Solar Fed SRM – Irrigation Water Pump

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Abstract*: The paper approaches the development of medium power solar water pump drive for irrigation which gives reliable operation. It uses the boost converter as a power amplification to drive the switched reluctance motor using a solar photovoltaic array. Here three phase SRM is driven by a boost converter which is used for smooth starting of SRM motor and to reduce the torque ripple. Here two converters are used one for controlling SRM and the other for controlling the H bridge inverter. In this system, the MPPT technique is used to extract maximum voltage an d current for efficient use of power. Simulation of the drive has been performed in MATLAB simulation. The system has been analyzed and tested at various conditions. Here single capacitor is used to develop the performance of the system.

***Keywords*: Boost Converter, MPPT, Switched reluctance motor, inverter.**

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I. Introduction

The application at the home appliance must have efficient use that results in saving of energy, which is extremely important in the current climate scenario. More sophisticated equipment is required in high living standard in domestic areas due to which necessitate the system based on an electric drive with advanced functionality.

The use of solar energy in the modern day has an effective way to advancement in technology. The solar-based PV system energies with an electric motor are the modest systems that are highly utilized in rural areas for irrigation pumps. As the PV system is cost-effective than the wind and diesel system due to which it is highly used in a remote area.

The total internal resistance of the PV system has regular power dissipation and its different behavior with environmental temperature gives in low efficiency. It is required to minimize the uncontrolled nature of the PV system and maximize its efficiency to achieve optimize output at different environmental conditions. To increases, the efficiency of solar system MPPT (Maximum power point technique) is used which are of different types reported in the literature [2-4]. Perturb and observe method is discussed in these papers due to its flexibility. The given paper used the perturb and observed MPPT algorithm which has the advantage of less implementation complexity and simple feedback control.[3]

The boost converter is discussed in this paper. It will boost the voltage and current of the PV system as the power produce by the system is low. When the system is unstable it required more components to stabiles due to which the cost of the system increases. Hence a system with efficient working should be used for good performance and better results.

A motor like SRM, BLDC, PMSM widely use as water pump applications [7-9]. Among these motors, the SRM motor is used in this paper to uplift the efficiency and manage the cost. As the SRM motor very low construction cost as the size of the motor is small giving the same performance as the other motors. The SRM motor needs the switching device to its stator for energizing the stator poles. The rotor of the SRM motor follows the low reluctance path and rotates. Due to this, it is observed that the SRM motor can be easily manipulated by the switching device at the stator for moderate power applications.

SRM drive with boost converter used in irrigation pumps and many household applications are less in practice. In a purpose system controlling the motor speed is given by the PWM technique. The other motors have less control on speed as it does not have any switching method as like the SRM motor. The number of practices on SRM motor is given in the literature [11-14].

The SRM motor with open-loop control has a different speed range and different control strategies [11-12]. However, design optimization is a vital point in every machine for flexible application. The SRM motor shows torque ripple because of the methods used in angle positioning and current chopping target in the system which can be minimized by using the PWM technique.

II. Theoretical Background

The PV panel is made by series and parallel combination of the silicon plates that consumes the sun energy and converts it into electric energy. According to this, the following circuit diagram is shown that gives an idea about the series and parallel combination of the resistance connected for the PV array. [15]

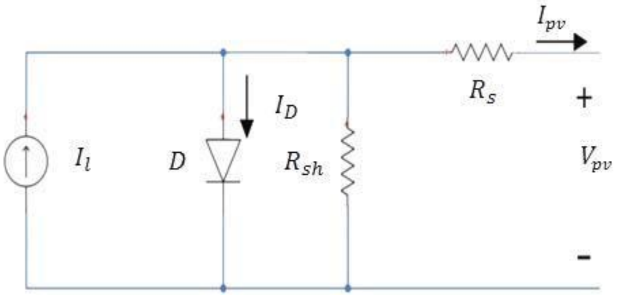

Fig. 1.The equivalent circuit diagram of solar photovoltaic panel

Solar PV current is shown by equation (1).

$$I = I_{pv} - I_o\left[exp\left(\frac{q(V_{pv}+R_sI)}{N_SKTA}\right) - 1\right] - \frac{V_{pv}+R_sI}{R_{sh}} \qquad (1)$$

Where,

I_{PV}=PV panel terminal current

V_{PV}=Output voltage

I_D=Diode current

I_i=Irradiance developed current

I_o=Reverse saturation current

q=Electric charge =1.6021747$\times 10^{-19}C$

R_s=Series resistance

K= Boltzmann's constant

A= Ideality factor

T= Actual temperature

R_{sh}=Shunt resistance

N_s=Cell connected in series

The PV panel rating is selected to be 1000W/m² for the efficient working of the panel. The proper connection to the PV panel of the system is made with the SRM motor. The give PV system is given to the single capacitor in which the fluctuation in the current waveform of the output of the PV array module is minimized and pure DC is given to the boost converter. Then boost converter converts low dc value to pure DC value which is given to the inverter. Inverter converter DC value into AC voltage and current and given to the SRM motor that runs according to our requirement.

III. Simulation Model of the System

Figure 2 follows the schematic diagram of the purpose system utilizing the boost converter. The purpose system contains PV array DC-DC converter, capacitor, MPPT controller, SRM pump logic circuit. Here for MPPT P and O method is used for taking efficient power. The speed control is achieved by the PWM technique.

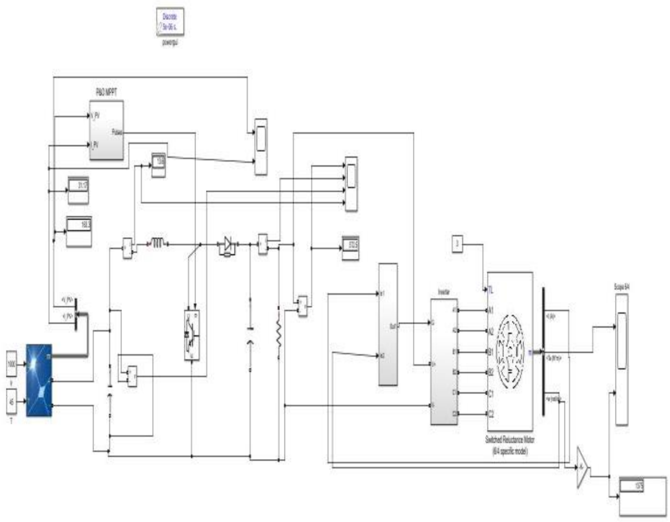

Fig.2. Simulation diagram of the system

IV. Design of Schematic System

The SRM motor speed is selected above 1500rmp so that it takes more work of pumping application. The SRM motor of 60Kw is selected for the required application.

A. PV array selection

The PV array module selected for the power solar system TP25OMBZ is proper for the given system. Each module contains 60 cells for the given PV array. The module is designed by Tata power solar system limited. The parameters of the required module are shown in table 1 [16]

TABLE I. PARAMETER OF PV ARRAY (At 45^{o}C, 1000 W/m^2)

PV Module	
OC voltage	36.8 V
SC current	8.83 A
MPP voltage	30 V
MPP current	8.3 A
PV array	
PV voltage, V_{PV}	158 V
MPP power, P_{mpp}	3.820kW
At MPP, I_{mpp}=I_{PV}	P_{PV}/ V_{PV} = 24.18 A
modules connected in series, N_S	V_{PV} / V_{mpp}=5
modules connected in parallel, N_P	IPV/ Impp = 5
Open-circuit voltage, V_{0C}	N_Sx V_0=25V
Vdc	361V

B. Selection of Boost converter

The system uses the boost converter for achieving higher DC value to assist the SRM motor drive. The maximum voltage photovoltaic array is 158V which increases up to reference DC voltage V_{dc}=361V.

The reliable value of maximum power point voltage and DC voltage gives proper values of duty ratio which makes the converter more efficient.

The duty ratio is calculated by

$$\frac{Vdc}{Vpv} = -\frac{1}{1-D}$$

$$D = \frac{Vdc - Vpv}{Vdc} = \frac{360-330}{360} = 0.56$$

Assuming switching frequency f_{sw}=20 kHz

V_{DC}=361V and ripple current magnitude in inductor L

L can be given as,

$$L = \frac{Vpv \times D}{\Delta iL \times fsw} = \frac{158*0.56}{30000\times1.89\times0.25} = 7.8mH$$-

The value of single capacitor C= 0.25µf

The value of resistance taken for the boost converter=100 ohms

Where,

i_{ph}= phase current of a motor

w=speed in rad/sec

ΔV_{DC}=ripple applying across DC voltage

C. Selection of irrigation pump

The torque of 23N-m is given by the pump which has a power rating of 60kW. Based on the Power speed characteristic the pump rating has been selected.

$K_p=\frac{Pm}{w^3}=\frac{4000}{157.08^3}=1.03\times 10^{-3}$ W/(rad/sec)^3

Where,

K_p = proportionality constant

The SRM motor for the given system is a 6/4 pole 3 phase machine that is suitable for irrigation purpose.

TABLE.II. SHOWS SRM PARAMETER

Quality	Value	Unit
Rated power P_m	60	kW
Speed, N	1800	Rpm
Direct Current-voltage, V_{DC}	361	V
stator poles, N_S	6	-
rotor poles N_R	4	-
phases	3	-

D. Control scheme for boost converter

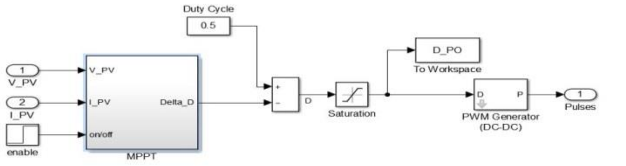

Fig. 3 Diagram for the generation of gate pulse for boost converter

Here the system input voltage and current are fed from the PV module. The MPPT gives the maximum output and current as shown in the result that is used for triggering the gate pulse of the IGBT of the boost converter. The output of MPPT is given to the comparator where the duty cycle is given it will be fed to the saturation curve and given to the PWM generator. The PWM generates the pulse for the gate.

E. System for controlling of SRM drive.

The controlling of the SRM drive is divided into two different parts.

(a) MPPT control through P and O method

(b) Speed control of motor

a) MPPT control through P and O method

The Hill climbing method or perturb and observed method is used for calculating the maximum voltage and current of the PV array. The duty ratio at the start was taken as 0.38 to run the motor safely. With the help of a flow chart, the P and O algorithm is studied and analyzed for a better result. The flow chart of the P and O method is given in figure 4 [16].

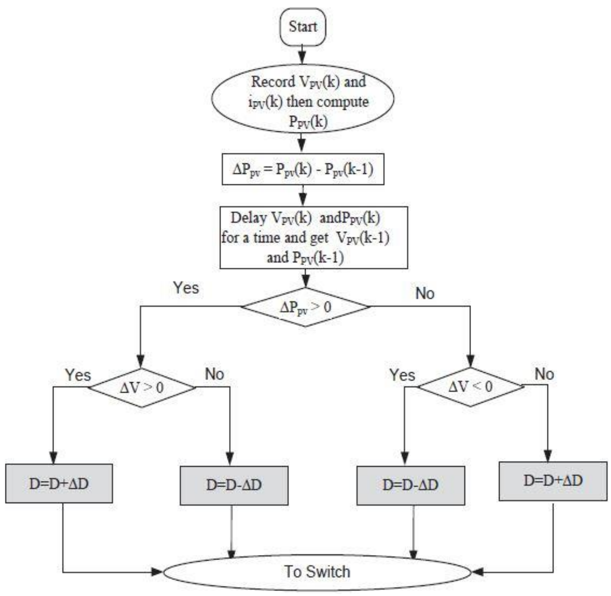

Fig. 4.P and O algorithm flow chart

b) SRM Speed control

The speed control of the SRM motor is achieved by boost converter control through PWM switching. The calculated and reference DC bus voltage are compared controller receive error values and behave as a voltage regulator.

Then current compares with PI controller to calculate final duty ratio. As the result of comparing the duty ratio wave and sawtooth wave, we have PWM signals. For predicting the speed of the motor the PWM pulse is required which is the combined result of the Hall effect sensor and logic gate AND. The duty cycle of the converter changes with a change in conditions by which speed can be controlled.[5]

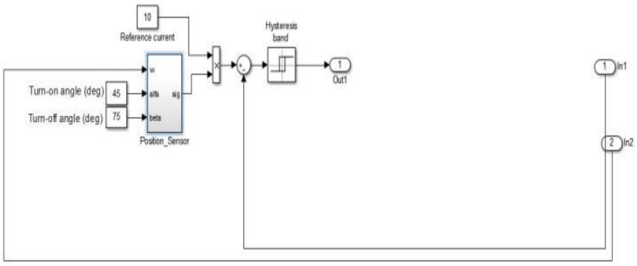

Fig. 5.simulation diagram for SRM speed and torque control

F. *Magnetization cure of SRM motor*

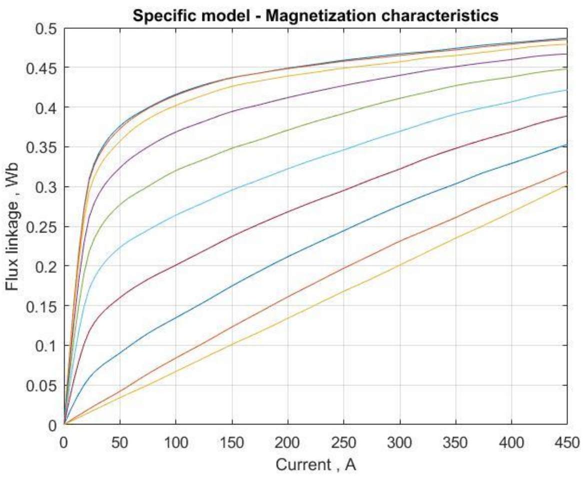

Fig. 6 Magnetization characteristic of SRM

The magnetization curve of the SRM motor is shown in the above graph between current and flux linkage, as the current increases the flux linkage increases.

V. Result

A. *Output waveform of the boost converter and PV system*

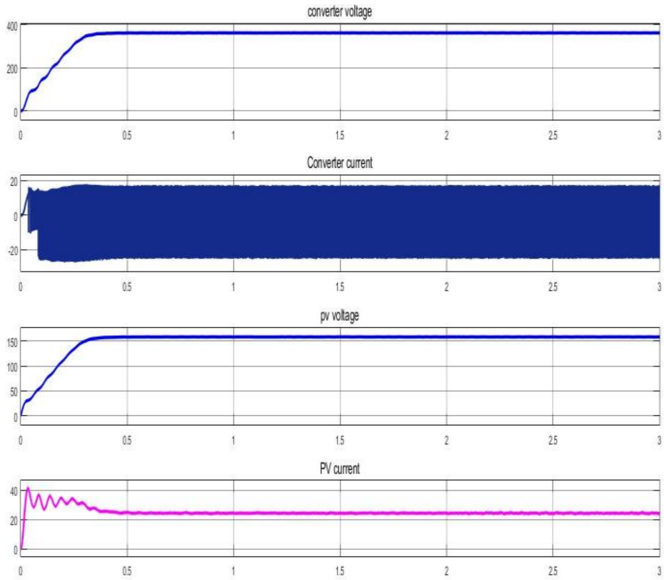

Fig. 7. The output of PV and converter module

B. *Output waveform of PV array*

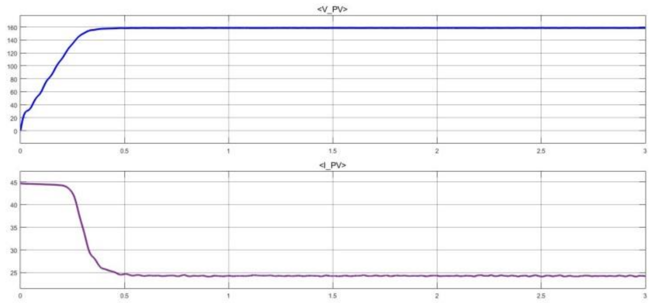

Fig. 8. Output PV voltage and current

C. *Output waveform of SRM motor*

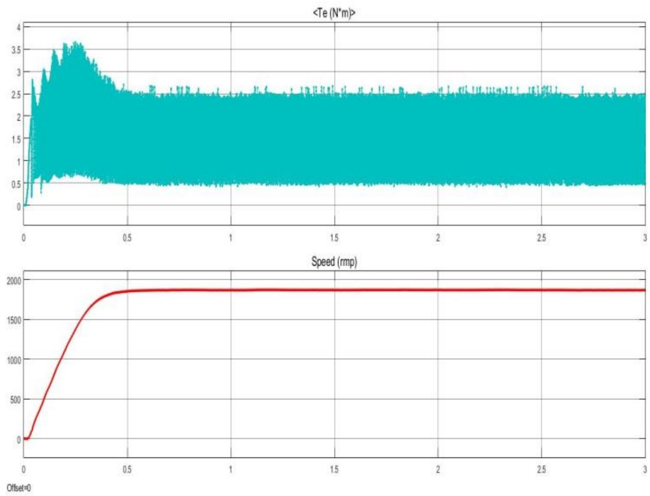

Fig. 9. SRM speed and torque

VI. Conclusion

The SRM motor using a boost converter has been simulated in the MATLAB. The required result of the system has been achieved by the simulation of the system. By the given model the system will run at various conditions. The soft starting and running of the motor are achieved by the position control method. The Perturb and observe method is easy and flexible for calculating MPPT.

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