Study of Single Phase Asynchronous Motor Based Solar Water Pumping System

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***Abstract:** In this work utilization of a boost converter for control of photovoltaic power using Maximum Power Point Tracking (MPPT) control mechanism is presented. First the photovoltaic module is analyzed using SIMULINK software. For the main aim of the project the boost converter is to be used along with a Maximum Power Point Tracking control mechanism. The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via the boost converter which steps up the voltage to required magnitude. The main aim will be to track the maximum power point of the photovoltaic module so that the maximum possible power can be extracted from the photovoltaic. The algorithms utilized for MPPT are generalized algorithms and are easy to model or use as a code. The algorithms are written in m files of MATLAB and utilized in simulation. Both the boost converter and the solar cell are modeled using Sim Power Systems blocks.*

***Keywords:** Solar PV systems, Water Pumping System, Solar energy, system efficiency, Maximum Power Point Tracking, Photovoltaic module*

1. INTRODUCTION

In the 21st century, human demand for new energy sources is urgent, because the traditional fossil energy is unable to meet human needs, and the fossil resource will make pollution, in this situation, solar energy gradually into the vision of scientists. As science advances, humans can already extensive use of solar energy to generate electricity.

Solar energy is an inexhaustible and clean energy. In the global energy crisis, environmental pollution is the growing problem of today. The use of solar energy research is to alleviate the energy crisis, protect the environment and ensure sustainable economic development of great significance. Solar industry is divided into solar thermal industry and solar photovoltaic industry; solar thermal industry's main products are solar water heaters. Scientists have made great process in study of solar power. Humans can do solar photovoltaic in the desert. Solar radiation on Earth is very large. About 40 minutes of solar radiation on Earth, it can suffice the consumption of the energy for all human for one year.

Nowadays, human built many solar photovoltaic plants to generate electricity, and many people are seting solar cells on the roof to generate electricity for their daily consumption. All these prove that solar energy has become increasingly popular. The Governments of China, The USA and some other countries also support the use of solar power, thus reducing the consumption of non-renewable resources and protect the environment.

Global warming and energy policies have become a hot topic on the international agenda in the last years. Developed countries are trying to reduce their greenhouse gas emissions. For example, the European union has committed to reduce their greenhouse gas to at least 20% below 1990 levels and to produce no less than 20% of its energy consumption from renewable sources by 2020 [1]. In this context, photovoltaic (PV) power generation has an important role to play due to the fact that it is a green source.

The only emissions associated with PV power generation are those from the production of its components. After their installation they generate electricity from the solar irradiation without emitting greenhouse gases. Water pumps are powered by the photovoltaic or PV array. There are three elements which include the pump itself, its controller and the three elements you can have a relatively inexpensive system that is low maintenance. The system is expected to operate if there is sunlight and water to pump. It is a good idea to either or both have water storage means and or having the array 'oversized' to pump water under low light conditions.

2. BOOST CONVERTER

Boost converter steps up the input voltage magnitude to a required output voltage magnitude without the use of a transformer. The main components of a boost converter are an inductor, a diode and a high supply power to the load at a voltage greater than the input voltage magnitude. The control strategy lies in the manipulation of the duty cycle of the switch which causes the voltage change [11] and [12].

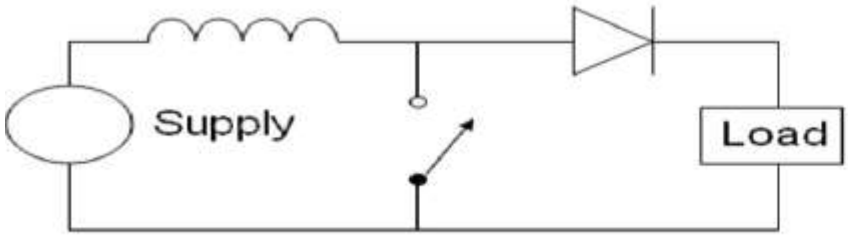

Fig. 1: A boost converter

3. MODELLING AND CONTROL STRATEGY

Water resources are essential for satisfying human needs, protecting health, and ensuring food production, energy and the restoration of ecosystems, as well as for social and economic development and for sustainable development [1].

PV module is the basic power conversion unit of solar power generator system. The output characteristic of the PV module basically depends on the solar illumination and temperature of the PV module.

3.1 System Modeling and Design

DC/DC conversion technology is a significant subject in research and industrial applications. Since the twentieth century, the DC/DC conversion technique has been greatly developed, and there are plenty of new topologies of DC/DC converters. DC/DC converters are widely used in communication equipment, hand-phone and digital cameras, computer hardware circuits, dental apparatus, and other industrial applications.

Since there are numerous DC/DC converters we have to sort them into six generations of DC/DC converters: classical/traditional converters (first generation), multi quadrant converters (second generation), switched-component converters (third generation), soft-switching converters (fourth generation), synchronous rectifier converters (fifth generation), and multi element resonant power converters (sixth generation). The first-generation DC/DC converters are so-called classical or traditional converters. These converters perform in a single-quadrant mode and in low power range (up to 100 W).

A solar cell basically generates a voltage around 0.5V to 0.8V depending on the type of semiconductor. This voltage is too less to use for pumping. Therefore, numbers of cells are connected in series and parallel, to get the higher voltage and current ratings called PV module [2]. The equivalent circuit of PV cell is shown below.

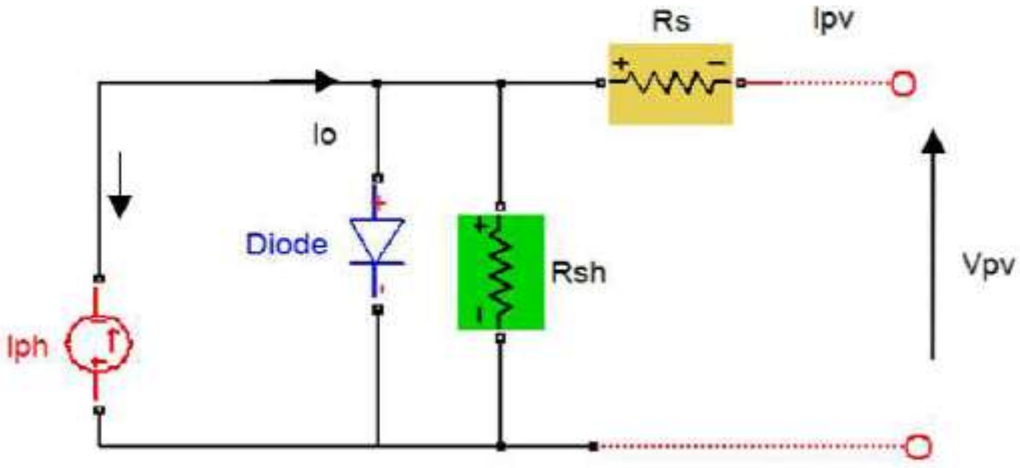

Fig. 2: The equivalent circuit of PV module

$$I_{pv} = I_{Li} - I_0\left[e^{\frac{q(V_{pv}+r_s)}{\eta A_i \Theta}} - 1\right] - \frac{V_{pv}+I_{pv}r_s}{r_{sh}}$$

Where Ipv output current of PV panel, ILi light induced current, Io is the reverse saturation current q is the electron charge, V_{PV} is the voltage of PV, η is the Boltzmann constant, Ai is the semiconductor material ideality factor and Θ is the cell temperature.

Light induced current is given as

$$I_{Li} = G(t)[I_{sc} + \beta_i(\Theta - \Theta_r\ A$$

Where G (t) solar irradiation in (w/m2) I_{SC} is short circuit current, β_i temperature coefficient in (per °C) and Θ_r is reference cell temperature and reverse saturation current is given as

$$I_0 = I_{rs}\left(\frac{\Theta}{\Theta_r}\right)^3 . e^{\left[\frac{E_b}{\eta A_i}\left(\frac{1}{\Theta_r} - \frac{1}{\Theta}\right)\right]}$$

Where I_{rs} reverse saturation current at standard testing condition and E_b is energy band gap.

4. SINGLE PHASE INVERTER CONTROL SCHEME

The model of a single-phase inverter can be divided into two categories: one category is based on a synchronous frame system (dq-frame) that usually adopts a PI regulator; another category is built upon a stationary frame system (αβ-frame) that employs the proportional-resonant (PR) regulator. The system also employs a PI controller. The task of the MPPT algorithm is just to calculate the reference voltage Vref towards which the PV operating voltage should move next for obtaining maximum power output. This process is repeated periodically with a slower rate of around 1-10 samples per second. The external control loop is the PI controller, which controls the input voltage of the converter.

The pulse width modulation is carried in the PWM block at a considerably faster switching frequency of 100 KHz. In our simulation, KP is taken to be 0.006 and KI is taken to be 7. A relatively high KI value ensures that the system stabilizes at a faster rate.

The PI controller works towards minimizing the error between Vref and the measured voltage by varying the duty cycle through the switch. The switch is physically realized by using a MOSFET with the gate voltage controlled by the duty cycle.

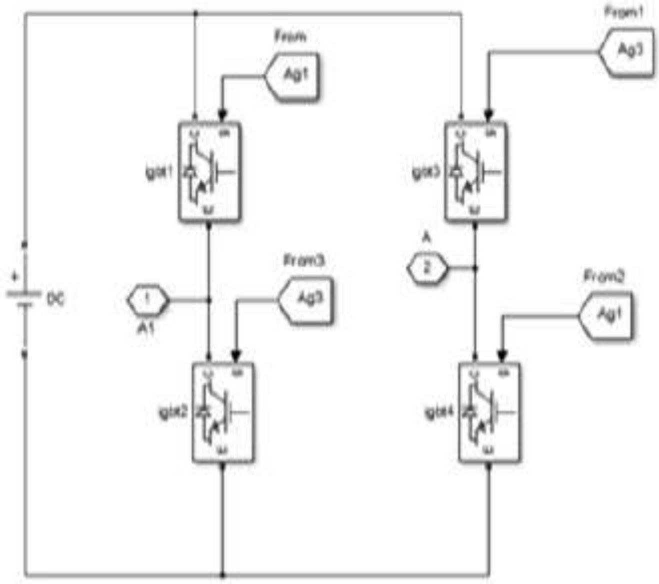

Fig. 3: Single phase inverter matlab model

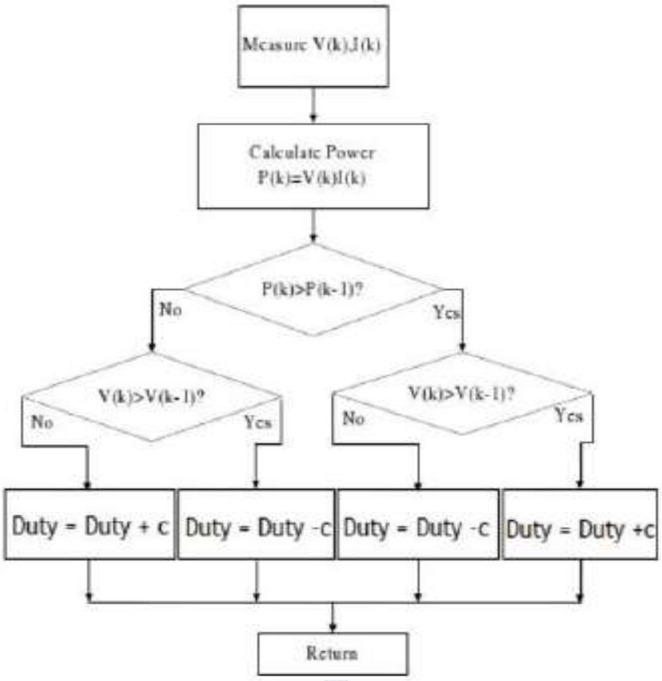

Fig. 4: Flow chart for perturb & observe

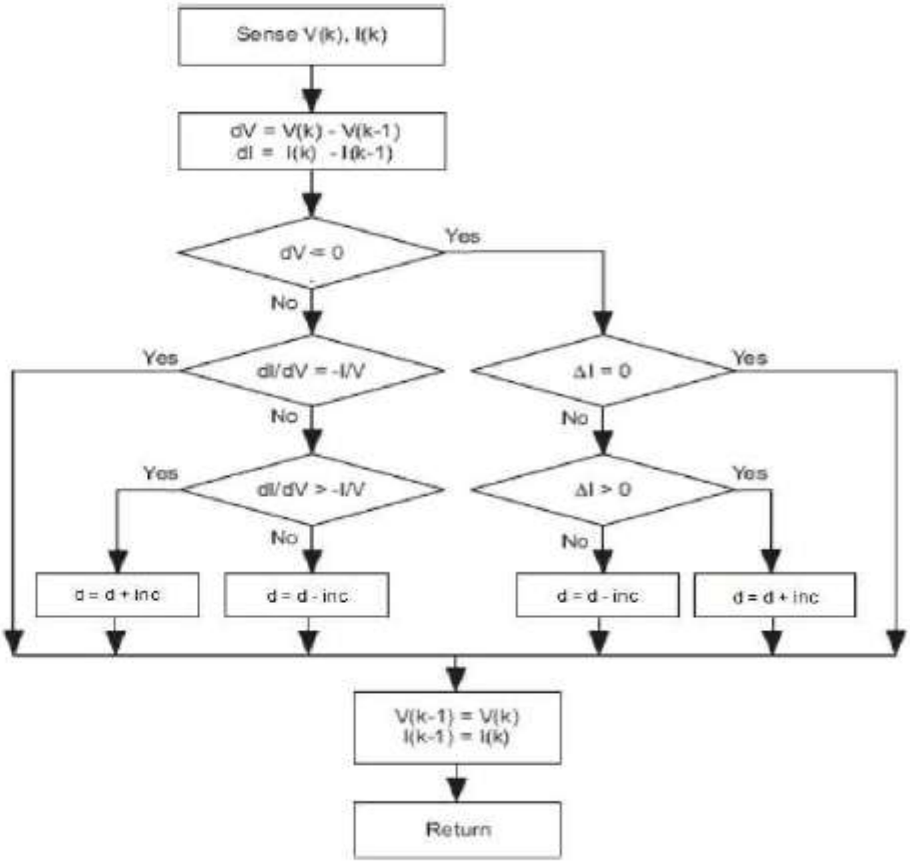

Fig. 5: Flow chart incremental conductance method

Out of these two algorithms P&O of Simulink, where the codes written inside the function block are utilized to vary certain signals with respect to the input signals implemented using the Embedded MATLAB function.

5. Model for Perturb & Observe Algorithm

The MPPT unit for this method current and voltage values as in incremental conductance method. Rest every unit is similar to the previous model units. The repeating sequence being utilized in the model has an operating frequency of 10 KHz. This is also the frequency of the gating signal.

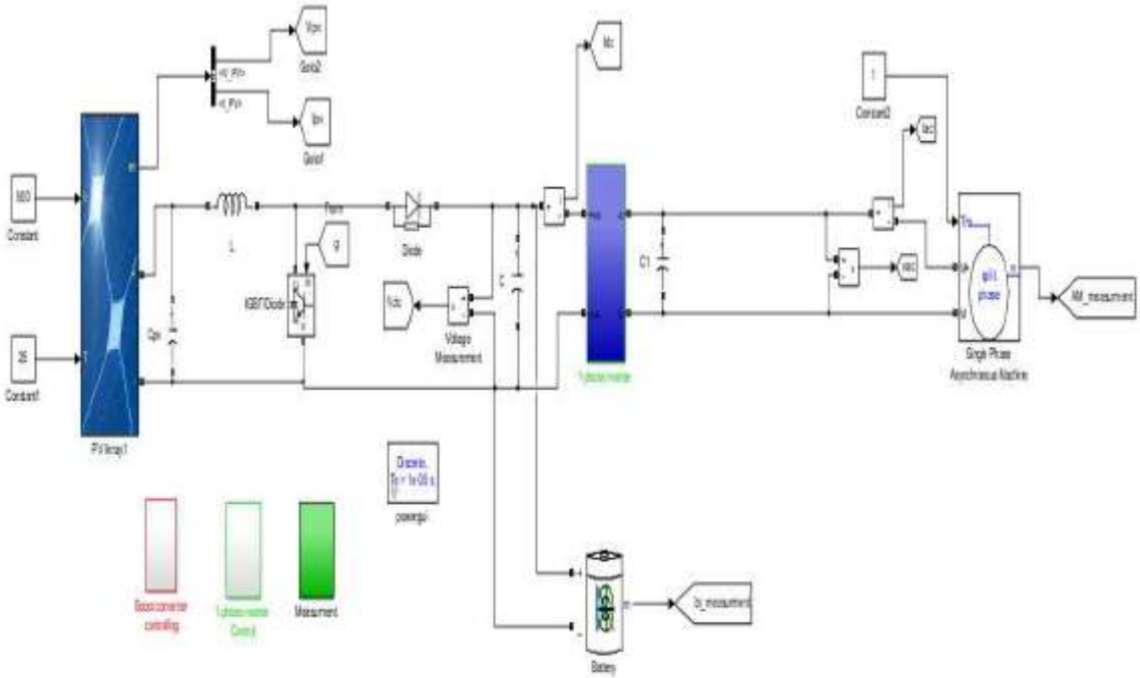

Fig. 6: Proposed model configuration

6. RESULT AND DISCUSSION

6.1 Simulink Model of Single Phase PV System

For Simulation of this standalone PV system a 30 kW PV generation is taken, where series connected PV modules are Ns=17 and parallel connected PV modules are Np=9 are considered during PV modeling. Series connection of PV module increases the voltage rating while parallel connection of PV module increases the current rating. In proposed research work are taken seventeen modules in one row having nine rows total.

BSS is nothing but a pack of batteries connected in parallel or series manner. In our simulation we have taken lead-acid battery bank which storage capacities are 1000Ah while nominal voltage is 800V. To extract maximum power from nature boost converter is used. Boost converter match the impedance of source to transfer the maximum power from source and impedance matching has done via Perturb and Observe control strategy. The boost converter parameter are inductor L= 4.5mH, dc link capacitor C= 500µF, switching frequency of 10 kHz.

6.2 Performance of PV system

Performance is evaluated in terms of solar irradiation G(t) in w/m^2, PV voltage (VPV), PV current (IPV), boost converter output current (Idc), power developed by PV module is (Ppv), DC voltage (Vdc), state of charging (SOC) of battery in percentage, proposed system perform under constant solar irradiation of 800 w/m^2 which is shown in Fig. 7.

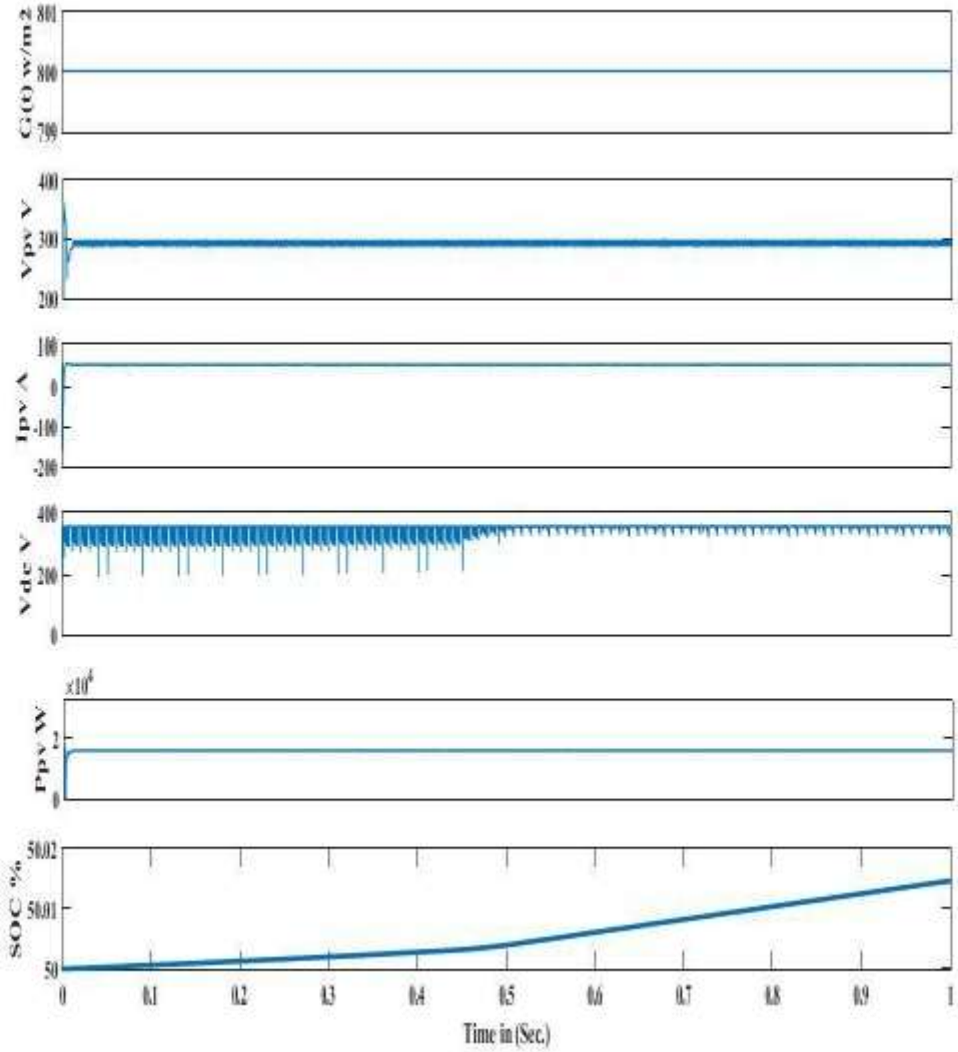

Fig. 7: Performance of PV system

6.3 Performance of pumping system

The performance of pump of PV system its plots is divided into four part first one is voltage at pump terminal, second is current through the pump load, third one is power demand by pump load and last one is soc of battery here load is less than power generation by PV system so battery is in charging mode which is shown in Fig. 5.2.

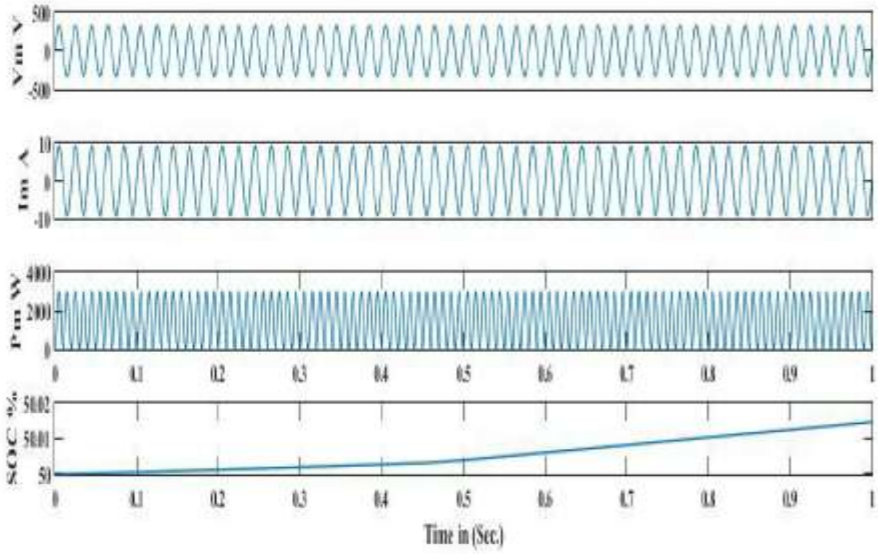

Fig. 8: Performance of pumping system

6.4 Performance of Battery Energy Storage System of PV pumping System

The performance of battery energy storage system of single phase PV system base pump system is shown in Fig. 9, its plots is divided into three part first one is battery voltage level second one is battery current when current is negative it work is in charging mode while current is positive battery work is in discharging mode. Third one is state of charging of battery.

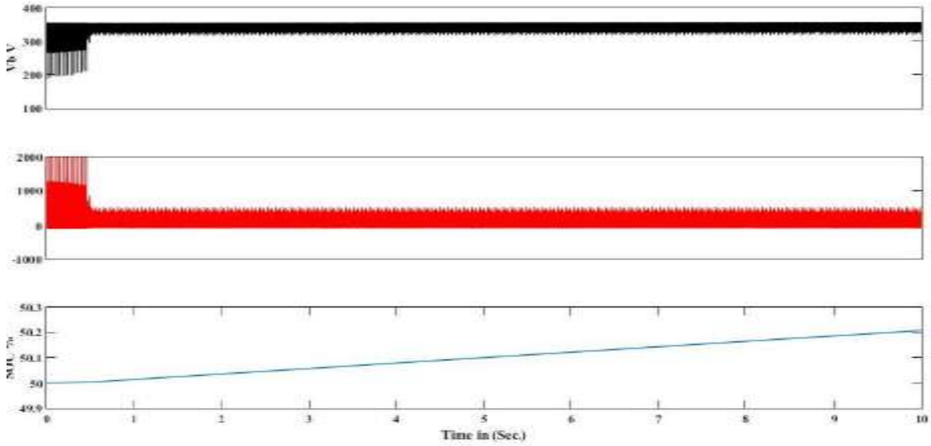

Fig. 9: Performance of Battery Energy Storage System of PV pumping System

6.5 Mechanical Performance PV based pumping System

Fig. 10 show the mechanical performance of single phase induction motor as pump system based on solar PV system. Single phase induction motor of rated 230V, 50 Hz, 4 poles, 2 hp motor. Its plots are plotted in three sub part first one is rotor speed in radian /sec. second one it mechanical torque in Newton meter and last one is mechanical angle theta.

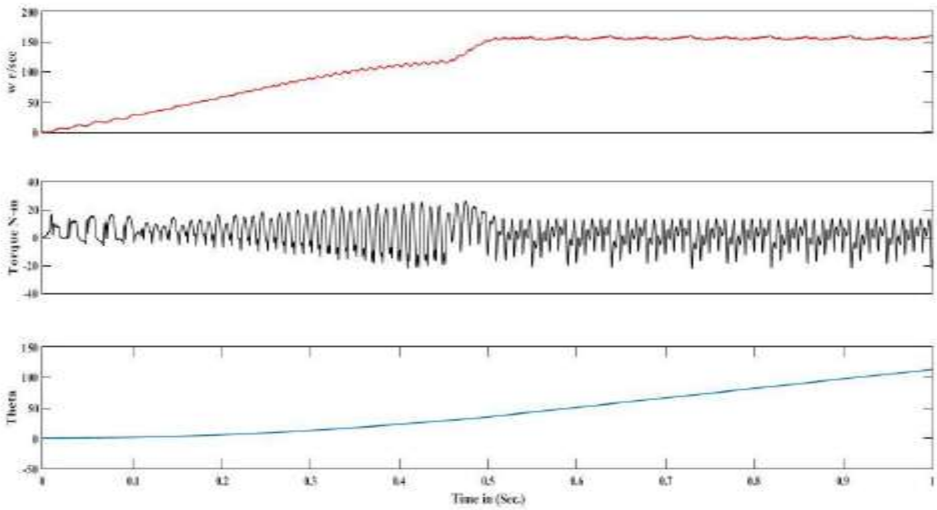

Fig. 10: Mechanical Performance PV based pumping System

6.6 Power quality analysis pump terminal voltage

Fig 11 shows the voltage waves of pump terminal voltage and its THDs analysed and observed that THDs was 1.51% with pump load. It is under the IEEE standard. This is possible due to control strategy of signal phase H-bridge inverter.

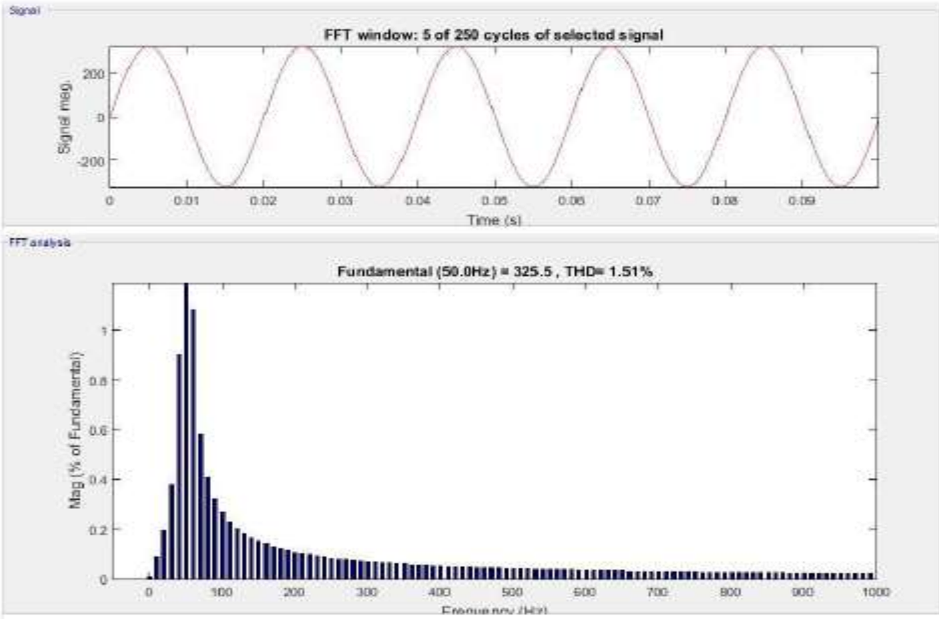

Fig. 11: Power quality analysis pump terminal voltage

7. CONCLUSION

This work provides the simulation model of PV system based Pumping system with boost converter to extract maximum power from nature and performance is shown in table 1. To store the surplus power of solar battery energy storage system is utilized. And to invert dc power into ac power its result is satisfactory obtained using MATLAB 2015a under discreet mode.

Table 1: performance of P&O and solar pump

Solar irradiation (W/m^2)	PV array			Battery		Load (Asynchronous motor)
	Voltage, V	Current, A	Power, KW	Power, KW	Mode	Power, KW
1000	500	68	33.48	31.98	Charging	1.5
800	470	54	25.8	24	Charging	1.5
600	450	40	19	17.5	Charging	1.5
0	0	0	0	1.5	Discharging	1.5

The model was simulated using SIMULINK and MATLAB. The simulation was first run with the switch on no MPPT mode, bypassing the MPPT algorithm block in the circuit. It was seen that when we do not use an MPPT algorithm, the power obtained at the load side was around 95 Watts for a solar irradiation value of 85 Watts per sq. cm. It must be noted that the PV panel generated around 250 Watts power for this level of solar irradiation. Therefore, the conversion efficiency came out to be very low.

The simulation was then run with the switch on MPPT mode. This included the MPPT block in the circuit and the PI controller was fed the Vref as calculated by the P&O algorithm. Under the same irradiation conditions, the PV panel continued to generate around 250 Watts power In this case, however, the power obtained at the load side was found to be around 215 Watts thus increasing the conversion efficiency of the photovoltaic system as a whole.

The loss of power from the available 250 Watts generated by the PV panel can be explained by switching losses in the high frequency PWM switching circuit and the inductive and capacitive losses in the Boost Converter circuit.

Therefore, it was seen that using the Perturb & Observe MPPT technique increased the efficiency of the photovoltaic system by approximately 126% from an earlier output power of around 95 Watts to an obtained output power of around 215 Watts.

REFERENCES

[1] M. G. Villalva, J. R. Gazoli, E. Ruppert F, "Comprehensive approach to modelling and simulation of photovoltaic arrays", IEEE Transactions on Power Electronics, 2009 vol. 25, no. 5, pp. 1198--1208, ISSN 0885-8993.

[2] M. G. Villalva, J. R. Gazoli, E. Ruppert F, "Modeling and circuit-based simulation of photovoltaic arrays", Brazilian Journal of Power Electronics, 2009 vol. 14, no. 1, pp. 35—45.

[3] Mummadi Veerachary, "Control of TI-SEPIC Converter for Optimal Utilization of PV Power", IICPE, 2010 New Delhi.

[4] 4. R. Sridhar, Dr. Jeevananathan, N. Thamizh Selvan, Saikat Banerjee, "Modeling of PV Array and Performance Enhancement by MPPT Algorithm", International Journal of Computer Applications (0975 – 8887) Volume 7– No.5, September 2010.

[5] Hairul Nissah Zainudin, Saad Mekhilef, "Comparison Study of Maximum Power Point Tracker Techniques for PV Systems", Cairo University, Egypt, December 19-21, 2010, Paper ID 278.

[6] Katherine A. Kim and Philip T. Krein, "Photovoltaic Converter Module Configurations for Maximum Power Point Operation", University of Illinois Urbana-Champaign Urbana, IL 61801 USA.

[7] 7. Huan-Liang Tsai, Ci-Siang Tu, and Yi-Jie Su, "Development of Generalized Photovoltaic Model Using MATLAB/SIMULINK", Proceedings of the World Congress on Engineering and Computer Science 2008 WCECS 2008, October 22 - 24, 2008, San Francisco, USA.

[8] 8. M. Berrera, A. Dolara, R. Faranda and S. Leva, "Experimental test of seven widely-adopted MPPT algorithms", 2009 IEEE Bucharest Power Tech Conference, June 28th - July 2nd, Bucharest, Romania.

[9] 9. P. S. Revankar, W. Z. Gandhare and A. G. Thosar Government College of Engineering, Aurangabad, "Maximum Power Point Tracking for PV Systems Using MATLAB/SIMULINK", 2010 Second International Conference on Machine Learning and Computing.