Simulation of Solar Powered Water Pumping System Using Induction Motor

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Abstract:- This paper is dealing with the design and simulation of single stage solar powered water pumping system using 5 hp three phase induction motor coupled to the pump. The main scope is for providing a economic way for pumping water to sub-urban areas. In this paper the designing and evaluation of the solar panels powered induction motor driven water pumping system is configured. The main functions of the proposed control strategy are: 1) making sure that starting motor is successful, 2) matching the available PV power with the available induction-motor pumping load, and 3) making the PV system for operating at the maximum power point by using MPPT algorithm. The simulation outputs will be available in numerical or graphical format. The induction motor has been chosen because these type of motors are low cost and are more robust when compared to the conventional DC motors. It is being expected that, with use of an induction motor, for equal amount investment the system performance may improve significantly. The energy source is a photovoltaic (PV) module as it is a current source. The Modelling & Simulation of system is being carried out with MATLAB software. The PV panel structure is designed for maintaining the systems operating point at the PV operation of the unified system using and not using controller in non varying and varying solar irradiations. The important objective is to run the system in non varying and varying solar irradiations as close as possible at the maximum power point operation.

I. INTRODUCTION

SPV (Solar Photo Voltaic) energy was introduced in late 80s and it has achieved high significance by mid 90s. Earlier PV cells were slightly inefficient having the efficiency as less as 5-6% and were costing high. However, as technological research has increased the efficiency of PV array, now a days, it has increased to 15-16% and the cost is being reduced gradually. Now a days, SPV array is seen as one of the promising choices for the fossil fuel based electricity generating systems, as there is no emission of toxic, no emission of greenhouse gases, no cost involvement of fuel, cost for maintenance is low, no usage of water etc. However, this technology is in developing phase andit has many challenges which need to be addressed. In sub urban areas where there is no electricity solar powered water pumps are getting popular. Moreover, solar power fed water pumps are the accesable method in the rural areas for irrigation, water plant treatment, and agriculture purpose. Countries like India, where 70% population are depending on agriculture so, water is essential for good yield. In the world. The design of a motor drive system powered directly from a PV source is demandng creative solution for facing the challenges of operation under the variable power restrictions and still maximizing the energy being produced and the amount of water pumped. The evolution is intended for developing production, reliabilty, maintenance-free and cheaper SPV water pumping system .The water pumping system fed directly from SPV array requires creative methods for operating under different power conditions and for maximizing the energy consumed from the solar array and amount of water being pumped. The presented paper deals with a three-phase IMD for solar water pumping which fulfils the need of life without electricity in remote locations. In this paper, inverteris fed with the DC voltage obtained from solar PV array at MPP for making it alternating in nature and induction motor is being fed with this voltage. A centrifugal pump that is mounted on the same shaft is driven of induction motor.

II. PHOTOVOLTAIC MODELLING

Basic unit of life is energy. The mankinds existence is not possible without energy. This paper is deals with electrical energy. In the present scenario, the electrical energy source is only from non-renewable resources. These resources are used for benefiting mankind. However, after some decades these non-renewable resources may not be available. The only possible way isto use renewable resources which are in abundance in nature. The photovoltaic resource has a key role amongst the renewable resources. This paper mainly focuses on how to utilize the solar power in a more efficient way for pumping water in sub urban areas where there is no electricity. A solar cell is traps the solar energy from sunlight. A converter has placed at the solar cell output side for processing the power being generated by the solar cell. A three phase inverter is chosen for water pumping application. There may be ripples in output voltage of the converter. To reduce this ripples LC filter is used next to the converter. The main disadvantage for using solar PV system is the fundamental cost. However, researches are going on to overcome this disadvantage.

➢ *Photovoltaic Cell*

The basic building block of solar photovoltaic is the solar cell. Solar cells have a pn junction in a thin wafer or layer of semi-conductor, the cell may be taken as a two-terminal device that conducts like a diode in the absence of sun light and generates a photovoltaic voltage in the presence of the sunlight. The surface is treated so that it can reflect visible light as little as possible and so it appears dark blue or black. to make electrical contact a pattern of metal contacts is imprinted on the surface. When kept in the sunlight, this basic unit produces a dc photo voltage from 0.5 to 1 volts and when short circuited, a photo current of some tens of milliamps per cm^2.

➢ *Photovoltaic module*

Though the current is okay, but the voltage is too small for many of the applications. So for producing required dc voltage the cells are connected in series and form modules. A module mostly have 28 to 36 cells in series, for generating a dc voltage of 12V as output in standard illumination conditions.12 V modules may be used single or connected in parallel and series in an array with a large currents and voltages outputs. Cells in module are attached with blocking diodes so that we can avoid the complete loss of power which can be resulting if one of the cells in the series has failed. Modules within arrays are protected in the same way. The arrays, which are also called a photovoltaic generators, are designed for generating power at some value of current and voltage which is the multiple of 12 V, under standard illuminations. For most of all application, illuminations are variables for the operation to be efficient at any time and the photovoltaic generators have to be integrated with a battery and with components for regulation of power as shown in Figure 3.1.

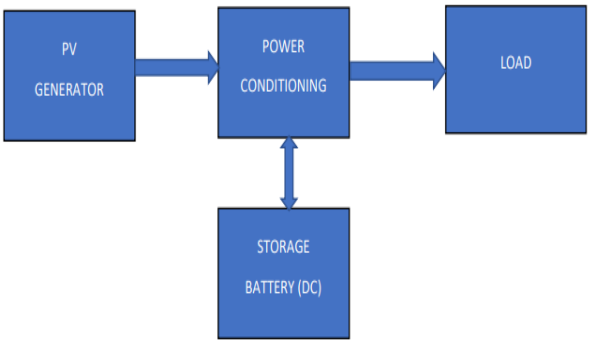

Fig. 3.1 Photovoltaic array integrates with components for charge regulation and storage

➢ *The Photovoltaic Effect*

Conversion of Solar power is a process of one-step conversion in which generates electrical energy from solar energy. The explanation depends on the idea taken through the quantum theory. Light is build with photons, whose energy depends only on the frequency, or colour, of the light. When cells are exposed to light photons with energy more than the energy of band gap of semiconductors is absorbed and created a electron-hole pairs. These carriers are moved under the influence of the internal electric field of the p-n junction by which creating a current proportional to incident radiation. When the cell is in a short circuit position, the current flows through the LOAD POWER CONDITIONING STORAGE BATTERY (DC) PV GENERATOR 9 in the external circuit; when the cell is in open circuit position, this current is shunted internally by an intrinsic pn junction diode. Normally, when matter absorbs light, electrons are excited to higher energy states by the photons within the material, but these electrons relaxes quickly and return to their initial state. In a photovoltaic device, however, there is some in-built feature which pulls the excited electrons back before they are being loosen up and fed them into the external circuit. The extra energy from the excited electrons is generating a potential difference, or electromotive force (e.m.f). This force is driving the electrons through a load in the external circuit for doing electrical work.

➢ *Single Diode Model of PV Cell Typically*

A solar cell maybe modelled by a current source and an inverted diode connected in parallel to each other as shown in Fig. 3.2. It will have its own resistance in series and parallel. The resistance in Series is because of hindrances in the way of electrons flow from the n to p junction and the resistance in parallel is because of the leakage currents.

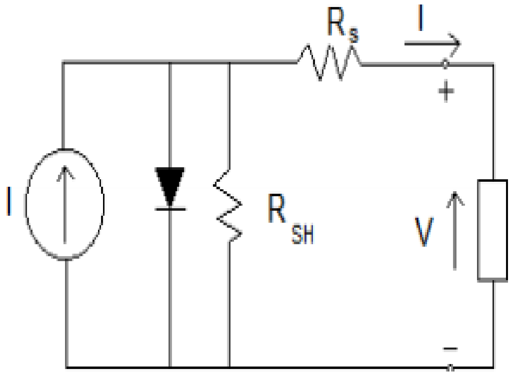

Fig. 3.2 Single diode model of a PV cell

From the above model we are considering a current source (I) along with a diode and resistance in series (Rs). The resistance in parallel(RSH) has a very high value, and it has a negligible effect so it is neglected. The output current from the photovoltaic array is

I=Isc–Id (3.1)
Id= Io (eqVd/kT -1) (3.2)

where Io is the diode reverse saturation current, q is the electron charge, Vd is the voltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the temperature of junction in Kelvin (K)

From eq. 3.1 and 3.2
I = Isc – Io (eqVd/kT -1) (3.3)

conisidering approximations,
I = Isc– Io (eq((V+IRs)/nkT) -1) (3.4)

where, I is the current of photovoltaic cell, V is the voltage of PV cell, T is the temperature (in Kelvin) and n is the diode ideality factor for modelling the solar panel accurately we are using two diodes model but in this paper the scope for studing is limited for the single diode model.

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➢ *Motor-Pump Subsystem*

Solar powered water pumping system is one of the most appreciated application to distribute energy generating systems. The three-phase inverter is generating a output waveform of variable frequency for driving the Induction Motor. A centrifugal pump which delivering the water output is driven by the motor. generally Induction Motor drive is based on v/f control, indirect field oriented control (IFOC) and slip control. The IFOC and the slip control makes sure that the decoupling between the flux control and the torque control. These control strategies are necessary for making sure the energy consumption by the machine acting on the electromagnetic torque, Te. So many different types of water pumps and motors are available on market. The type of pumps which are commonly used are the centrifugal pumps. For low head applications, Single-stage centrifugal pumps are mostly used in PV shallow water pumping. And for PV subterranean water pumping multistage centrifugal pumps are more. The performance curves of the pumps with good accuracy at high speed are not very accurate at low speed and with constant head applications. at very low speeds, the pressure of the pump is low when compared to the static pressure and the rotations just circulate the water within the pump. When the speed aproaches a threshold or base value the pump starts pumping water out and the rate of flow of water (Q, litre/min) varies linearly with the speed (ω). The torque of the motor for a centrifugal pump is directly proportional to the square of the speed of the motor. Tαω2 T=Kω2 Where K is the gain factor is considered as the value of 0.00279, this is calculated at the rated values of the motor i.e. K=T/ ω2 take the T as rated load torque in N-m ,take w as the rated speed in rad/sec Then T=0.00279ω2 from this formula only we will model the Induction Motor

Motor and PV Array Specifications

Motor specifications RATING: 5hp (4KW)
VOLTAGE: 400V
FREQUENCY: 50hz
SPEED: 1430 rpm.
Based on the pump specifications, motor specifications we have to take and we have to design the PV array module.

PV array specifications

SUN IRRADIANCE INITIAL VALUE=400W/m2
◊INPUT
1 SUN IRRADIANCE FINAL VALUE= 600W/m2
TEMPERATURE=280C,◊INPUT
2 Parallel strings=1
Series connected modules per string= 20,
Cells per module =60
Open circuit voltage Voc=37.1V,
Short circuit current Isc=8.18A,
Maximum power=228.735W/module

Consider the nonlinear model state equation of the two tank sytems as mentioned above. Designing of FOSMC involves two most important steps: (a) properly defining the sliding surface, (b) Designing the control law so that system trajectories reaches the sliding surface.

III. SIMULATION RESULTS

After running the complete MATLAB Simulink model of solar powered water pumping system using the three phase induction motor shown in Fig 4.6, Satisfactory results of change in insolation level from 400W/m2 to 600W/m2 are shown in Fig.4.7. In Fig 4.7, from 0 sec to 5 sec, solar insolation is 400W/m2 . In this condition, the motors are operated in rated conditions. The speeds and torques are maintained at their reference values. At 5 s, solar insolation level is changed to 600 W/m2 . Under this condition, torque and speed are increased and the stator currents are maintained sinusoidal. After change in solar insolation level, again the motor is operated with rated speed and frequency. The gate triggering circuit generates the pulses which are fed to the gate terminal of IGBT switches of the inverter. The pulse waveform is as shown in the Fig.5.1.

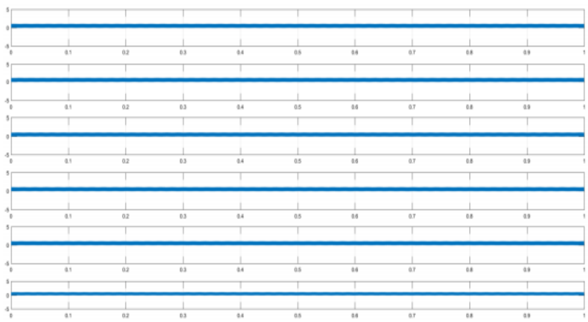

Fig. 5.1 Gate pulses triggering waveform

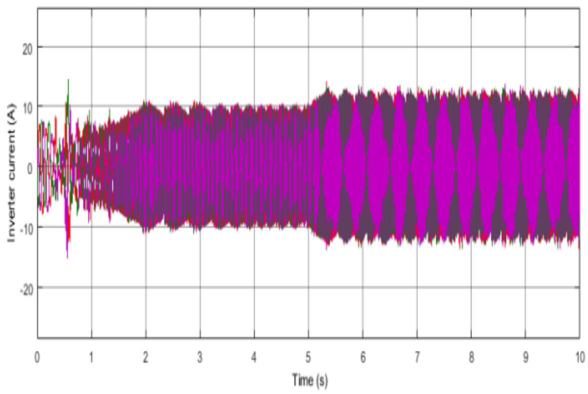

Fig 5.2 Three phase AC current waveform

The inverter converts the obtained DC output from the solar into AC. From the three-phase inverter we will obtain the three phase AC current and the voltage. Three phase current waveform is depicted in Fig.5.2 and three phase line voltage waveform is depicted in the Fig.5.3.

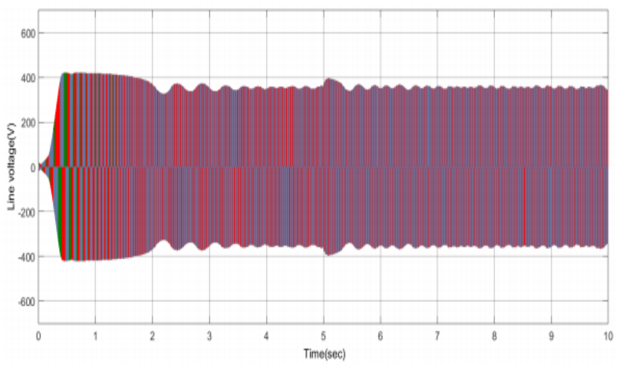

Fig 5.3 Three phase line Voltage Wave Form

By the change in insolation level from 400W/m2 to 600W/m2

the speed torque characteristics also vary as shown in the Fig.5.4.

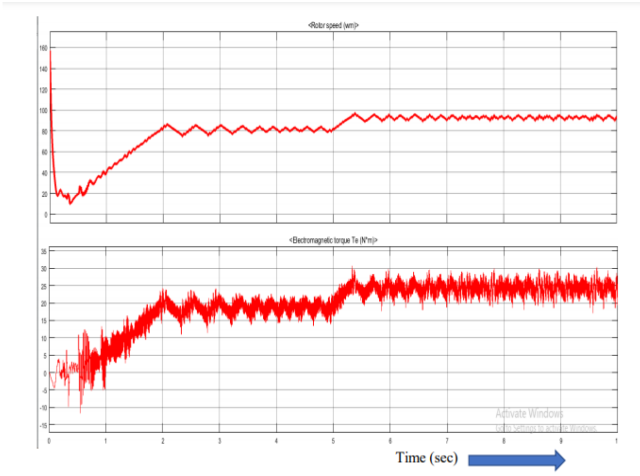

Fig 5.4 Speed and Torque waveforms of the Induction motor by the change in irradiance.

IV. CONCLUSIONS

In this paper a squirrel cage induction motor for water pumping application which is fed from a solar PV array is used. On the basis of simulation result it is shown that the IM is driven by PV energy. Solar PV array is operated at maximum condition during variable solar irradiation. Maximum power is achieved effectively from panel using MPPT (P&O) technique at different irradiances. The available DC power is converted into AC with IGBT based inverter. The SPWM technique for inverter switching is implemented on the system.

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