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Grid Interfaced Solar Photovoltaic Array Based Water Pumping System

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ABSTRACT

This study proposes design of grid interfaced solar photovoltaic array-based water pumping system. DC-DC boost converter is used to step up Solar Photovoltaic Array. Single phase inverter is implemented to convert DC output into AC. Single phase induction motor is coupled with centrifugal pump. The proposed system is simulated in MATLAB and results are to be verified.

Keywords : SPV Array, DC-DC Boost Converter, Single Phase Inverter

I. INTRODUCTION

Indian economy is mostly based on agriculture sector, due to this reason water pumping is very important aspect. In many of the rural area of our country i.e. remote and tribal areas are not facilitated with electric power supply. Also, in many areas electric power supply is not reliable for agriculture sector. Thus, agriculture is mostly affected due to frequent power cuts.

To overcome these problems, there should be a particular solution which will satisfy the reliability of electric power supply. For such scenario the best alternative for conventional sources is Solar Energy. Solar energy is available in ample and it is environment-friendly. But in order to trap this solar energy in terms of electric energy there is need of designing power electronic circuits. This energy is sensitive to environmental condition like temperature, sun rays, etc. This solar system can be used in two ways i.e. stand alone and grid interface, due to the certain disadvantages of standalone system, grid interfaced based system is preferred. Still in grid interfaced system research work is going on in order to utilize more solar energy effectively. Hence in this project, work is focused on grid interfaced system for solar water pumping application.

II. METHODS AND MATERIAL

The system configuration of PV array based water pumping system is depicted in fig 1.

In the proposed system 0.5hp induction motor is used. Considering all the losses, 600W solar PV panel is used. Using MPPT system when operated at maximum power point, we get 104 as output voltage at 600W as output power. This output voltage is fed to DC-DC boost converter, which steps up this output voltage to 350V. By using proportional integral controller ripples in the output voltage of converter are controlled. Single phase inverter is used to convert DC to AC; this square wave output is passed through the LC filter to obtain the sinusoidal output, which is fed to single phase induction motor.

A. Solar array design

The panels in the array can be electrically connected together in series, parallel, or a mixture of two, but generally a series connection is chosen to give an increased output voltage. Modules are connected in series to form PV (photovoltaic) array of 600 Watt. In this system6 solar panels are used of 100Watt. The specification of the solar panel are as follows:

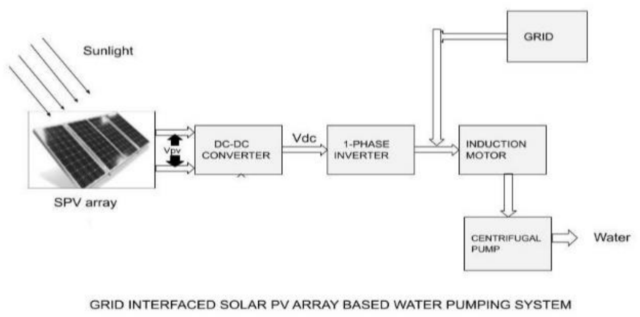


Fig.1 Grid Interfaced Solar PV Array Based Water Pumping System.

Table 1

Maximum Power (Pmax)	100 W
Open circuit voltage (V_{oc})	21.6V
Short circuit current (Isc)	6.588 A
Voltage at maximum power (Vmp)	17.4 V
Current at maximum power(Imp)	5.747 A
Maximum system voltage	1000 VDC
Maximum reverse current	7 A

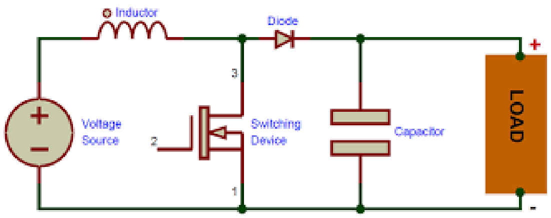
B. DC link voltage

The DC link is selected higher than peak amplitude of phase voltage of the motor for proper control as,

$$V_{dc} < \sqrt{2} \times V_L = \sqrt{2} \times 220 = 311\ V$$

Hence, 350 is selected as DC link voltage.

C. DC-DC boost converter



The output voltage from the PV array is 104V at maximum power point and this voltage is boosted to the DC link voltage equal to 350V.

The duty ratio for the boost converter is calculated as,

$$D = \frac{V_{dc} - V_{in}}{V_{dc}} = \frac{350 - 104}{350} = 0.70$$

The value of the inductor can be calculated as,

$$L = \frac{V_{in}D}{\Delta I f_s} = \frac{104\ \times 0.70}{0.2 \times 2.6 \times 20000}$$
$$= 7.0 \times 10^{-3}\ H$$

Where, f_s is the switching frequency and ΔI is the ripple allowed in the current, which is taken as 20% of rated load current. Hence the value of inductor is selected as 8$\times$ 10^{-3} H.

D. Single phase inverter

The desired voltage to drive the induction motor is 230V in form of AC voltage, so the DC output of DC-DC converter is to be converted into AC and hence the single-phase inverter is used and this AC signal is then filtered to get the sinusoidal AC wave.

To filter out this AC signal LC filter is used to get smooth sinusoidal AC wave. The inductor and capacitor is designed as per the designed equation given here,

$$L_1 > \frac{V_{dc}}{\sqrt{2}\pi f_{sw} 3\Delta I}$$

$\boldsymbol{V_{dc}}$ is input DC voltage which is 350V,
switching frequency ($\boldsymbol{f_{sw}}$)is 20000 Hz,
Hence $\boldsymbol{L_1}$ is selected as 0.025 H.
The frequency for capacitor can be selected as,

$$10 \times f_o < f_{res} < \frac{1}{2} f_{sw}$$

$$\boldsymbol{C_1 = \frac{1}{4\pi^2 f_{res}^2 L_1}}$$

The value of resultant frequency is selected as 750 Hz. The value of capacitor is calculated as $2\mu F$.

E. Parameter for pump:

For water pump proportionality constant is estimated as,

$$\boldsymbol{k = \frac{\tau}{\omega_r^2}}$$

Where, τ is the load torque of the pump,
ω_r is the speed of the motor in rad/sec.
The rated torque of selected induction motor is taken as 2.5 Nm.

$$\boldsymbol{k = \frac{\tau}{\omega_r^2} = \frac{2.5}{(2\pi \times \frac{1430}{60})^2} = 1.11 \times 10^{-4}}$$

So, proportionality constant is taken as 1.11×10^{-4}.

III. CONTROL SCHEME FOR PROPOSED SYSTEM

A. Proportional integral (PI)controller

The proportional integral mode controller is commonly used in slow to moderate speed process. The use of an integral controller always reduce the relative stability of the system. This can be overcome to some extend by adding a proportional controller. Therefore, the integral mode is frequently combined with the proportional mode to provide the automatic next action that eliminates the proportional offset.
The integral term is given by

$$I_{out} = K_i$$

The controller output is given by

$$K_P \Delta + K_i \int \Delta \, dt$$

Where Δ is the error or derivative of actual measured value (PV) from the set point (SP).
Δ= SP-PV
Where, $K_P$is proportional gain and K_i is integral gain . The combination of proportional and integral term is important to increase the speed of the response and also to eliminate the steady state error.

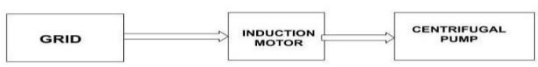
B. Sinusoidal pulse width controller

PWM is the technique to control the output voltage of the inverter. In this method the reference sinusoidal wave is compared with carrier triangular wave to produce pulses at intersection points. The output voltage of inverter and its frequency is controlled by the reference signal. The ratio of the reference wave to the carrier wave is termed as modulation index. The modulation index ranges from 0 to 1. Higher the value of modulation index lesser is the total harmonic distortion content of output voltage waveform. The ratio of carrier frequency to that of the frequency of the reference is termed as frequency modulation rate.

IV. RESULT AND DISCUSSION

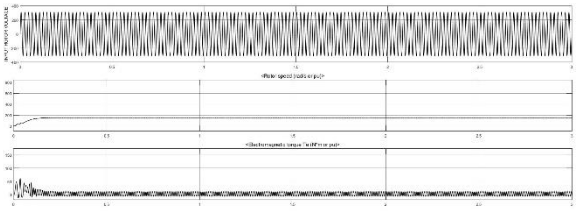
Simulation is used to evaluate the performance of grid interfaced solar PV array-based water pumping system. Using MATLAB/Simulink proposed system is designed, modelled and simulated. The simulation result are as follows

A. Performance of grid connected water pumping system



GRID CONNECTED WATER PUMPING SYSTEM

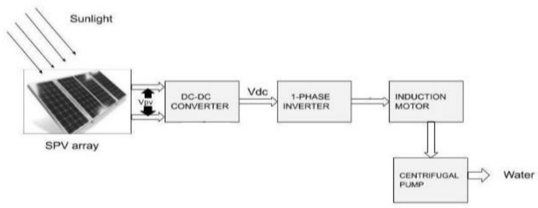
When induction motor is connected directly to grid, output waveform obtained as follows



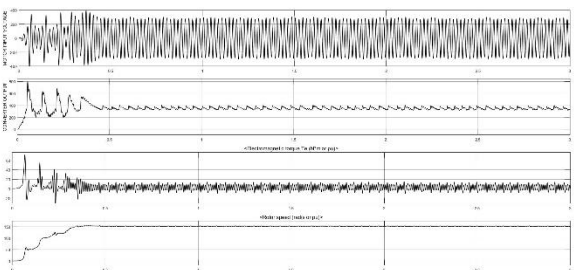
After initial variation in torque and speed, constant value of torque and speed is obtained giving required value of voltage for driving the induction motor.

B. Performance of solar PV array-based water pumping system

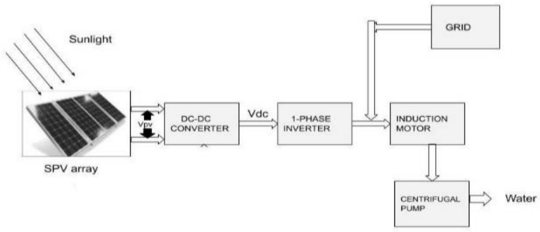
In this case, initially the value of DC-DC converter output voltage is not constant. When the torque and rotor speed value stabilize, DC output voltage become constant .Also, the required voltage of inverter is obtained.



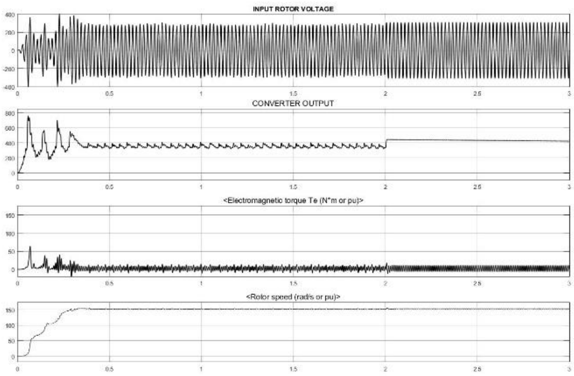
Solar PV Array based water pumping system



C. Performance of grid interfaced solar PV array based water pumping system



GRID INTERFACED SOLAR PV ARRAY BASED WATER PUMPING SYSTEM



When grid and solar PV array is interfaced initially solar PV array is operating. In this state, torque and DC output is having minor instabilities. When solar PV array is disabled then grid gets connected to the induction motor. Relatively, outputs of the grid connected system are more stable.

V. CONCLUSION

For driving the pump, the PV powered single phase induction motor can be used. The voltage obtained from PV panel is boosted using DC-DC converter and then converted to AC signal using single phase voltage source inverter (VSI) with the help of sinusoidal pulse width modulation (SPWM) technique. Single phase motor is driven by the output of VSI.

V. REFERENCES

[1]. K Ramaya, S. R. Reddy, “Design a simulation of photovoltaic induction motor coupled water pumping system,” International Conference on Computing, Electronics and Electrical Technology (ICCEET), pp.32-39,2012.

[2]. B. Singh, S. A. Daniel, H. H. Sait, “Analog controller for photovoltaic array fed inverter driven single phase induction motor.”

[3]. K. J. Lee, H. G. Kim, T. W. Chun, “High performance drive of single-phase induction motor,” IEEE International Symposium on Industrial Electronics (ISIE), pp.983-988,2001.

[4]. H. Kukde, A. S. Lilhare, “Solar powered brushless DC motor drive for water pumping system,” International Conference on Power and Embedded Drive Control (ICPEDC), pp.405-409,2017.

[5]. N. Mohan, T. Unleand, W. Robbins, “Power electronics: converters, applications and design,” vol. 3, India, John Willey & Sons Inc.,2009.

[6]. Sachin Jain, Athiesh Kumar T,” A single-stage photo voltaic system for a dual-inverter fed open-end winding induction motor drive for pumping applications,” IEEE, pp.0885-8993,2014.

[7]. Bhim Singh, Utkarsh sharma, sahilendra kumar, ” Standalone photovoltaic water pumping system using induction motor drive with reduced sensors,” IEEE, pp.0093-9994,2018.