# Photovoltaic Powered Centrifugal Water Pump

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### Abstract

In this paper a modest Photovoltaic (PV) powered centrifugal water pump scheme for underground water pumping is presented. The decline in fossil fuel resources has led to the exploration of nonconventional energy resources. Thus, in this paper the use of solar energy using photovoltaic array is presented. The underground water pumping is a daily affair in houses, industries and irrigation. Also, water pumping is required in remote locations where grid electricity is not available. Thus, using solar energy for water pumping is one of the solutions available. The DC power generated from photovoltaic array is converted into AC through inverter using sinusoidal pulse width modulation (SPWM) and pulse amplitude modulation (PAM).

**Keywords**: Photovoltaic array, PV array, solar energy, centrifugal pump, SPWM, PAM.

# 1. Introduction

Water is daily required for drinking, irrigation and industrial processes. The water required is pumped from ponds, rivers or underground reservoirs. The pumps run on electricity. Thus, pumps are major consumers of electrical energy [1]. Electricity is primarily produced using fossil fuels, which causes pollution. Fossil fuel resources are declining very fast and the cost is rising up too. All these problems have led to the exploration of non-conventional energy resources for electricity generation. Thus, the use of solar energy is on the rise. Though the system initial cost is high and efficiency is less electricity can be easily generated from solar energy using solar cells (Photovoltaic cells) which is pollution free. Research is going on to bring down the cost and improve the efficiency of solar cells. Thus, solar energy is a good alternative to fossil fuels for electricity is not available or less available. In such cases too using solar energy is a good option. The pumps mainly used for water pumping are

positive displacement pump and centrifugal pump. The centrifugal pump is used for constant head applications. In this paper the pumping scheme is designed for constant head underground water pumping. PV system can be used to drive a permanent magnet synchronous motor (PMSM) drive to run a pump under wide variation of solar radiation [2]. Induction motor (IM) can also be used to run a submersible pump [3].  $3-\phi$  PMSM and IM are used for high power applications. For low power application  $1-\phi$  IM is used as it offers high starting torque required for pumping operation. Thus, in this paper photovoltaic powered induction motor driven centrifugal water pump is presented.

### 2. Proposed Model

The photovoltaic powered induction motor driven centrifugal water pump is modeled using MATLAB/SIMULINK environment. Figure 1 shows the proposed MATLAB/SIMULINK model of the photovoltaic powered centrifugal pump.



Fig. 1: Proposed MATLAB/SIMULINK model.

PV array composed of several solar cells traps the incident solar radiations and convert it into electricity. The PV array is a dc current source. A converter is used to make the PV array a voltage source. The output of this converter is scaled to required voltage level by a DC-DC boost converter. The dc electricity is converted to ac electricity using an inverter. In the inverter there are three components. The first component sinusoidal pulse width modulation (SPWM) block converts the dc electricity to non-sinusoidal ac electricity. The second component pulse amplitude modulation (PAM) block converts the non-sinusoidal ac waveform to approximate sinusoidal waveform. Finally, the third component filter block outputs a pure sinusoidal ac waveform which is applied to the 1- $\phi$  IM. The centrifugal pump is mechanically coupled to the shaft of IM. The discharge pipe of the centrifugal pump is connected to the tank.

Using equation (2) the rating of motor required is calculated. For a head of 45 m, flow rate 50 l/min and pump efficiency 60% the motor of rating ~0.63 kW is required. The closest matched motor available is of rating 0.75 kW. Therefore a 1- $\phi$  220 V 50 Hz 0.75 kW induction motor is used in the presented scheme. The PV array used in the presented scheme consists of three 250 W solar panels, thus the total rating of the PV array is 0.75 kW.

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# 3. System Details 3.1 PV Array



Fig. 2: Equivalent model of a solar cell.

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Table 1: Electrical specifications of

Parameter	Value
Maximum power	250 [W]
Voltage at maximum power	29.8 [V]
Current at maximum power	8.39 [A]
Open circuit voltage	36.9 [V]
Short circuit current	9.09 [A]

The equivalent model of a practical PV cell is shown in figure 2. Equation (1) gives the practical model a PV cell [4]. Based on this equation a solar cell is modeled in MATLAB/ SIMULINK. Using the specifications [5] from table 1, 60 solar cells are connected in series to obtain a PV panel of 250 W.

$$I = I_{ph} - I_s \left( e^{\frac{q(V+R_s I)}{NkT}} - 1 \right) - \frac{(V+R_s I)}{R_{sh}}$$
(1)

250 W PV panel.

Where I is the output current,  $I_{ph}$  is the photocurrent proportional to Insolation,  $I_s$  is the reverse saturation current of the diode, q is the electron charge, V is the output voltage,  $R_s$  is the series resistance,  $R_{sh}$  is the shunt resistance, N is diode ideality factor, k is Boltzmann's constant, T is the junction temperature.

#### 4. Motor and Pump

 $1-\varphi$  induction motor with cage rotor is used in the presented scheme. Two value capacitor or Capacitor start-Capacitor run method is employed for starting the  $1-\varphi$  IM. The start capacitor cuts out of the circuit when the motor speed becomes 75% of its synchronous speed. This method is used for loads of higher inertia. Thus, this method is suitable for Pumping operation. Also, this method is highly efficient. The centrifugal pump is of the rotating impeller type. The power required at the pump shaft is dependent on the head and flow rate of the fluid. Equation (2) gives the power required at the pump shaft.

$$P = \frac{q\rho gh}{3.6 \times 10^{-6}} \times \frac{1}{\eta}$$
(2)

Where P is the powered required at the pump shaft [kW], q is flow rate [m3/hr],  $\rho$  is density of fluid [kg/m<sup>3</sup>], g is acceleration due to gravity [m/s<sup>2</sup>], *h* is head [m] and  $\eta$  is efficiency. Using the specifications [6] from table 2 the IM and centrifugal pump is modeled in MATLAB/SIMULINK.

Table 2: Pump spe	cifications
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Power	Voltage	Current	Maximum flow rate	Maximum Head
0.75 [kW]	220 [V]	4.8 [A]	50 [l/min]	45 [m]

# 5. Simulation Results

The power-voltage (PV) and current-voltage (IV) curves of the photovoltaic array at Standard Test Condition (STC) i.e. at 25 [°C] temperature and 1000 [W/m<sup>2</sup>] irradiance and Nominal Operating Cell Temperature condition (NOCT) i.e. 20 [°C] temperature and 800 [W/m<sup>2</sup>]irradiance is shown below in figures 3 to 6.





The output of the constant current to constant voltage source is shown in figure 7. The output of this block is 110.7 [V] dc at STC. The output of the DC-DC boost converter is shown in figure 8. The dc voltage is boosted to 220 [V]. The output of the SPWM inverter is shown in figure 9. The output is a non-sinusoidal ac waveform. The output of the PAM block is shown in figure 10. The output of the filter block is shown in figure 11. The output of this block is a sinusoidal ac waveform.





Fig. 11: Filter output.

Thus, the motor is run at 220 [V] 50 [Hz] ac. The motor current, torque and speed curves are shown below in the figures 12 to 14.





The pump pressure in [psi] is shown in figure 15. The water flow rate in [l/min] is shown in figure 16. The water volume in the tank in [l] is shown in figure 17. The simulation results show that under STC a 1000 [l] tank can be filled in 22 [min].



# 6. Conclusion

The photovoltaic powered centrifugal pump is presented in the paper. The power required by the pump can be delivered by either PMSM or IM depending on the head and flow rate. In this paper a 1- $\varphi$  IM is used to drive the pump for mentioned head and flow rate. The 1- $\varphi$  IM is powered by a 0.75 [kW] PV array. A constant dc voltage can be obtained using DC-DC boost converter. The inverter comprising of SPWM, PAM and filter blocks delivers a sinusoidal ac waveform to the 1- $\varphi$  IM. The scheme can be developed for any power requirement using equation (2) and connecting more PV panels in series.

# References

- [1] Chufu L, Xiaobin H, Weidong G. *Application of distributed wind (solar)/grid complement system for oil pumping machines in oilfields*. World Non-Grid-Connected Wind Power and Energy Conference (WNWEC), 2010; 1-3.
- [2] Dubey M, Sharma S, Saxena R. *Solar PV stand-alone water pumping system employing PMSM drive*. IEEE Students' Conference on Electrical, electronics and Computer Science 2014; 1-6.
- [3] Vivek V, Uma G, Devi R.P.K, Chellamuthu C. Performance of induction motor driven submersible pump using Matlab/Simulink. International Conference on Power System Technologies 2002 Proceedings PowerCon 2002; 2:765-768.
- [4] Villalva M.G, Gazoli J.R, Filho E.R. *Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays.* IEEE Transaction on Power Electronics 2009; 24(5):1198-1208.
- [5] Information on http://www.kyocerasolar.com/assets/001/5130.pdf
- [6] Information on http://omeik.en.alibaba.com/product/721218846-214867047/JET\_S\_series\_1kw\_pump.html
- [7] Krause P.C, Wasynczuk O, Sudhoff S.D. Analysis of Electric Machinery. IEEE Press 1995.