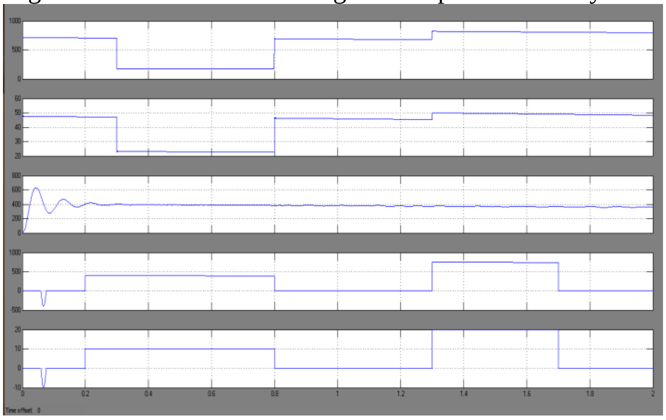


Fig. 8. (a)Simulation results of the proposed system during the sequence of events considered

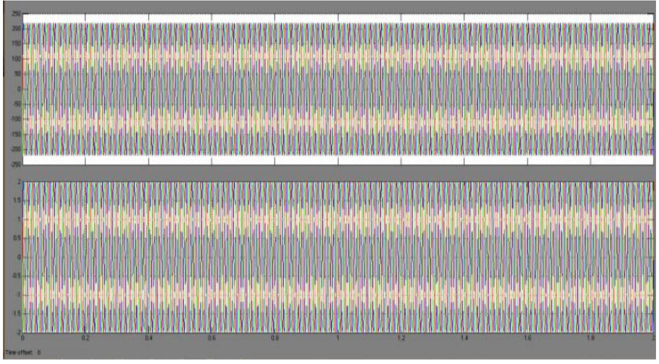


Fig. 8. (b)Simulation results of the proposed system across load

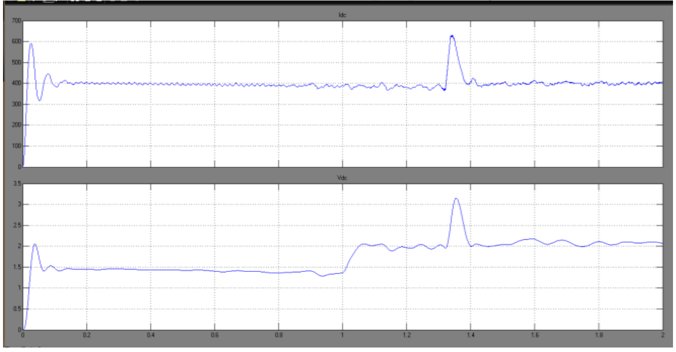


Fig. 9(a).Dynamic Response to step change in effective load

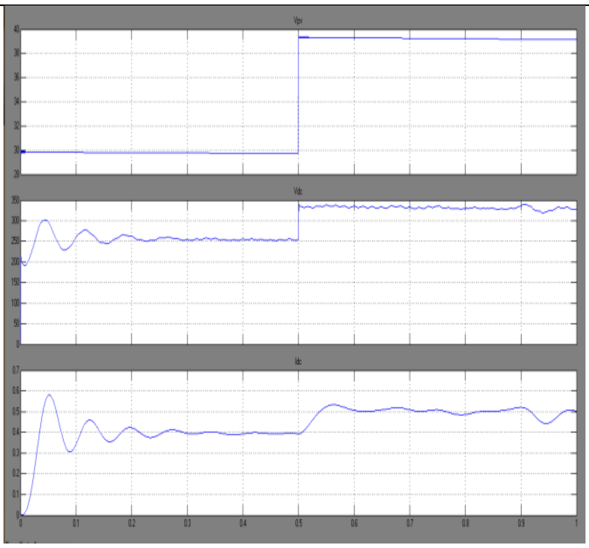


Fig. 9(b).Dynamic Response to step change in reference dc link voltage

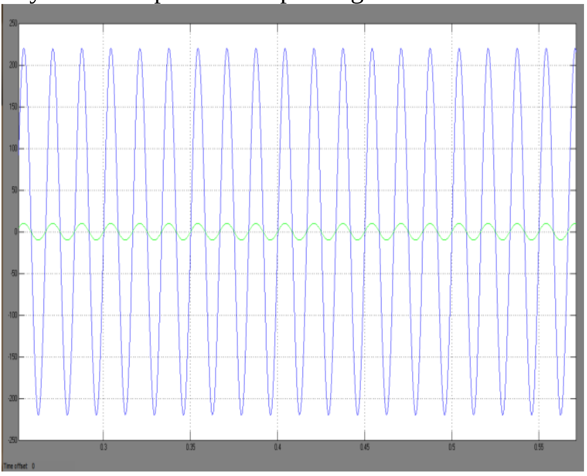


Fig. 10. Output of grid-connected system (only one phase is shown for clarity).

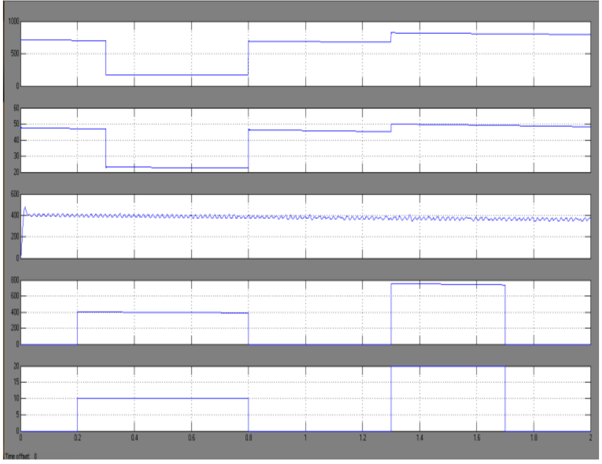


Fig. 11 Simulation results of the proposed system with fuzzy

The proposed control scheme was simulated in MATLAB/Simulink software. It was analyzed that when compare to traditional controller fuzzy dynamic response has high performance.

IV. CONCLUSION

This paper has described and implemented a novel $3 - \emptyset$ solar PV inverter system for stand-alone applications. Considering that high PV side voltage leads to several drawbacks, a low voltage PV source is used in the system. The limitation of low-voltage PV source is overcome by using a special high voltage-gain front-end dc–

dc converter capable of operating at high efficiency and MPPT. The proposed scheme is particularly conducive to long battery life by as it ensures no battery overcharge or deep discharge. For this purpose, the conventional MPPT scheme is replaced by RPT, which ensures that only the required power is tracked from the PV source. This prevents the drawing of excess power from the PV source and the use and management of expensive "dump" loads. Not only the main power stage but also the battery interfacing bidirectional stage also supports high voltage gain with high efficiency. Due to the use of special high-gain high-efficiency converters in the power stage, the overall efficiency of the system is 94%. Preliminary investigations have yielded encouraging results. The capacity of the proposed control strategy can be enhanced for high-power operation by interfacing other renewable sources (fuel cell stack, wind, etc.) to the dc link of the proposed system without significantly altering the control strategy. A comparison of some of the existing control techniques for stand-alone systems with the proposed control scheme stand-alone systems with the proposed control scheme and fuzzy outputs are simulated.

REFERENCES

[1] S. R. Bhat, A. Pittet, and B. S. Sonde, "Performance optimization of induction motor-pump system using photovoltaic energy source," *IEEE Trans. Ind. Appl.*, vol. IA-23, no. 6, pp. 995–1000, Nov. 1987.

[2] S. Duryea, S. Islam, and W. Lawrence, "A battery management system for standalone photovoltaic energy systems," in *Conf. Rec. 34th IEEE IAS Annu. Meeting*, Phoenix, AZ, USA, Oct. 1999, vol. 4, pp. 2649–2654.

[3] M. Uzunoglu, O. C. Onar, and M. S. Alam, "Modeling, control and simulation of a PV/FC/UC based hybrid power generation system for stand-alone applications," *Renew. Energy*, vol. 34, no. 3, pp. 509–520,Mar. 2009.

[4] R. M. Cuzner and G. Venkataramanan, "The status of dc micro-grid protection," in *Conf. Rec. IEEE IAS Annu. Meeting*, Oct. 2008, pp. 1–8.

[5] P. Sharma and V. Agarwal, "Exact maximum power point tracking of grid-connected partially shaded PV source using current compensation concept," *IEEE Trans. Power Electron.*, vol. 29, no. 9, pp. 4684–4692,Sep. 2014.

[6] S. Duryea, S. Islam, and W. Lawrance, "A battery management system for stand-alone photovoltaic energy systems," *IEEE Ind. Appl. Mag.*, vol. 7,no. 3, pp. 67–72, Jun. 2001.

[7] D. Fuente, C. L. T. Rodriíguez, G. Garceraá, E. Figueres, and R. O. Gonzalez, "Photovoltaic power system with battery backup with grid-connection and islanded operation capabilities," *IEEE Trans. Ind.Electron.*, vol. 60, no. 4, pp. 1571–1581, Apr. 2013.

[8] C. S.Moo, K. S. Ng, and Y. C. Hsieh, "Parallel operation of battery power modules," *IEEE Trans. Energy Convers.*, vol. 23, no. 2, pp. 701–707, Jun. 2008.

[9] S. T. Hung, C. D. Hopkins, and C. R. Mosling, "Extension of battery life via charge equalization control," *IEEE Trans. Ind. Electron.*, vol. 40,no. 1, pp. 96–104, Feb. 1993.

[10] R. D. López, J. M. L. Rojas, and J. L. B. Agustín, "Comparison of different lead-acid battery lifetime prediction models for use in simulation of stand-alone photovoltaic systems," *Appl. Energy*, vol. 115, pp. 242–253,Feb. 2014.