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SOLAR PV POWERED SRM MOTOR DRIVE FOR WATER PUMPING USING SINGLE STAGE POWER CONVERSION

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ABSTRACT- The power outage of electricity and high diesel costs widely affects the pumping needs of rural area water supplies and irrigation so using solar energy for water pumping is a promising substitute of conventional electricity and diesel based pumping systems. Photovoltaic (PV) technology is used in solar water pumping, that converts solar energy into electrical energy to run a DC or AC motor based water pump. This paper proposed a mathematical model of solar photovoltaic based pumping system and study the analysis of solar photovoltaic pumping system using SRM motor. A solar panel having several modules in series and parallel is designed and track the maximum power point in the panel. This paper deals with the simple and efficient Switch Reluctance Motor (SRM) which is supplied by solar photovoltaic (SPV) array directly through Asymmetric converter. In this system power is converted in DC - DC converter which leads to a decreased cost, size, complexity and increase efficiency. An optimize control of Duty ratio through Incremental Conductance Maximum Power Point Tracking (MPPT) algorithm offers smooth and soft starting on SRM Motor. The other features of the SPV fed system is that the motor current is restricted to an upper limit of PV array current. So that motor winding and power semiconducting switches can be protected against excessive current flow. The steady-state and dynamic Behaviors of SRM motor coupled water pump powered by SPV array at various conditions are presented to demonstrate the novelty of the proposed system. The modeling and simulation has been carried out using Simulink software environment with MATLAB.

Keywords—MPPT, SRM MOTOR, PV , PUMPING

1.INTRODUCTION

The high reduction in the cost of power electronic devices and extinction of fossil fuels in near future invite to use the solar photovoltaic (SPV) to generate the electrical energy for various applications as far as possible. The water pumping is a standalone application of the SPV array generated electricity, receiving wide attention now a day for irrigation in the fields, household applications and industrial use. Various researches have been taken out in an area of SPV array fed water pumping, combine with various DC to DC converters and motor drives.

The current world's consumption of electric energy is around 20-22 TW and the earth receives more solar energy in 1 hour than is the energy used in 1 year globally, considering the solar constant 1.7 x 10.5 TW at the top of the earth's atmosphere. However the solar energy incidence, around 1000W/m2, is quite dilute and requires vast area of energy converters to meet the world's energy consumption. Therefore high efficiency solar energy conversion is crucial. The volume of water, pumped by a solar powered pump in a given interval of time depends on the total amount of solar energy available in that time period. Particularly, the flow rate of the water pumped is determined by both the intensity of the solar energy available and the size of the PV array used to convert that solar energy into direct current (DC) electricity. The main components in a solar-powered water pump system include:

- The PV array and its supporting structure,
- An electrical controller or Pump Controller, and
- An electric-powered Water Pump.

It is important that the components can be designed as part of an integrated system to ensure that all the equipment is compatible and that the system operates as projected. It is therefore suggested that all components be obtained from a single supplier to ensure their compatibility. The conventional topologies adopt two stage solar energy conversion system, which essentially require an intermediate DC-DC converter to optimize the operating power point of a PV array. This power conversion causes an increased cost, size, complexity and reduced efficiency. As a unique solution of the aforementioned problems, the present work proposes a maximum power Point tracking in solar PV to improve the DC-DC conversion stage. It is capable of operating the solar PV array at its peak power using the same Asymmetric converter used for motor control. In addition, it constitutes the attractive merits of conventional topology, such as the elimination of SRM motor phase current sensing and soft starting. The speed of SRM motor is controlled through the optimum power of solar PV array. The bulky capacitor at the DC link is replaced with a low valued capacitor using a pulse width modulation (PWM) switching Asymmetric Converter. As of now, a single stage PV system has been proposed for an induction motor driven water pump. No attention has been paid towards SRM motor drive for such a system.

2.LITERATURE SURVEY

To ground this thesis, many research papers have been read have been based on performance evaluation, optimization, sizing techniques, efficiency improvement, and factors affecting system performance, economical and environmental aspects of PV pumping systems. The highlights of these research investigations are presented in this chapter under various section.

2.1 Performance parameters of a solar pump

In this section performance evaluation methodologies used in various studies are reviewed to provide further insight to the researcher. Gad [6] developed a system for performance calculation of a direct coupled PV water pumping system in South Sinai, Egypt using a computer simulation program. The program calculates the hourly performance of the system at any day of the year, under different PV array orientations. The model is found to be capable of pumping 24.06 l/day, 21.47 l/day and 12.12 l/day in summer solstice, equinoxes and winter clear sunny days respectively. The PV array efficiency are observed in the ranges from 13.86% in winters to 13.91% in summers. Katan et al. [7] observed the performance of a solar water pumping system consisting of a PV array, sun-tracker, a permanent-magnet (PM) DC motor, a helical rotor pump and observed that the performance of the system is improved when maximum power point tracker (MPPT) and a sun-tracker are added to the system. The analysis of the PV array was carried out using PSPICE software. Theoretical results are verified by field tests. Khan et al. [8] designed a solar photovoltaic water pump by feeding direct to a DC–DC buck converter to provide current boosting to the DC pump. No battery and inverter are used in the system so as to decrease the cost and maintenance. The highest no load speed goes up to 3000–3200 revolutions per minute (rpm). The results from the no load test given away that the integration of DC motor with the centrifugal pump has paired quite perfectly. A direct coupled system without an inverter and battery is compared with DC–DC convertor type system. The DC motor operating parameters such as voltage, current, shaft rpm and the discharge rate at diverse pressures during different times of a day for both systems are calculated and enhancement in the electrical power output is found in the designed DC water pumping system.

Setiawan et al. [9] presented various steps of development of a solar water pumping system to solve difficulty of water supply in Purwodadi Village, Gunungkidul, India. The authors suggested two important design parameters which are: analysis of piping system to determine the type of pump to be used and the power system planning. PV water pumping system developed was able to lift water to 1400 m. The system uses 32 solar PV panels to produce 3200Wp maximum power and operates two submersible pumps. The flow rate of water produced is about 0.4–0.9 l/s.

Reddy and Reddy [10] designed control system of electrical power supplied by PV to a single phase induction motor which is used for water pumping applications. The overall performance of a photovoltaic system can be enhanced with dynamic models for the Z-source inverter, single phase induction motor and artificial neural network based maximum power point tracking.

2.2 Optimal sizing of PV pumping system

Yesilata [11] used a simplified multi-step optimization procedure to improve operation of a direct-coupled photovoltaic water pumping systems. The main highlights of the study are as follows: Calculated the optimal monthly slope by the linear search method, Determined optimal solar radiation interval by utilizability method, Selected optimal PV array configuration as determined by a non-linear search method based on statistical parameters. Algorithm developed is simple, fast, and has no numerical problems. The performance of the system is analyzed for 16 years between 1985 and 2001. The system performance is found good with a lesser photovoltaic array area. The developed methodology is applicable to any other site in the world if long-term weather data are available.

3. SOLAR CELLS

Converting solar energy into electrical energy by using PV cells is the most recognized way to use solar energy. Since PV cells are semiconductor device, they have a lot in common with processing and production technologies of other semiconductor devices such as diodes, computers and memory chips. As it is well known, the requirements for purity and quality control of semiconductor devices are quite large and for solar cells purity is at least 99.9999 %. With today's production, which reached a large range, the whole industry production of solar PV cells has been developed and, due to low production rate, it is mostly located in the Far East. Crystalline silicon are used as semiconductor material to produced Photovoltaic cells by the majority of today's most large producers. Solar photovoltaic modules, which are a result of combination in series of photovoltaic cells to increase their power, are highly reliable, durable and low noise devices to produce electricity. The fuel for the PV cell is free. The light energy of sun is the only resource that is required for the operation of PV systems, and its energy is almost endless.A typical photovoltaic cell efficiency is about 15% to 20%, which means it can convert 1/5 to 1/6 of solar energy into electricity. PV systems produce no noise as there are no movi0ng parts and they do not emit pollutants into the atmosphere therefore we get clean energy from solar cells. Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit as compare to the energy produced from fossil fuel technologies. Photovoltaic cell has a lifetime of more than twenty five years and is one of the most reliable semiconductor products. Most solar cells are produced from silicon, which is non-toxic and is found in abundance in the earth's crust in major form of sand.

PV modules require minimal maintenance. PV modules bring electricity to remote areas especially to rural areas where there is no electric power grid, and thus increase the life value of these areas. PV systems will continue the future development in a direction to become a key factor in the production of electrical energy for households and buildings in general. The systems are installed on existing roofs and/or are integrated into the facade (BIPV panels). These systems contribute to reducing energy consumption in buildings. Also, PV technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electricity supply. By the beginning of incentives for the energy produced by renewable sources in all developed and developing countries, photovoltaic systems have become very affordable, and timely return of investment in photovoltaic systems has become less and constantly decreasing. In recent years, this industry is growing at very fast rate and the photovoltaic technology creates thousands of jobs at the local level.

4. SWITCHED RELUCTANCE MOTOR (SRM)

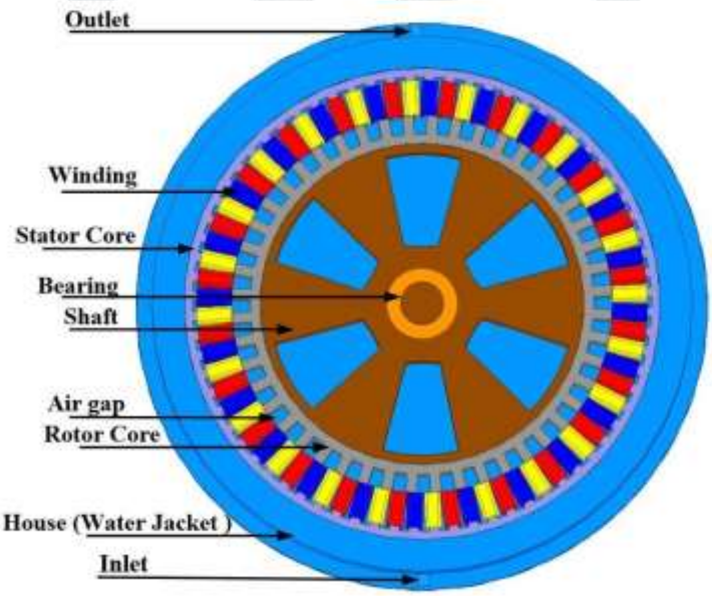

Figure 1.1:SRM Cross-Sectional View

The SRM is one of the oldest designs for an electric machine, dating back to the 19th century; it is also one of the simplest designs. Similar to the more popular designs, the SRM has a salient stator with windings. However, the rotor of an SRM is much more simplistic. The rotor contains no windings, brushes, or magnets; it is simply a salient piece of iron, Figure 1.1. This simple rotor design makes the machine significantly cheaper to fabricate. Another advantage of the SRM is the fact that the machine's phases operate independently. Torque is generated by pulsing a particular phase which generates a magnetic field. The rotor, attempting to minimize reluctance, generates torque to align with the pulsed phase. Torque can be maintained by independently pulsing the phases. Since the phases are operated independently, they can be controlled independently, and if one phase happens to fail the others can still operate. Furthermore, the SRM can reach higher speeds compared to other common machine designs. While the most common machines in industry are the Induction Machine, the Synchronous Machine, and the Permanent Magnet Machine, the SRM is experiencing an increase in popularity due to the fact that it is cheaper, can obtain higher speeds, and each phase can be controlled independently

5. PROPOSED SYSTEM

An appropriate design and specifications of SRM motor- pump and solar PV array play a significant role in the desired operation of a centrifugal water pump. A 6/4- 3 phase, 1500 rpm, 750 W SRM motor is chosen to drive the water pump. The PV array, DC link capacitor and SRM motor are selected such that functioning of the system is not deteriorate even by sudden change in the atmospheric conditions. The detailed specifications of SRM motor are

Parameter	Value
Rs	0.05 ohms
Ls	0.8 mH
Trated	5 Nm
Nrared	1500 rpm @ 130 V
Rated Power	750W
No. Of Phase	3
Inertia	0.05 kg.m.m
Friction	0.02 N.m.s

Table 5.1: Specification of SRM Motor

5.1 Estimation of Parameters of Solar Photovoltaic Array

A PV array with a maximum power capacity of 2.8 kW at standard atmospheric condition (1000 W/m2; 25°C) is designed as per the ratings of a selected SRM motor-pump. The operating power capacity of selected PV array is sufficient to run the motor-pump system at its rated condition, in addition to compensate the power losses associated with the Assymettric converter and motor-pump. A PV module with 60 cells connected in series is considered to make a PV array of the relevant size. Since a solar cell has an open circuit voltage in the range of 0.5 V-0.6 V at standard atmospheric condition, it is assumed that a module generates 60*0.6 = 36V as its open circuit voltage. The voltage of a module at MPP is around 75%-80% of the open circuit voltage. Therefore, it is estimated as, 36*0.8 = 29 V. The PV array voltage required at the DC link of ABC to run the selected SRM motor-pump at its rated torque and speed is 150 V. It is obvious that the voltage of PV array at MPP should be 150 V. Thus, the numbers of series connected modules are approximated as, 150/29 ≈ 5. Since the required maximum power capacity of the PV array is 750 W, the PV current at MPP is estimated as, 750/150 = 5 A. As per the design, this current is generated by the four modules connected in parallel, provided each module has an MPP current of 7.3A. It is generally found to be between 78% and 92% of short circuit current. The short circuit current of each module is therefore estimated as 6.74/0.9 ≈ 7.48 A. Ultimately, 24 modules each with PV voltage and current of 36V and 7.84 A at MPP, are connected (6 in series and 4 in Parallel) to design the PV array of 150 V , 5 A and 750W at MPP. The detailed design parameters are tabulated in Table.5.2

SPV Modules Parameter	**Values**
Voc	36 V
Isc	7.84 A
Vm	29 V
Im	7.35 A
Ns	6
Np	4
SPV Array Parameter	
Voc	36*6 = 216 V
Isc	7.84*4 = 31.36 A
Vm	29*4 = 116 V
Im	7.35*4 = 29.4 A

Table 5.2 SPV Parameters

5.2 Mathematical Modeling in Matlab

Simulink model of Solar Powered SRM Motor Drive for Water Pumping using Single Stage Conversion are shown in MATLAB

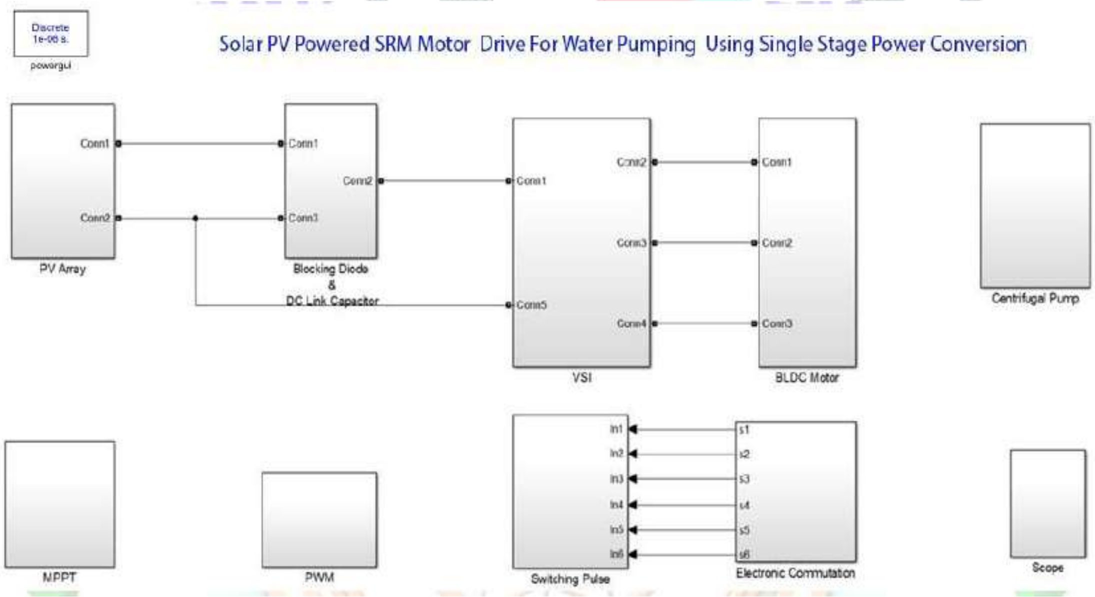

Fig 5.2.1 Matlab/Simulink model of Solar Powered SRM Motor Drive for Water Pumping using Single Stage Conversion

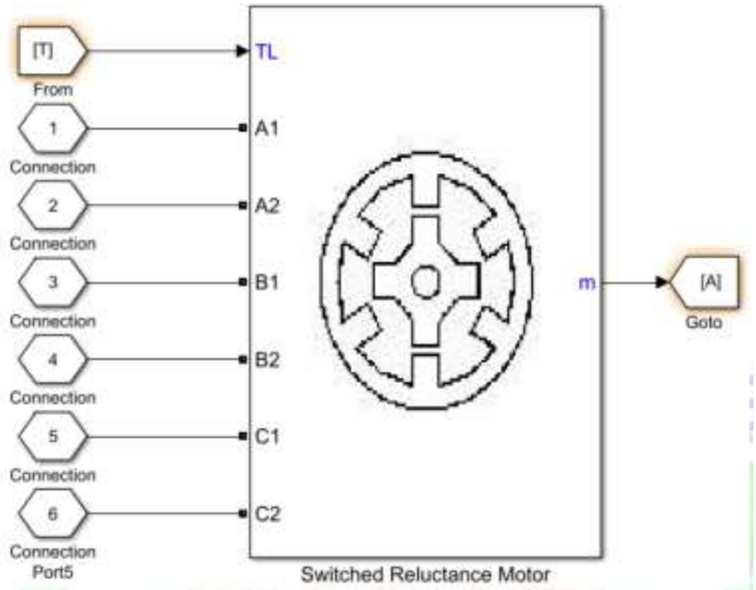

Fig 5.2.2 Simulink/Matlab Model for SRM Motor

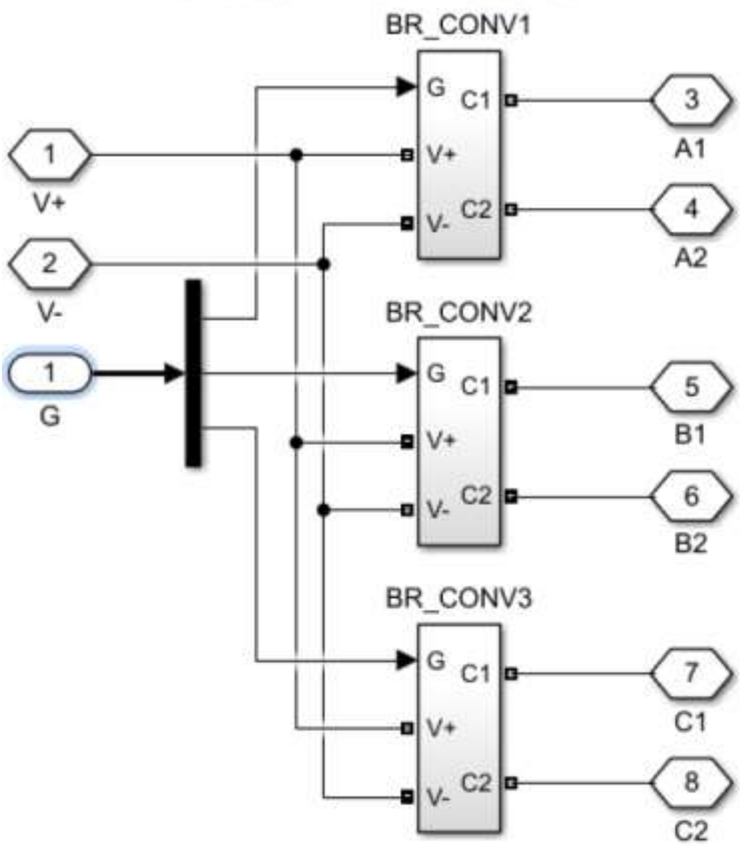

Fig 5.2.3 Simulink/Matlab Model for Switching Pulse of VSI

6. RESULT

The proposed system was simulated by MATLAB/SIMULINK to evaluate the system capability in response to different operation conditions. The PV array output power range is about 0.5 W to 1000W. Three different Steady state operating conditions are simulated and their results for different parameters Such as motor phase currents, voltages, rotor speed , electromagnetic and load torques and PV output power, voltage and current are observed. To elaborate the dynamic performance of the proposed system, the solar irradiance level is varied from 1000 W/m2 to 500 W/m2 and vice versa. These results verify the satisfactory performance of the proposed system even under the rapid variations in weather condition. An excellent tracking performance by the INC-MPPT technique at 1000 W/m2 and even under the dynamically changing weather condition also. Simulated results of proposed system are shown in Figs. 6.1.1 to 6.4.2.

6.1 Steady State Performances at 1000W/m2

Figs. 6.1.1 and 6.1.2 present the steady state performance of solar PV array and SRM Motor at 1000 W/m2 respectively. The PV voltage, VPV, PV current IPV are presented at an irradiance of 1000 W/m2 in fig 6.1.1. These indices demonstrate a fine tracking of the MPP. The speed N (rpm), Electromagnetic Torque Te (N*M), Stator Current I(a) , Flux v(s), Motor are presented in fig 6.1.2. The motor develops a rated torque, and the pump is operated at its full speed. A small ripple in the torque appears because of phase current commutation and phase current sensor-less operation of the motor. This causes acoustics and vibration in the motor, in general, at low speed. At higher speed range, there is no significance of these physical phenomena, as then the motor gains a sufficient kinetic energy because of its inertia and speed.

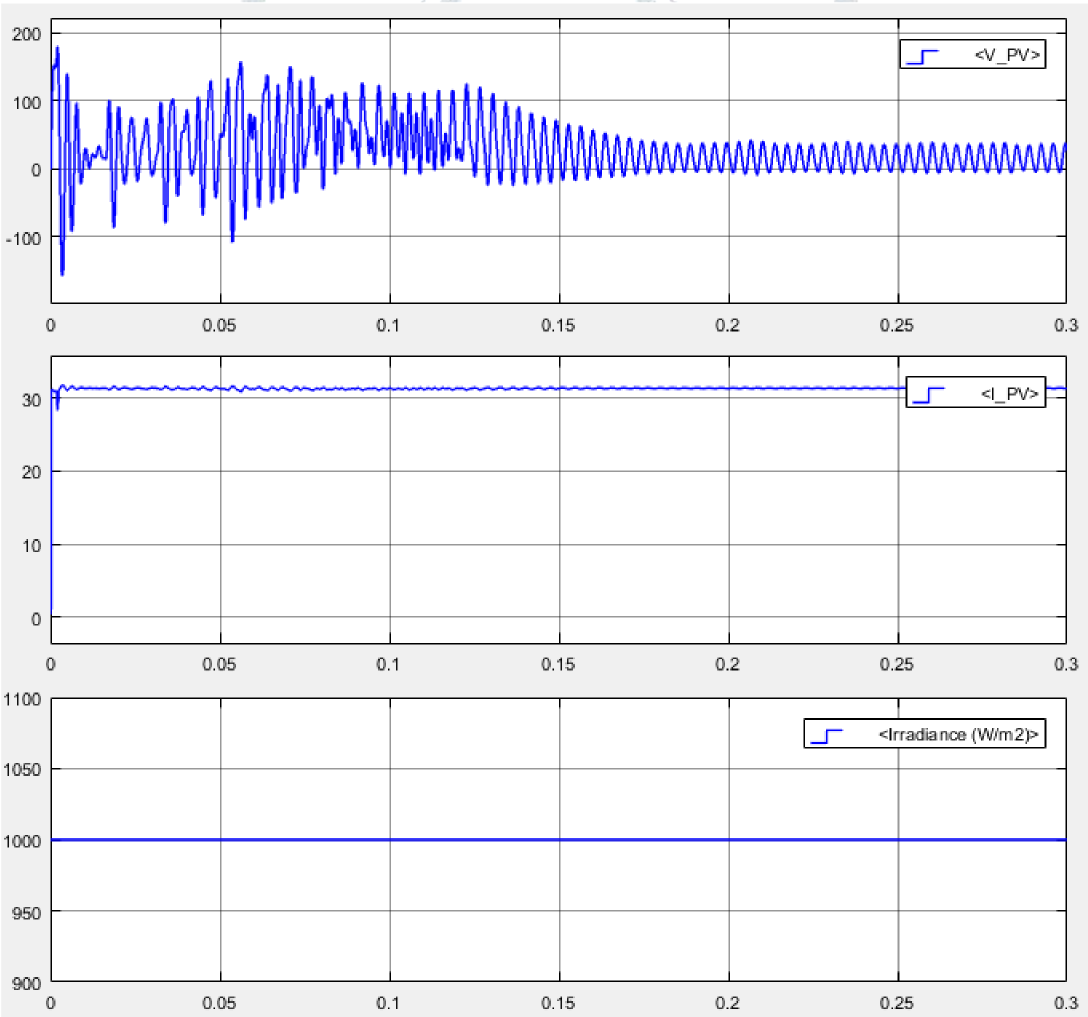

Fig 6.1.1 Steady State Behavior of solar PV array at 1000W/m2

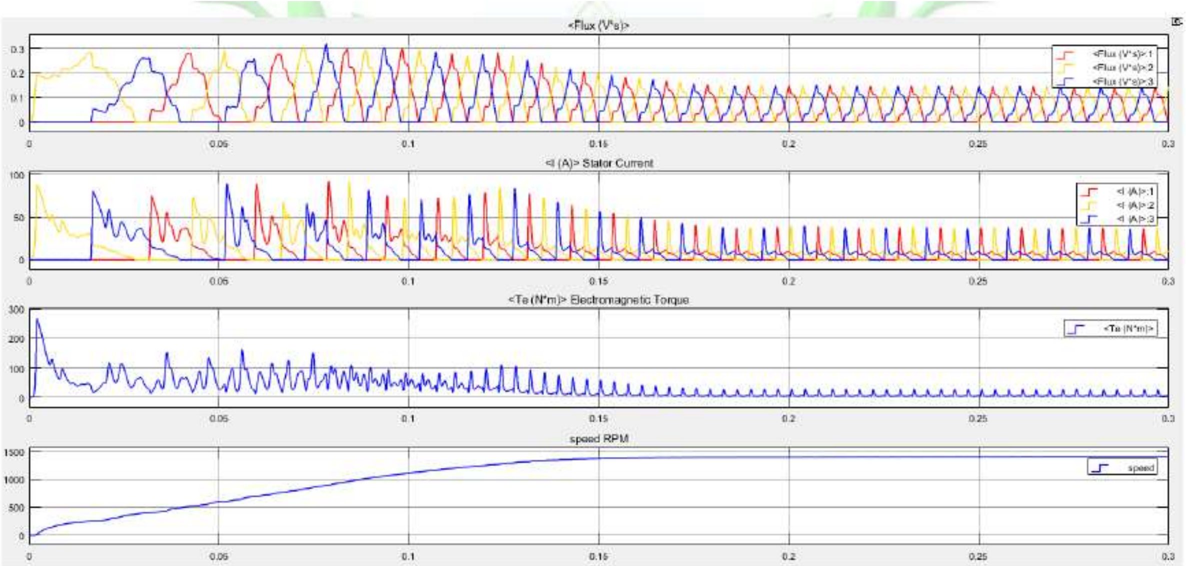

Fig 6.1.2 Steady State Behavior of SRM motor at 1000W/m2

6.2 Steady State Performances at 500W/m2

Figs. 6.2.1 and 6.2.2 present the steady state performance of solar PV array and SRM Motor at 500 W/m2 respectively. The PV voltage, VPV, PV current IPV are presented at an irradiance of 500 W/m2 in fig 6.2.1. An optimum duty ratio is generated which is further used to control the motor pump speed by adjusting the duty ratio of ABC. The back emf e_a, winding current isa, speed N, Torque Te and Load Torque TL of SRM Motor are presented in fig 6.2.2. The motor develops sufficient torque, and the pump is operated at speed of1500 rpm.

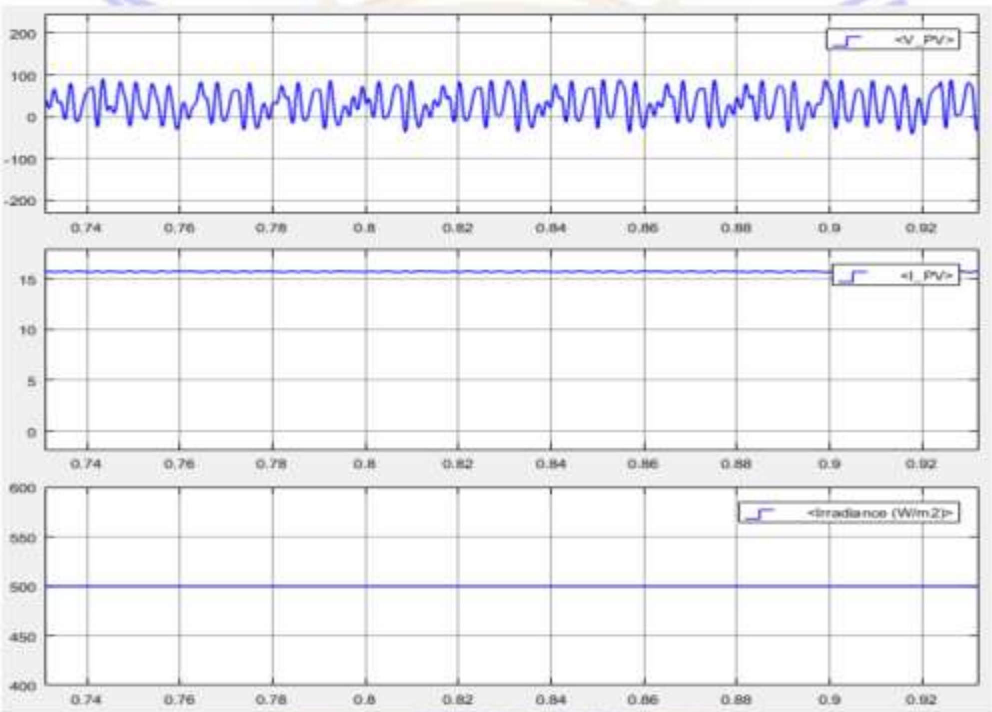

Fig 6.2.1 Steady State Behavior of solar PV array at 500W/m2

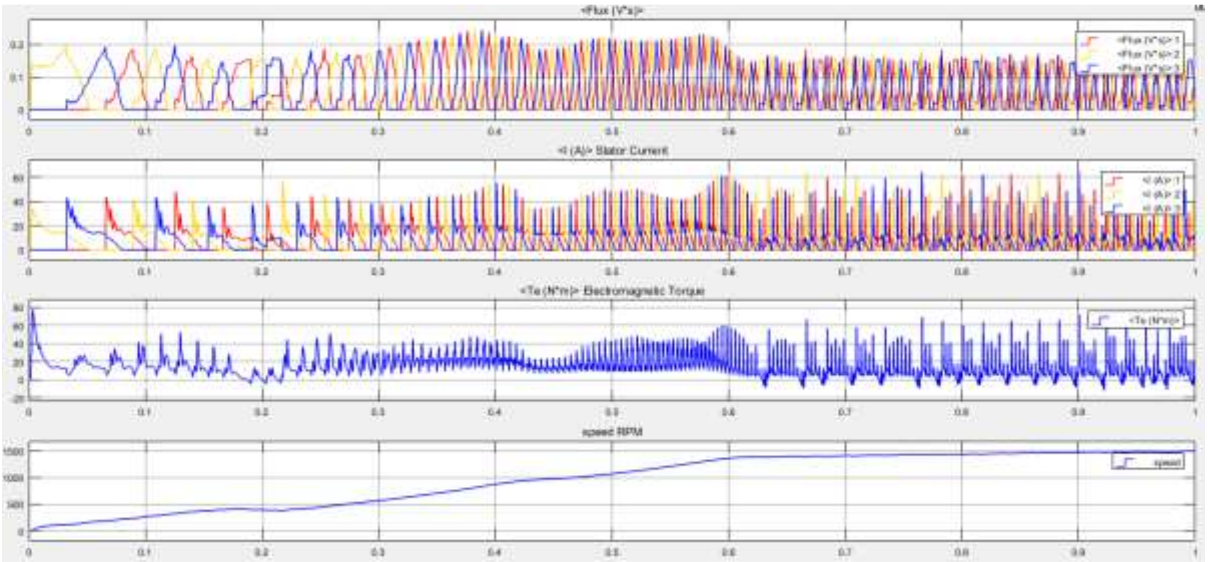

Fig 6.2.2 Steady State Behavior of SRM motor at 500W/m2

7.CONCLUSION

Water pumping is an important application of solar power. A single stage scheme for solar PV array fed SRM motor drive has been proposed. This paper proposes a hall sensor controlled SRM motor supplied by PV array based on ABC. On comparing the conventional PV systems needing two stages of power converters the proposed system has employed just a Asymmetric bridge Converter extracting the maximum power of PV array and driving a hall sensor comtrolled SRM motor simultaneously for different operation conditions. Less number of power switches associated with less switching losses is achieved. Also the good steadiness capability of system for every simulated stage can be clearly seen from the simulation results. Less power losses, rapid tracking of MPPT and low electromagnetic torque ripple, demonstrating high current control capability, have been achieved by appropriate designing an integrated controller for whole system. A novel approach based on MPPT controller for calculating the reference speed has been implemented utilizing the curvature of the P-V characteristic of solar PV array. SPV array has been operated at maximum power even at variation in the atmospheric conditions. MPPT controller helps in harnessing maximum output from the solar array by controlling the output voltage of solar array. Present paper has proposed a novel method to realize PWM technique based solar water pumping system. It can be seen that, by controlling the duty ratio obtained from MPPT the output voltage of solar PV array can be controlled and so the power level by varying the duty ratio cycle for generating PWM signals such that maximum power can be obtained from the solar array for the purpose of driving the SRM motor. The proposed work contains the mathematical analysis for single stage power conversion of solar water pumping system and the Matlab/Simulation based results are obtained for the pumping system. A simple technique to generate switching pulses for a SRM motor using the hall sensor is simulated using MATLAB/SIMULINK. Simulated results show that the SRM motor drive performs satisfactorily during starting, dynamic and steady state conditions.

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