Advance in Electronic and Electric Engineering.
ISSN 2231-1297, Volume 3, Number 2 (2013), pp. 193-204

http://www.ripublication.com/aeee.htm

Experimental Results of Photovoltaic Powered Induction Motor Drive for Pumping

K. Vijaya Bhaskar Reddy[1] and G.V. Siva Krishna Rao[2]

[1]*Research Scholar, Andhra University, waltair, A.P, India.*
[2]*Professor, Dept. of Electrical Engineering, Andhra University, Waltair, A.P, India.*

Abstract

A pumping system powered from Photovoltaic array is modeled and simulated using Matlab Simulink. Detailed evaluation of energy processing in Photovoltaic pumping system is presented. A low voltage DC is stepped by using DC to DC Push -Pull converter. DC output from the PV Cell is converted into high frequency AC using a Push Pull Inverter. This is stepped up to 200v using a high frequency steps up transformer. The output of step up transformer rectified using an uncontrolled rectifier. The DC is converted into three phase AC using inverter. Variable voltage variable frequency AC is applied to the Induction motor. This drive has advantageous like utilization of non-conventional energy and improved efficiency. The experimental results are compared with simulation results.

1. Introduction

Photovoltaic technology is one of the most promising for distributed low-power electrical generation. The steady reduction of price per peak watt over recent years and the simplicity with which the installed power can be increased by adding panels are some of its attractive features. Among the many applications of photovoltaic energy, pumping is one of the most promising. In a photovoltaic pump-storage system, solar energy is stored, when sunlight is available, as potential energy in a water reservoir and consumed according to demand. There are advantages in avoiding the use of large banks of lead-acid batteries, which are heavy and expensive and have one-fifth of the lifetime of a photovoltaic panel. It is important, however, that the absence of batteries does not compromise the efficiency of the end-to-end power conversion chain, from panels to mechanical pump. A typical configuration of a battery less photovoltaic pumping system is shown in Fig. 1. The system comprises of the following components: 1) photovoltaic panels; 2) DC/DC converter; 3) DC/AC Inverter; 4) Induction motor; and 5) Centrifugal pump. The design of an effective photovoltaic pumping system without the use of a battery bank represents a significant challenge. It is necessary to deal with the effect of the stochastic nature of solar installation on the entire energy conversion chain, including the nonlinear characteristics of photovoltaic panels, Boost converter and the electromechanical power conversion device. In general terms, it is necessary to obtain the best performance from each system component over a wide input power range. Photovoltaic panels require specific control techniques to ensure operation at their maximum power point (MPP). Impedance matching issues mean that photovoltaic arrays may operate more or less efficiently, depending on their series/parallel configuration [1], [2]. In this paper, a minimum number of series connections are adopted. This means that a relatively high dc voltage gain (between six and ten) is necessary to provide the drive voltage required by the induction motor. The proposed system uses a push–pull converter and is based on the solution presented in [3]. The choice for this specific DC/DC converter topology is basically dictated by the requirement for galvanic isolation between the low- and high-voltage sides. Such a requirement precludes the use of low-cost and high-efficiency converter topologies [4]–[6]. A study of how the converter topology affects the MPP tracking (MPPT) of a photovoltaic system is reported in [7] and [8]. In addition to its voltage-boosting function, required for load matching, the DC/DC converter implements MPPT for the photovoltaic array. Several MPPT methods have been described in the technical literature [2], [9]. The above literature does not deal with modeling and simulation of PV Powered Induction motor drive. This work proposes PV Cell for the control of Induction motor.

2. Voltage Boost

The DC/DC converter boosts the photovoltaic panel voltage up to the value required to drive an off-the-shelf induction motor. This is needed to accommodate the requirement that relatively few photovoltaic panels be connected in series. The push–pull converter topology ensures galvanic isolation between input and output voltages, as well as provides the required voltage gain. The basic circuit diagram of the step-up converter is shown in Fig.2. The operation of this converter relies on the time intervals in which power switches q_a and q_b conduct. Fig. 3 shows a typical switching pattern for one period T. In this figure, D denotes the duty cycle defined by

$$D = Ton/T \tag{1}$$

Where T_{on} corresponds to the total time interval that both Switches conduct (T_{on}=DT). The output voltage (E) depends on the input voltage (V), the duty cycle (D), and the high-frequency transformer turns ratio (n), i.e.,

$$E = [n/1 - D]\ V \tag{2}$$

When designing a push–pull converter, it is convenient to select the transformer turns ratio n such that duty cycle D does not vary in a wide range. At the same time, high values for n should be avoided to ensure that the pulse width modulation (PWM) voltage inverter operates with low modulation index.

2.1 Push–Pull Gain

Acting as an adjustable-ratio DC transformer, the DC/DC converter allows impedance matching between the panels and the motor that drives the centrifugal pump. The choice of converter gain is most easily explained using an example. Consider the following: 1) The electrical load is a 230 V/50 Hz 0.5 hp induction motor; 2) The photovoltaic array is composed of ten 130 Wp panels arranged in a 2 (series) × 5 (parallel) layout; and 3) The losses are neglected. Fig. 4 shows the mechanical torque of the motor, the pump characteristic (upper plot), and the motor efficiency (lower plot) curves as functions of rotor (mechanical) speed. Assuming that the motor operates at a constant volt/hertz ratio, the operating points are determined by the intersection of the mechanical torque and load (pump) characteristic curves. Based on the power level demanded by the load, it is possible to determine the numerical values for the input and output push–pull voltages. For each operating point, therefore, it is possible to recover values for the motor line voltage to determine the minimum required DC-bus voltage, which corresponds to the push–pull output voltage. The push–pull input voltage is the MPPT panel array voltage. Thus given the motor output power, it is possible to numerically find the push–pull input voltage.

3. Simulation Results

Push Pull inverter system alone is simulated as shown in figure 3(a). The output of the Push Pull inverter is stepped up using step up transformer. DC input voltage is shown in figure 3(b). Drive pulses for S_1 and S_2 are shown in figure 3(c). It is 24 volts. This voltage is stepped up to 220 volts as shown in figure 3(d).

Push Pull inverter based drive system is shown in figure4 (a). The transformer output is shown in figure 4(b). The rectifier output voltage is as shown in figure4(c). The driving pulses for $M_{1,}$ M2 and M_3 are shown in figure 4(d). The phase voltage applied to the motor is shown in figure 4(e). The voltages are displaced by 120 degrees. The phase currents are shown in figure 4(f). The speed response is shown in figure 4(g). The speed increases and settles at 1460 rpm.

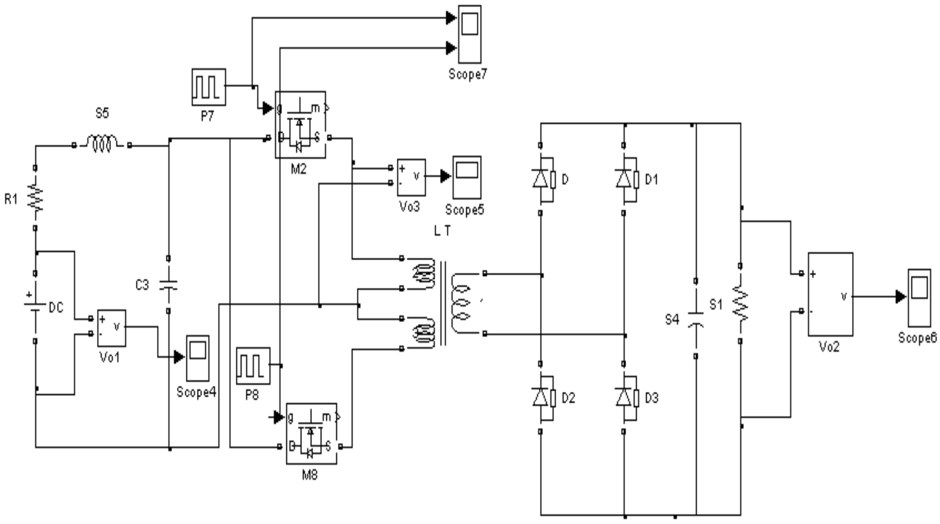

Figure 3a: Push Pull DC to DC Converter.

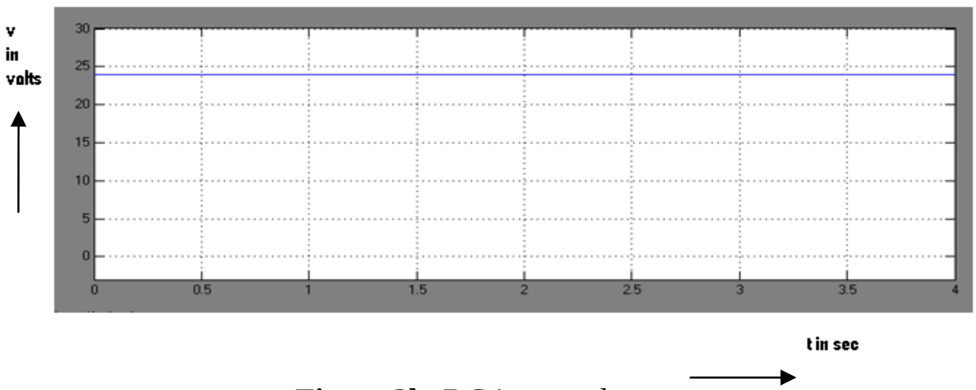

Figure 3b: DC input voltage.

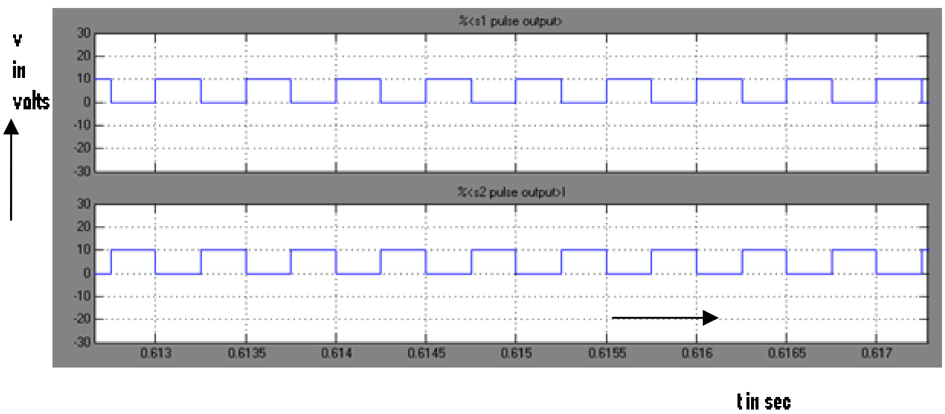

Figure 3c: Driving pulses for M_1 and M_2

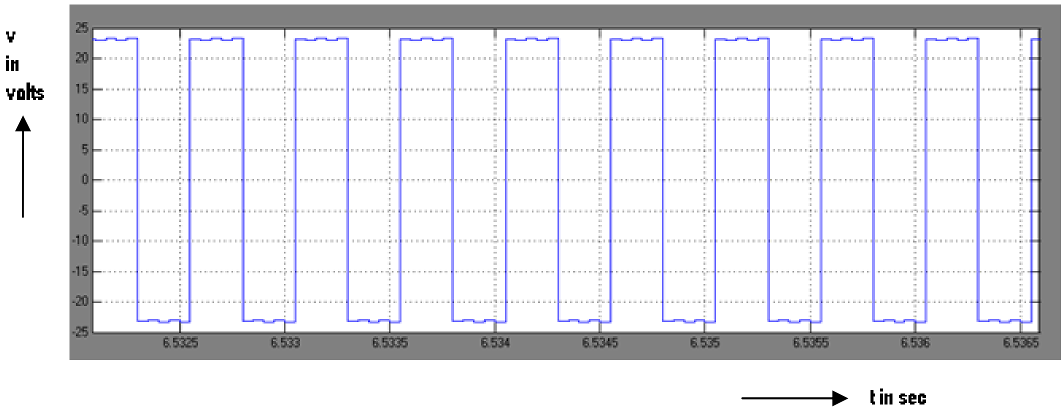

Figure 3d: Transformer primary voltage.

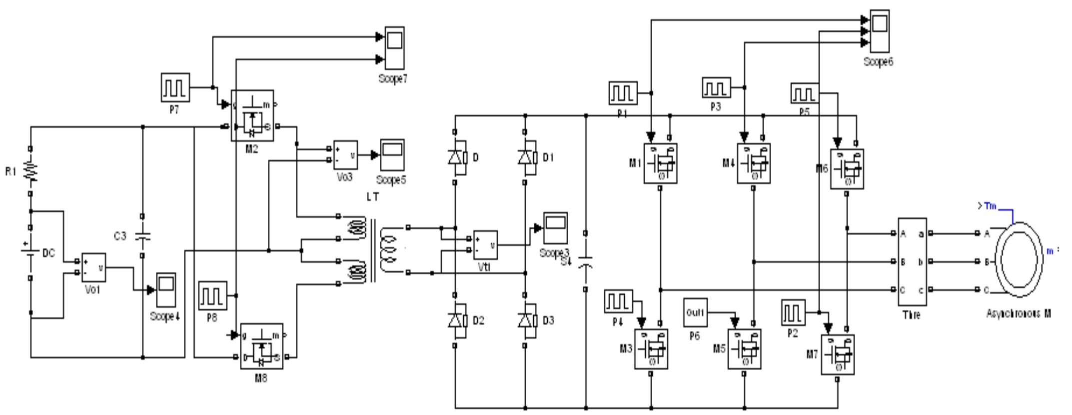

Figure 4a: Three Phase Inverter with Motor load

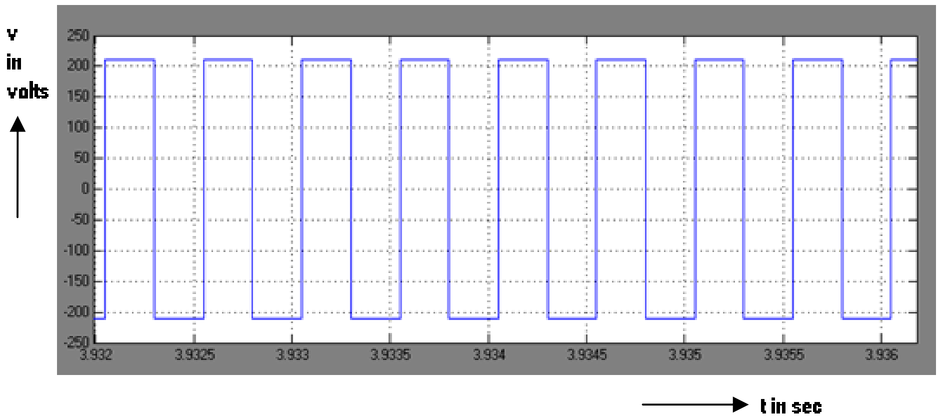

Figure 4b: Transformer secondary voltage.

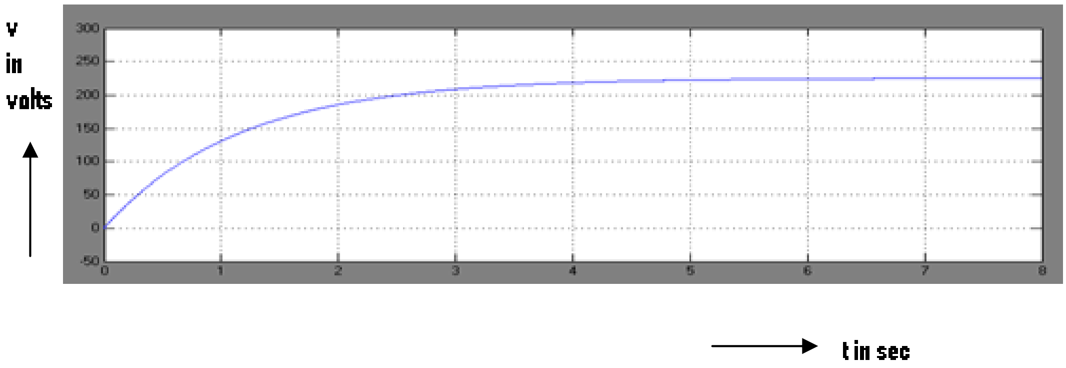

Figure 4c Rectifier output voltage.

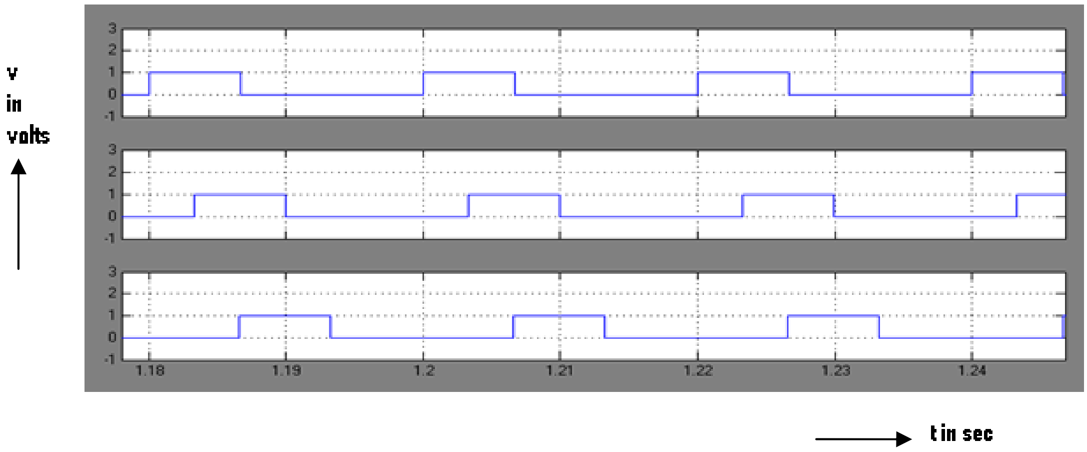

Figure 4d: Driving Pulses for M_1, M_2 and M_3

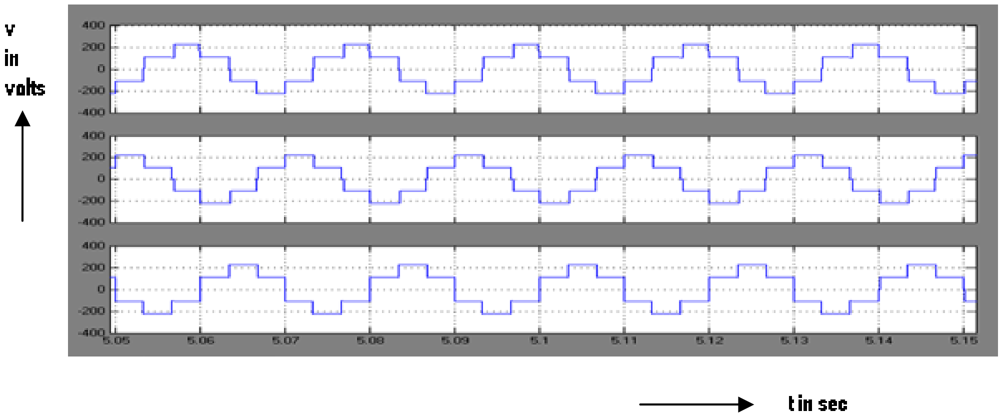

Figure 4e: Phase Voltage waveforms.

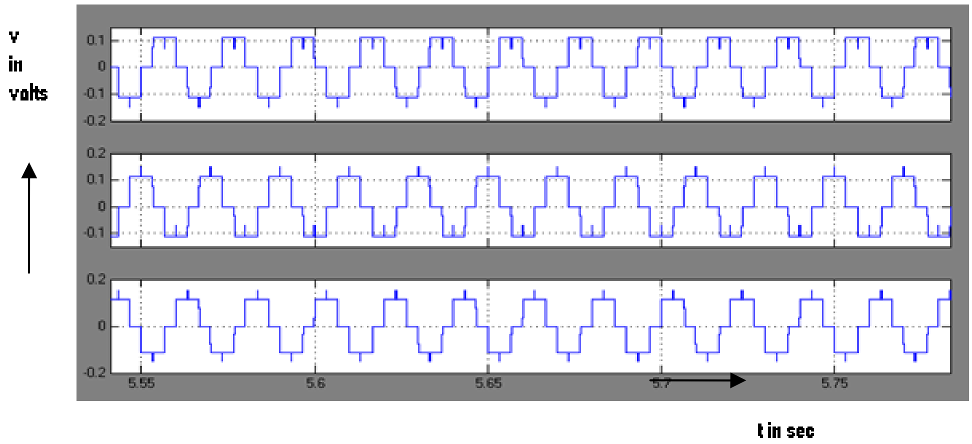

Figure 4f: Phase Current Waveforms.

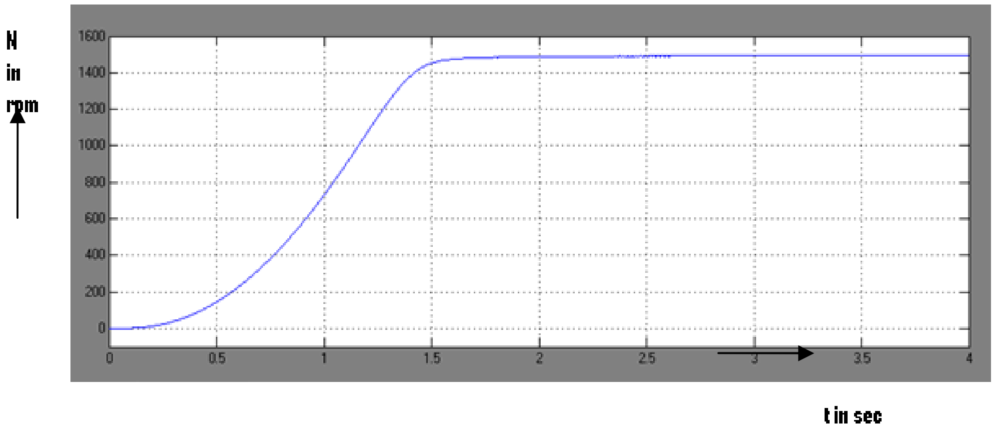

Figure 4g: Rotor Speed in RPM.

4. Experimental Results

The hardware of PV Powered Induction motor drive is fabricated and tested in the laboratory. The experimental set up of the hardware is shown in figure 5a. This consists of inverter board, Push Pull board and control board. The hardware of control circuits alone is shown in figure 5b. The hardware of Push Pull Converter is shown in figure 5c. This consists of two MOSFETS. The switching pulses for the Push Pull Converter are shown in figure 5d. The pulses are displaced are displaced by 180 degrees. The output of the Push Pull Converter is shown in figure 5e. DC output of the rectifier is shown in figure 5f. The phase voltage of the three phase inverter is shown in figure 5g. The line voltage of three phase inverter is shown in figure 5h.

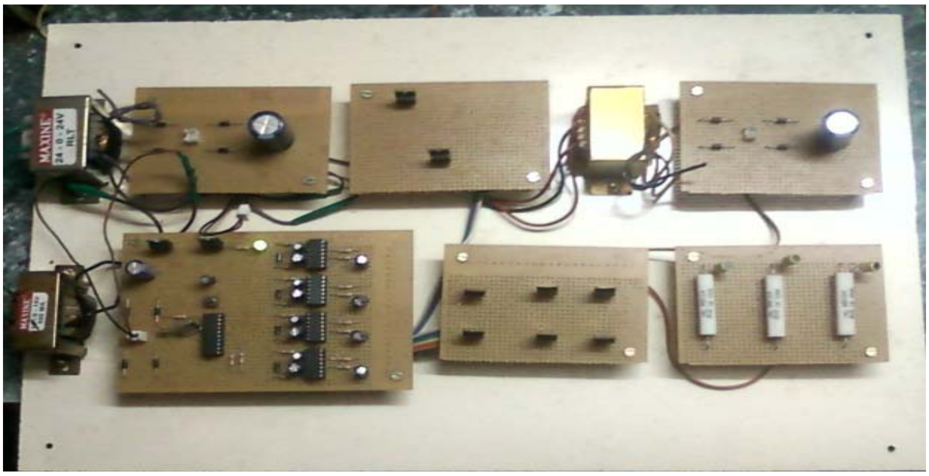

Figure 5a Hardware circuit.

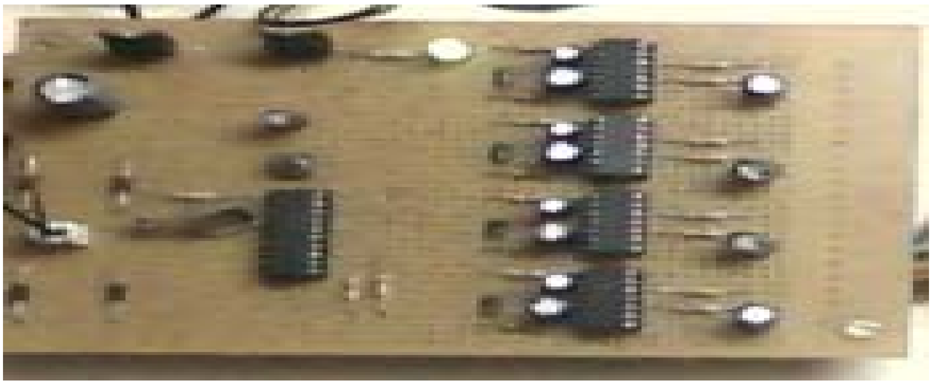

Figure 5b:Control circuit.

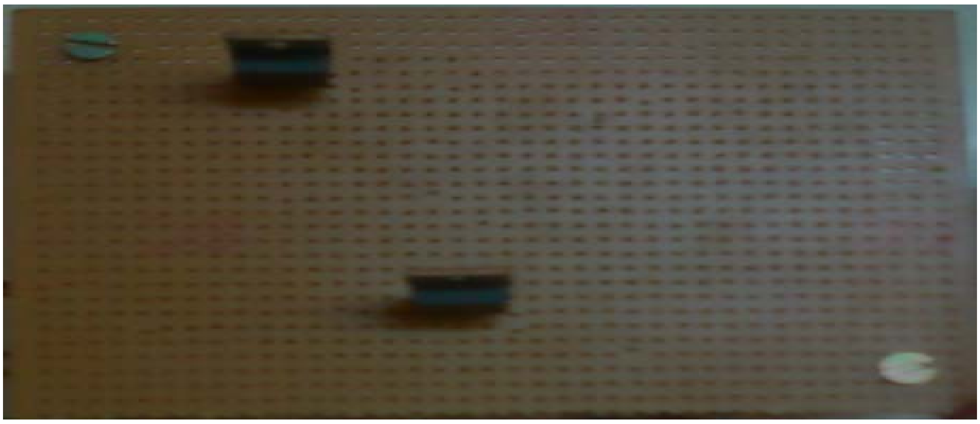

Figure 5c:Push pull converter.

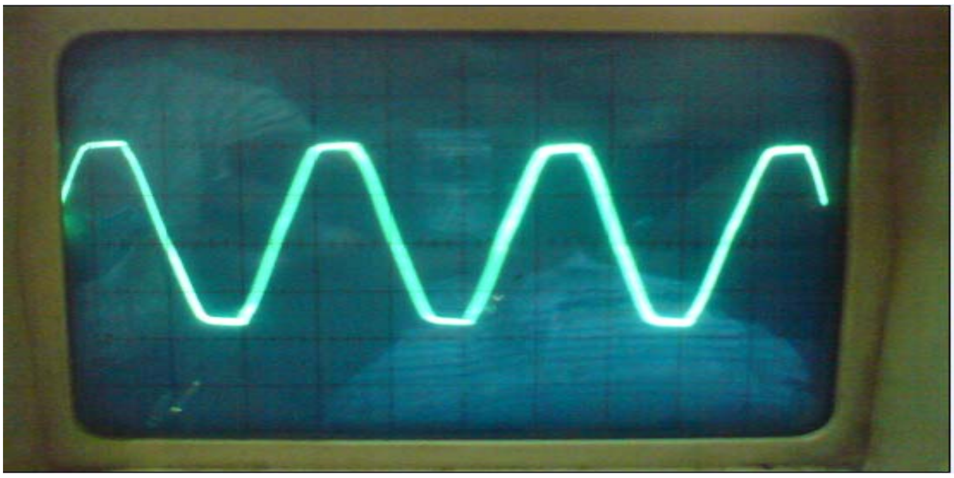

Figure 5c: Input voltage waveform (48v).

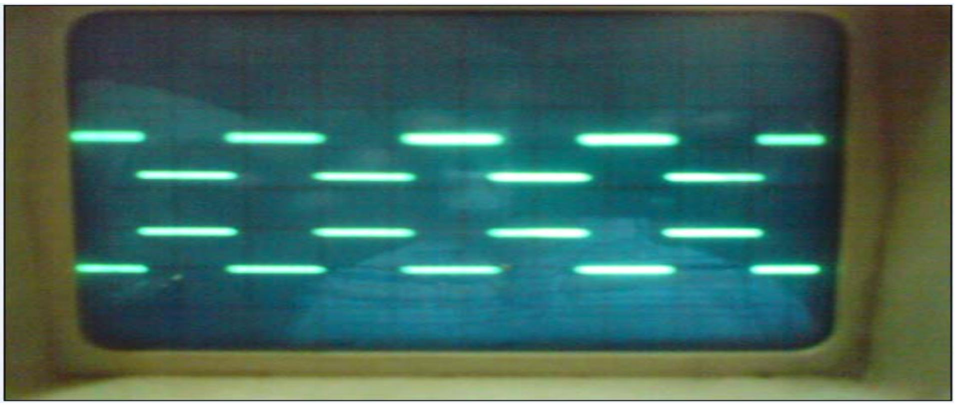

Figure 5d: Switching pulse for push pull converter.

Figure 5e: Output voltage of Push pull converter.

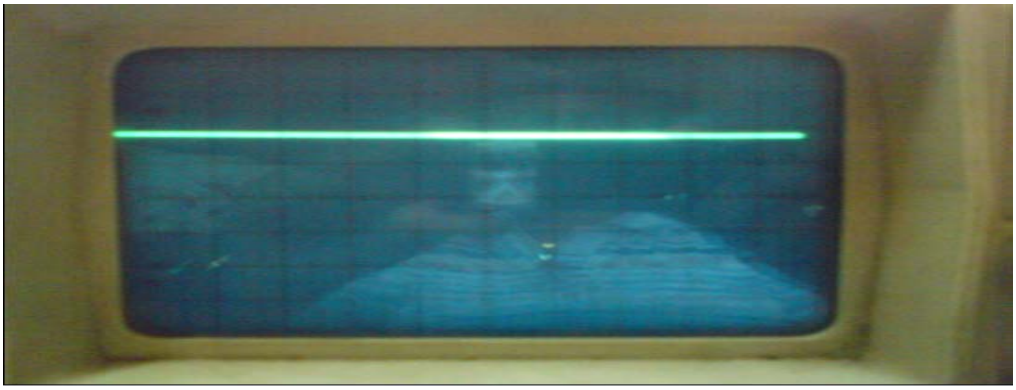

Figure 5f: Rectifier output voltage waveform.

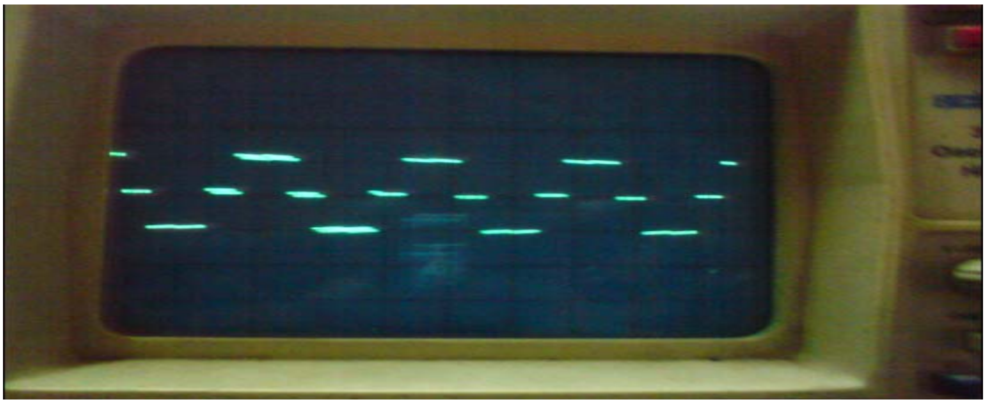

Figure 5g: Phase voltage of three phase inverter.

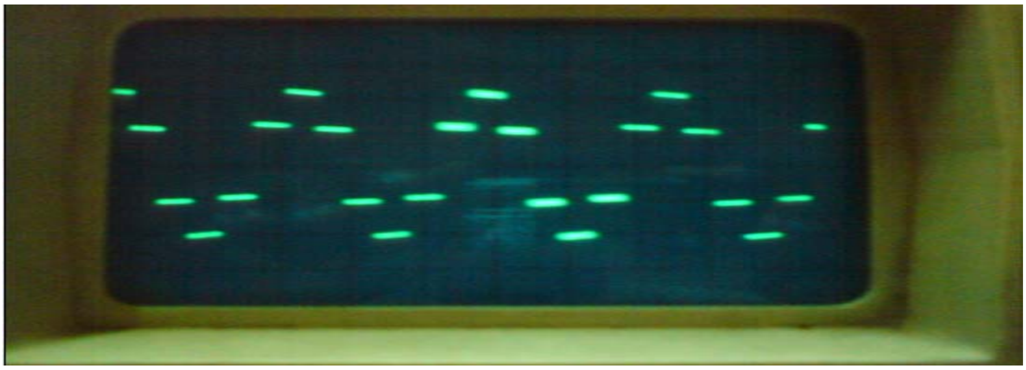

Figure 5h: Line voltage of three phase inverter.

5. Conclusion

This work has evaluated the strategy for utilization of PV Cells for induction motor pumping. The electricity bill gets reduced since solar energy is utilized for agriculture pumping. The Photo Voltaic powered three phase induction motor drive system is successfully designed, modeled and simulated using matlab simulink. The concept of

Photo Voltaic pumping is proposed. The simulation and experimental results of three phase induction motor for Photo Voltaic pumping are presented. The simulation results are in line with the theoretical results. The scope of this work is the simulation and implementation of three phase PV Powered Induction motor drive system. The experimental results are similar to the simulation results.

References

[1] R. Gules,J.D.P.Pacheco,H.L.Hey,andJ.Imhoff,"A maximum power point tracking system with parallel connection for PV stand-alone applications," IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2674–2683, Jul. 2008.

[2] N. Femia, G. Lisi, G. Petrone, G. Spagnuolo, and M. Vitelli, "Distributed maximum power point tracking of photovoltaic arrays: Novel approach and system analysis," IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2610–2621, Jul. 2008.

[3] D. Holmes, P. Atmur, C. Beckett, M. Bull, W. Kong, W. Luo, D. Ng, N.Sachchithananthan, P. Su, D. Ware, and P. Wrzos, "An innovative, efficient current-fed push–pull grid connectable inverter for distributed generation systems," in Proc. IEEE PESC, 2006, pp. 1–7.

[4] Y. Chen and K. Smedley, "A cost-effective single-stage inverter with maximum power point tracking," IEEE Trans. Power Electron., vol. 19, no. 5, pp. 1289–1294, Sep. 2004.

[5] S. Busquets-Monge, J. Rocabert, P. Rodriguez, S. Alepuz, and J. Bordonau, "Multilevel diode-clamped converter for photovoltaic generators with independent voltage control of each solar array," IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2713–2723, Jul. 2008.

[6] J.-M. Kwon, B.-H. Kwon, and K.-H. Nam, "Three-phase photovoltaic system with three-level boosting MPPT control," IEEE Trans. Ind. Electron.,vol. 23, no. 5, pp. 2319–2327, Sep. 2008.

[7] K. K. Tse, B. M. T. Ho, H. S. H. Chung, and S. Y. R. Hui, "A comparative study of maximum-power-point trackers for photovoltaic panels using switching-frequency modulation scheme," IEEE Trans. Ind. Electron., vol. 51, no. 2, pp. 410–418, Apr. 2004.

[8] W. Xiao, N. Ozog, and W. G. Dunford, "Topology study of photovoltaic interface for maximum power point tracking," IEEE Trans. Ind. Electron., vol. 54, no. 3, pp. 1696–1704, Jun. 2007.

[9] N. Femia, G. Petrone, G. Spagnuolo, andM. Vitelli, "Optimization of perturb and observe maximum power point tracking method," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 963–973, Jul. 2005.

[10] W. Xiao, M. G. J. Lind,W. G. Dunford, and A. Capel, "Real-time identification of optimal operating points in photovoltaic power systems," IEEETrans. Ind. Electron., vol. 53, no. 4, pp. 1017–1026, Jun. 2006.

[11] J.-H. Park, J.-Y. Ahn, B.-H. Cho, and G.-J. Yu, “Dual-module-basedmaximum power point tracking control of photovoltaic systems,” IEEETrans. Ind. Electron., vol. 53, no. 4, pp. 1036–1047, Jun. 2006.
[12] T. Esram, J. W. Kimball, P. T. Krein, P. L. Chapman, and P. Midya, “Dynamic maximum power point tracking of photovoltaic arrays using ripple correlation control,” IEEE Trans. Power Electron., vol. 21, no. 5, pp. 1282–1291, Sep. 2006.

About Authors

K. Vijay Bhaskar Reddy is a Research scholar in EEE Dept, Andhra University, waltair, A.P, India. He has received B. Tech and M. Tech Degree in Electrical and Electronics Engineering. He is currently pursuing Ph.D at Andhra University. He is having 10 years of teaching and 8 years of industrial experience. He has published three research papers in the national journals & six papers in international journals. His research interest includes induction motor drives.

Dr. G. V. Siva Krishna Rao has received his Ph.D in Electrical and Electronics Engineering from Andhra University, in 2007. At present, he is a Professor in Electrical and Electronics Engineering Department, AU College of Engineering, Andhra University, Waltair, AP, and India. He is having 18 years of teaching and research experience. He has published 20 research papers in the International journals.