International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 5, No. 2, October 2014, pp. 203~210
ISSN: 2088-8694

Photovoltaic Cell Fed 3-Phase Induction Motor Using MPPT Technique

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Article Info

Article history:

Received Mar 17, 2014
Revised May 4, 2014
Accepted Jun2, 2014

Keyword:

DC-DC Converter
Dspic4011
MPPT
PhotoVoltaic

ABSTRACT

This Paper emphasizes on proposing a cost effective photovoltaic (PV) fed 3 phase Induction motor drive which serves for rural pumping applications. Generally in a standalone system, the PV unit will charge the battery and the battery set up in turn will serve as a source for the inverter. A new single stage battery less power conversion is employed by designing a maximum power point tracker (MPPT) embedded boost converter which makes the overall cost of the setup to go down considerably. The realized as a prototype consisting PV array of 500watts, MPPT aided boost converter, three phase inverter and a three phase squirrel cage induction drive of 300 watts. An efficient and low cost micro controller dspic4011 is used a platform to code and implement the prominent perturb and observe MPPT technique. Sinusoidal pulse width modulation (SPWM) is the control technique employed for the three phase inverter. To validate the experimental results simulation of the whole set up is carried out in matlab /simulink environment. Simulation and hardware results reveal that the system is versatile.

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1. INTRODUCTION

The induction motors do not require an electrical connection between stationary and rotating parts of the motor. Therefore, they do not need any mechanical commutator (brushes), leading to the fact that they are maintenance free motors. Induction motors also have low weight and inertia, high efficiency and a high overload capability. Therefore, they are cheaper and more robust, and less proves to any failure at high speeds. A variable frequency is required because the rotor speed depends on the speed of the rotating magnetic field provided by the stator. A variable voltage is required because the motor impedance reduces at low frequencies and consequently the current has to be limited by means of reducing the supply voltages. Before the days of power electronics, a limited speed control of induction motor was achieved by switching the three-stator windings from delta connection to star connection, allowing the voltage at the motor windings to be reduced. Induction motors are also available with more than three stator windings to allow a change of the number of pole pairs.

2. PHOTOVOLTAIC TECHNOLOGY

Converting the sun’s radiation directly into electricity is done by solar cells. These cells are made of semiconducting materials similar to those used in computer chips. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the photovoltaic effect. Photovoltaic's (PV) are thus the field of technology and research related to the application of solar cells that convert sunlight directly into electricity. Solar cells, which were originally developed for space applications in the 1950s, are used in consumer products such as calculators or watches, mounted on roofs of houses or assembled into large power stations. Today, the majority of photovoltaic modules are used for grid-connected power generation, but a smaller market for off-grid power is growing in remote areas and developing countries. Given the enormous potential of solar energy, photovoltaic may well become a major source of clean electricity in the future. However, for this to happen, the electricity generation costs for PV systems need to be reduced and the efficiency of converting sunlight into electricity needs to increase.

3. PHOTOVOLTAIC ARRAYS

Due to the low voltage of an individual solar cell typically 0.5V, several cells are wired in series in the manufacture of a "laminate". The laminate is assembled into a protective weatherproof enclosure, thus making a photovoltaic module or solar panel. These solar panels are linked together to form photovoltaic Arrays. The panels are connected in series The current through the cell is constant and the voltage across the cell adds up. The panels are connected in parallel The voltage through the cell is constant and the current across the cell adds up.

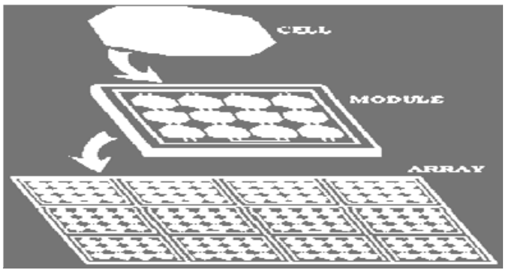


Figure 1. PV array

When photons of light strike the material, however, some normally non-mobile electrons in the material absorb the photons, and become mobile by virtue of their increased energy. This creates new holes too - which are just the vacancies created by the newly created mobile electrons. Because of the "built in" electric field, the new mobile electrons in the n-material cannot cross over into the p-material. In fact, if they are created near or in the junction where the electric field exists, they are pushed by the field towards the upper surface of the n-material. If a wire is connected from the n-material to the p-material, however, they can flow through the wire, and deliver their energy to a load.

On the other hand, the holes created in the n-material, which are positively charged, are pushed over into the p-material. In fact, what is really happening here is that an electron from the p-material, which was also made mobile by the adsorption of a photon, is pushed by the electric field across the junction and into the n-material to fill the newly created hole. This completes the circuit as the electrons flows in all the ways around the circuit, dropping the energy they acquired from photons at a load.

4. BLOCK DIAGRAM OF PHOTOVOLTAIC PUMPING SYSTEM

The design of an effective PV 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 PV pumping, the voltage 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.

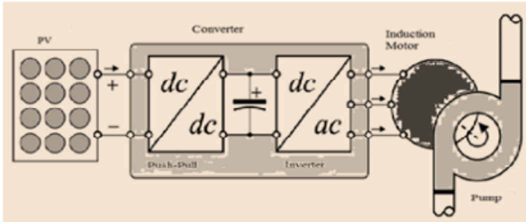


Figure 2. Photovoltaic pumping systems

Currently, solar water pumps are used in the western United States as well as in many other countries or regions with abundant sunlight. Solar pumps have proven to be a cost effective and dependable method for providing water in situations where water resources are spread over long distances, power lines are few or non-existent, and fuel and maintenance costs are considerable.

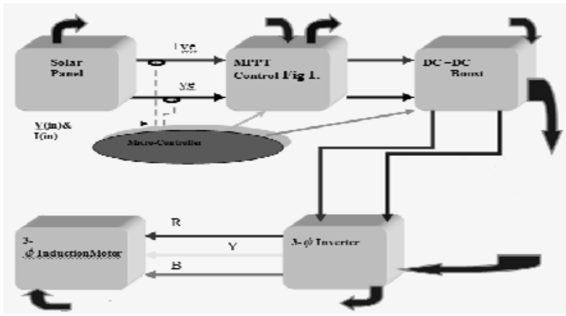


Figure 3. MPPT control technique of Induction Motor

5. PV CELL MODELLING

Renewable energies are on demand these days and amongst them, Solar is the most popular because of the basic fact that it is clean, green and its availability is boundless. It's almost been decades and using solar energy has become a tradition now and the best part is that it is still escalating at tremendous pace with newer and more efficient technologies. Right from monocrystalline and polycrystalline we have leaped towards amorphous silicon, thin film technology, Cd-teThin film, CIGS thin film and flexible thin films. Though these trends are still in the research stag and not yet popular two players who have contributed to almost 90% of the solar panels are Monocrystalline and Polycrystalline Silicon. Solar cells are connected in series and parallel to get the desired output as a single solar cell could only contribute a peak voltage of 0.5 to 0.7 volt. Such designed unit is called a PV panel and these panels are in turn arranged series and parallel to form PV array.

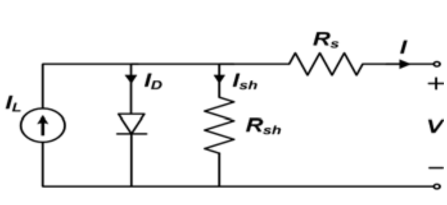


Figure 4. PV cell equivalent diagram

In the equivalent circuit, I_{pv} and V_{pv} are the PV current and voltage respectively. R_s and R_{sh} are the series and shunt resistances respectively. Now the current to the load is given by:

$$I = N_p I_{pv} - N_p I_s \left[\exp\left[\frac{q(V + R_s I)}{nN_s KT} - 1\right]\right] - \frac{V + R_s I}{R_{sh}} \quad (1)$$

In this equation, I_{pv} is the photocurrent, I_s is the reverse saturation current of the diode, q is the electron charge, V is the voltage across the diode, K is the Boltzmann's constant, T is the junction temperature, n is the ideality factor of the diode, and R_s and R_{sh} are the series and shunt resistors of the cell, respectively. N_s and N_p are the number of cells connected in series and parallel respectively.

As mentioned earlier PV current is a function of temperature and solar irradiation.

$$I_{pv} = \left[I_{sc} + K_i(T - 298)\right]\frac{\beta}{1000} \tag{2}$$

Where K_i=0.0017 A/◦C is the cell's short circuit current temperature coefficient and β is the solar radiation (W/m2). The diode reverse saturation current varies as a cubic function of the temperature and it can be expressed as:

$$I_s(T) = I_s\left[\frac{T}{T_{nom}}\right]^3 \exp\left[\left[\frac{T}{T_{nom}} - 1\right]\frac{E_g}{nV_t}\right] \tag{3}$$

Where I_s is the diode reverse saturation current, T_{nom} is the nominal temperature, E_g is the band gap energy of the semiconductor and V_t is the thermal voltage.

6. PERTURB AND OBSERVE MPPT TECHNIQUE:

The basic disadvantages which PV system face is that the irradiance of sun is never constant and hence it is difficult to yield the full performance from the panel. Hence whenever the source is varying one it is often better to work on the existing output obtained and mould it accordingly such that despite the loss at input side, the output remains unaltered. This is what a MPPT does precisely. Maximum Power Point Tracking is electronic tracking-usually digital. The charge controller looks at the output of the panels, and compares it to the battery voltage. It then figures out what is the best power that the panel can put to charge the battery. It takes this and converts it to best voltage to get maximum AMPS to the battery. MPPTs are most effective when weather is cold, when the battery charge is lo/w and the cable wires used for connection are long. Hence these days MPPTs have become mandatory. In perturb and observe technique, the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common, although this method can result in oscillations of power.

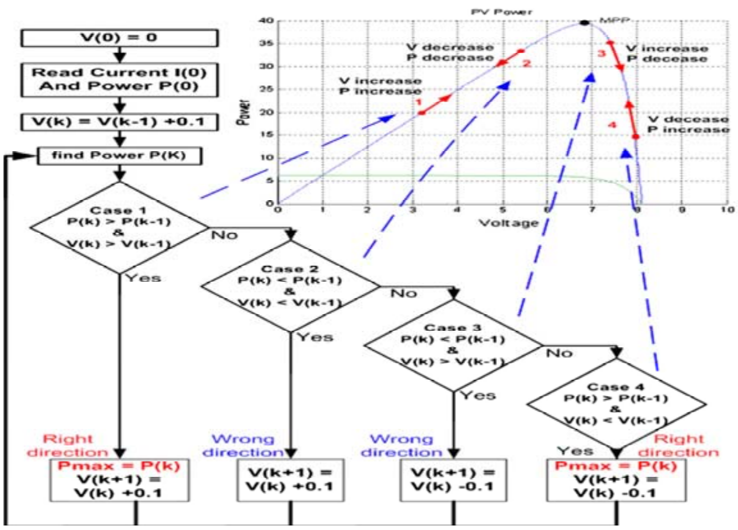


Figure 5. Perturb and observe MPPT technique

7. INDUCTION MOTOR:

The only effective way of producing an infinitely variable induction motor speed drive is to supply the induction motor with three phase voltages of variable frequency and variable amplitude. A variable frequency is required because the rotor speed depends on the speed of the rotating magnetic field provided by the stator. A variable voltage is required because the motor impedance reduces at low frequencies and consequently the current has to be limited by means of reducing the supply voltages. Before the days of power electronics, a limited speed control of induction motor was achieved by switching the three-stator windings from delta connection to star connection, allowing the voltage at the motor windings to be reduced. Induction motors are also available with more than three stator windings to allow a change of the number of pole pairs. However, motor with several windings is more expensive because more than three connections to the motor are needed and only certain discrete speeds are available. Another alternative method of speed control can be realized by means of a wound rotor induction motor, where the rotor winding ends are brought out to slip rings.

8. INDUCTION MOTOR SPECIFICATIONS:

Table 1. Induction Motor specifications

Rated Power	0.37kW/0.5 HP
Rated Current	1.4A
Voltage	415V
Speed	1330 rpm
% Efficiency	64
Frequency	50Hz

9. RESULTS

Computer simulation is a widely accepted tool for analysis and design of electrical systems, the large interconnected power systems. Digital simulation tools like MATLAB offer a convenient mechanism to solve these problems.

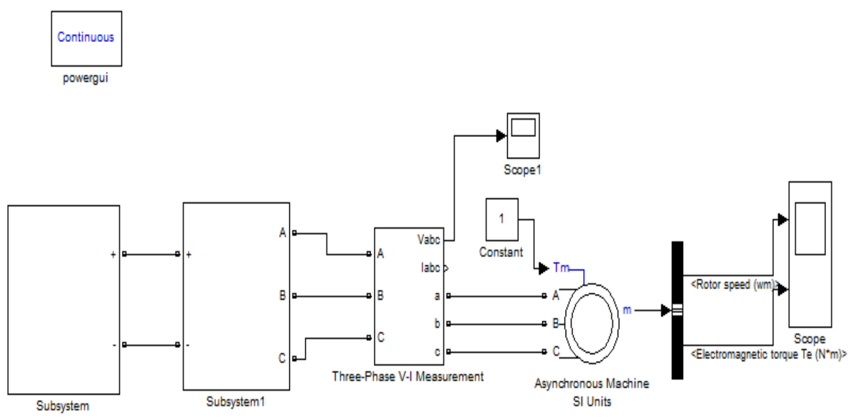


Figure 6. Complete system simulation Diagram of PV Cell Fed induction Motor

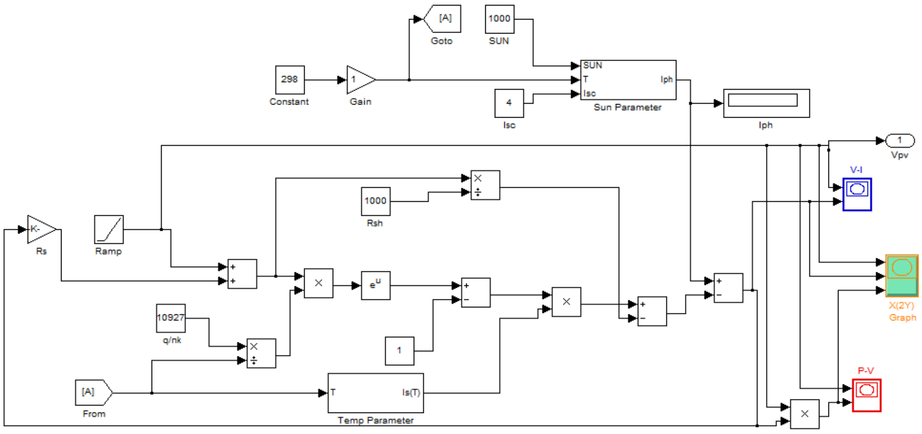


Figure 7. Subsystem of PV Cell

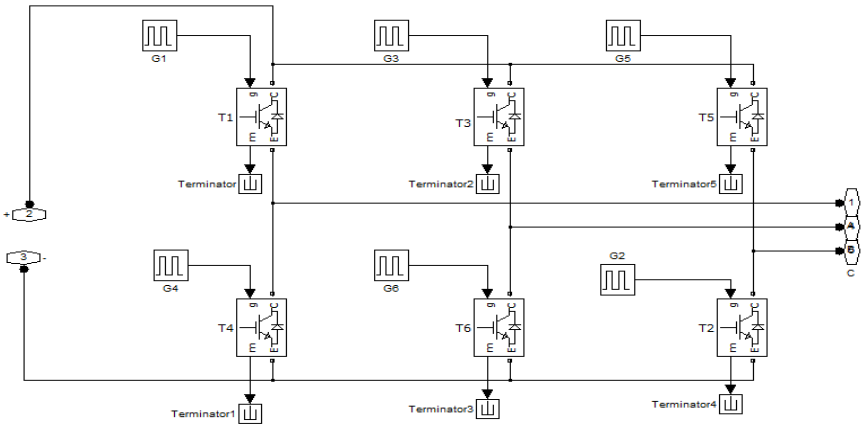
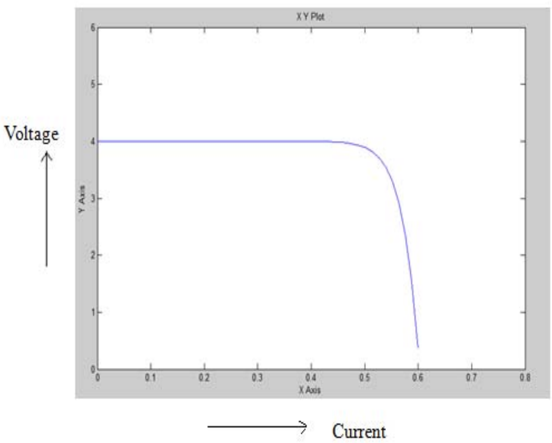


Figure 8. Subsystem of Voltage Sourse Inverter



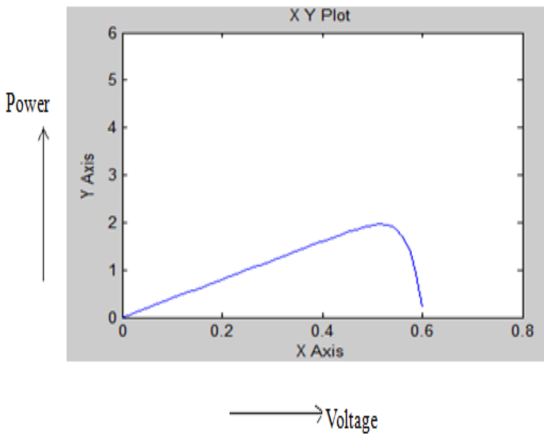


Figure 9. V-I Charactorstics Of Induction Motor

Figure 10. P-V Charactrostics of Induction Motor

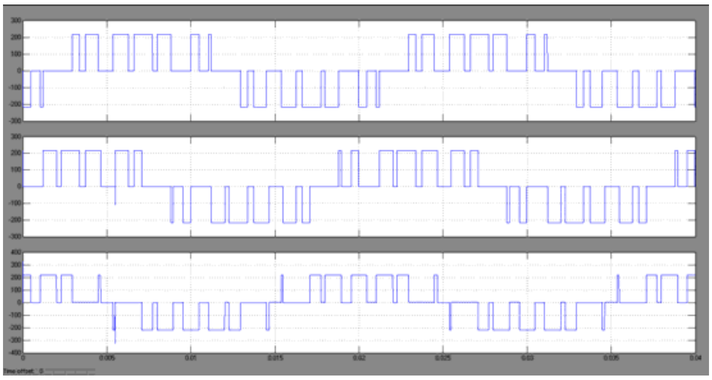


Figure 11. Inverter Output Voltages of Va, Vb, Vc

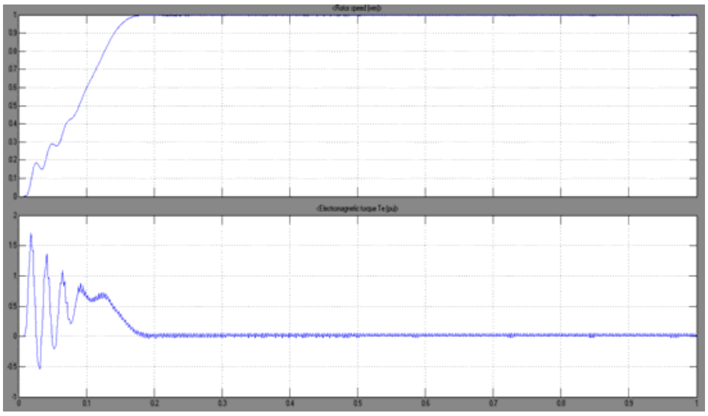


Figure 12. Speed and Torque characteristics Induction motor

10. CONCLUSION

The main objectives were to achieve maximum power output from the PV array and to inject a high quality AC current into the grid to transfer that power. To that aim, the PV cell equivalent circuit model was obtained to construct the system and then focus was directed towards the power conditioning system (PCS) and its controls.The first stage of the PCS was a DC-DC boost converter responsible for extracting maximum power from the PV array and increasing its output voltage. The second stage of the PCS was a current controlled voltage source inverter (VSI) that converted the DC power of the array into AC power and injected it into the grid. The control technique relied on transforming the three phase currents and voltages into a rotating reference frame and then regulated the resulting *dq* current components.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the K.Vasavi, K L University, Vijayawada. and particularly the Principal, Prof. K. Phanidra Kumar for the financialy support and for the facilities offered in these researches.

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