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Switched Reluctance Motor Drive Water Pumping System Using Zeta Converter Powered By PV Array

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Abstract: Solar power used is the best alternatives. It produces electrical energy which is low cost and efficient, used in pumping application which is simple, robust. The innovation of the work is to implement Perturb and observe algorithm based Maximum Power Point Tracker (MPPT) to boost the systems capability. A PV array is proposed for extracting power and in between the SRM drive and PV array a zeta converter is provided for continuous operation of MPPT thereby shrinking the amount of sudden current flow to the system. An SRM uses a spilt phase capacitor drive for providing the required voltage pulses for phase windings excitation in all of the four phases in SRM. A zeta converter is also proposed as it does not need any additional circuit to limit the sudden flow of current to the system. The SRM drive is controlled with variable DC link voltage of spilt phase converter and it depends upon the different environmental conditions and irradiance level of SPV array. The obtained results have shown that the efficiency of the proposed system is better at higher irradiance levels.

Keywords: Maximum Power Point Tracking (MPPT), Perturb and Observe (P&O), Switched Reluctance Motor(SRM), Zeta converter

I. INTRODUCTION

Providing pure and secure water sufficient quantities, protecting health and ensuring sustainable development are the major concern for farmers and ranchers [2]. PV array pumping system is coherent, authentic and inexpensive for livestock watering irrigation purposes and for supplies water for domestic applications. PV array based pumping system posits different DC and AC motors for maximum utilization and energy saving process. Induction Motor is widely used for its simple construction, it is of low cost and also authentic, but it involves power electronic devices to convert DC power to AC power with reduced harmonics. On the other hand DC motor is the most complicated and expensive motor. The use of commutators and brushes leads to certain maintenance problems. Various motors are being matched up and inference is that the special machines are finest for its use in SPV fed pumping system. The BLDC motor is complex as its inverter topology is complicated. From the above comparisons SRM drive is the better choice for PV array pumping system. Firstly due to their strong structure, its robustness to certain operating state, and also large competency over a wide range of speed applications. The SRM rotor does not contains any conductors or permanent magnets. For detecting the position of rotor sensing machines are used. SRM could be appropriate for large efficiency cost effective pump system powered by PV array

II. PROPOSED SYSTEM

Figure 1 shows the posit SPV array fed pump system employing a zeta converter and SRM drive. It consists of the PV array, a zeta converter, the split phase converter feeding the SRM and a coupled water pump. The panel's voltage is tracked by MPPT which absorbs intense power from PV. For increasing the productivity of pumping system, Perturb and observe (P&O) method also called hill climbing method, which enhance production of the PV array .The output signals taken from the MPPT is given to the gate which in turn drives the converter. The functioning of converter is used to run in continuous conduction mode in which current is continuous this helps to reduce tension on the device.

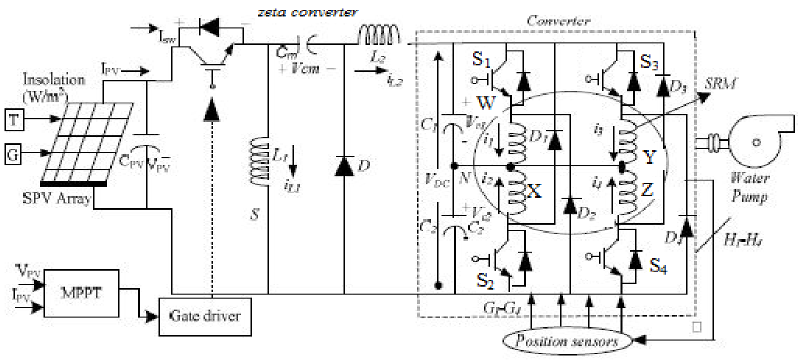

Fig .1 Circuitry representation of SPV based SRM drive for water pumping

The yield of the zeta converter is given to the SRM with split phase converter. During conduction period the energy is supplied to the phases by one half of the power supply. During turn off period the phases demagnetize into other half of the power supply. When the power semiconductor S_1 is turned on and the phase winding X is energized by the capacitor C_1.When S_1 is turned off the stored energy in phase winding X is feedback to the capacitor C_2 through the diode D_2. When S_2 is turned on the phase winding Y is energized by the capacitor C_2. Here fundamental switching of the spilt phase converters are obtained through sensing machine which is located at the stator part of the SRM and the output is given to drive pump.

III. DESIGN OF PROPOSED SYSTEM

An easy way is used here to carry out the modeling, simulation and functioning of proposed pumping system in MATLAB/Simulink environment with required calculations. The zeta converter is an integral part which works as a DC-DC converter for implementing an InC-MPPT and P&O MPPT algorithm operated in CCM. The process to design each part of system is carried out at a standard test condition i.e. 1000W/m^2 at 25 degree Celsius. The detailed design procedure for different parts of proposed system is clarified in following sub-sections.

A. Design of SPV Array

The Switched Reluctance motor of 4.4kW is choice for the posit system. If losses of the machines are neglected, the maximum amount of the array should be equivalent to the motor capacity .The capacity of each SPV module is of 60W. The specification of SPV Modules are as, open circuit module voltage (V_{OC}) of 21V, short circuit module current (I_{SC}) of 4.25A.

The supreme power for SPV array is given as,

$$P_{mp}=(N_p* I_{mp})*(N_s*V_{mp})= 4.4 \text{ kW} \quad (1)$$

Where, N_s &N_p= number of series and parallel

strings of PV module, I_{mp}, V_{mp}= current and voltage of PV module at MPP.

The PV modules connected in series string,

$$V_{mp}= N_s*V_m \text{ or } N_s= 290V/17V=17 \text{ divisions} \quad (2)$$

PV modules current,

$$I_{mp}=P_{mp}/V_{mp}= 15.5 \text{ A.} \quad (3)$$

Number of parallel strings connected,

$$I_{mp}= N_p*I_m= 4 \text{ modules} \quad (4)$$

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TABLE I. DESIGN VALUES FOR SPV ARRAY

Voltage at MPP, $V_{mp=}V_{pv}$	290 V
Power at MPP, P_{mp}	4.4 kW
Current at MPP, $I_{mp}=I_{pv}$	15.5 A
Number of series strings	17
Number of parallel strings	4

B. Design of Zeta Converter

The zeta converter in the proposed water pumping system is utilized to provide variable regulated DC voltage to the mid-point converter in addition to limitless region for accomplishment of MPPT technique. A converter requires two inductors and series capacitors for operating in either boost or buck mode. The input and output inductors of zeta converter are operated in CCM without any impact of isolation levels. The design procedure of zeta converter requires the estimation of input inductor, L_1, output inductor, L_2, middle or energy forward capacitor also called flying capacitor Cm and output split capacitors of mid-point converters. The approach for zeta converter with SRM drive includes charging and discharging conditions of different indices of zeta converter and associated waveforms are given in Figs.2 Table II shows the calculated values of zeta converter elements with required calculations. The various approach for operating a zeta converter of posit pumping system are as follows.

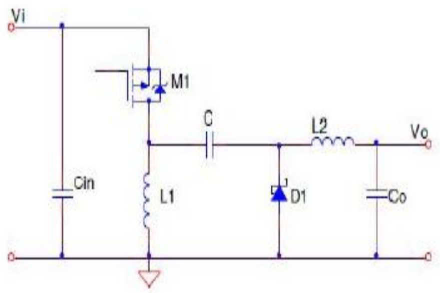

Fig 2. Circuit of Zeta converter

Mode I: When switch (S) is turned on, the input side inductor (L_1) and the output side inductor(L_2) start charging. The intermediate capacitor (Cm) discharges and it charges the DC-link capacitors as shown in Fig. 2. The voltage across phase-1 of SRM is Vdc/2.

Mode II: When the switch (S) is turned ‘off’, the energy stored in the input and the output inductors (L_1 and L_2) starts discharging to intermediate capacitor (Cm) and the DC-link capacitors. The diode (D) starts conducting in this mode of operation. Hence, the voltage across the intermediate capacitor (Cm) and DC-link voltage increases in this mode of operation. The motor phase-1 is still energized and experienced a voltage of magnitude Vdc/2. Duty cycle,= 0.62.

TABLE II. DESIGN VALUES OF ZETA CONVERTER

Variables	**Expression**	**Design value**	**Values**
Input Inductor L_1	$L_{1=}V_{mp}*D$ $/i_{L1}*f_{sw}$	$L_{1=}330*0.62/2.19$ $*20*10^3$	4.71mH
Output inductor L_2	$L_{2=}(1\text{-}D)V_0/$ $I_{L2}*f_{sw}$	560(1-0.62)/ $1.53*20*10^3$	5.9 mH
Capacitor C_m	$C_m=(1\text{-}D)I_{in}/$ $V_{cm}*f_{sw}$	C_m=12.93(1-0.62)/ $19.02*20*10^3$	2.9µf
Dc link capacitor C_2	$C_1=C_2$ $I(30\text{-}\alpha)/$ $2\omega V_{dc}$	7.67*15/ 2*6*1500*5.6	1141µf

C. Design and Modeling of SRM

Switched Reluctance Motor consists of four phase 8/6 configuration including a spilt phase converter. SRM is carried out on the supposition that the magnetic coupling between two consecutive windings of SRM is negligible and its phase inductance profiles have the non-linear shape. 'I' is the phase current of SRM assuming all phases have equal magnitude of current and it is determined as,

$$I = P/V_{dc} = 4300/560 = 7.67\ \text{A} \tag{5}$$

D. Design of Water Pump

For the selected water pump, proportionality constant K is given as

$$K = T_p/\omega^2 = 25/157.08^2 = 0.001 \tag{6}$$

Where T_p is the rated torque of SRM which is equal to the rated pump torque and is equal to 25Nm, ω is the rated speed of SRM drive in rad/sec.

IV. CONTROL OF PROPOSED SYSTEM

The constraints for PV array fed water pumping system utilize SRM drive which is controlled using MPPT using Zeta converter.

A. Incremental Conductance Algorithm(INC)

In Incremental Conductance MPPT (INC-MPPT) the controller measures incremental changes in PV array current and voltage to predict the effect of a voltage change. The INC algorithm is based on that fact that slopes of the curve power v/s voltage of the PV module is zero at MPP, affirmative on the left side and dismissive on the right.

Incremental Conductance can determine rapid increase and decrease in insolation condition with higher accuracy. The MPPT can be determined by matching the instantaneous conductance (I/V) and incremental conductance. The instantaneous conductance is given by,

$$P = VI$$

The incremental conductance is given by,

$$\frac{dP}{dV} = \frac{d}{dV}(VI)$$

$$\frac{dP}{dV} = I + V\frac{dI}{dV}$$

So at peak instant,

$$\frac{dI}{dV} = -\frac{I}{V}$$

Provided the value of instantaneous conductance and incremental conductance is same then maximum power point can be obtained.

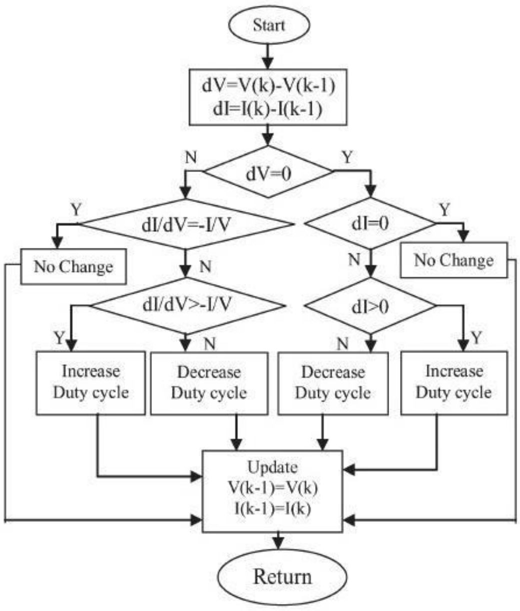

Fig 3. Flow chart of INC algorithm

B. Perturb and Observe Algorithm (P&O)

The P&O algorithms are widely used in control of MPPT thanks to their simple structure and reduced number of necessary measured parameters [6]. The flow chart implementation of P&O method is As the name implies, the concept behind of this method is based on observation of arrays yield power and its perturbation by changing the current or the voltage of PV array operation. The algorithm increases or decreases uninterruptedly of the reference voltage or current based on the previous value of power until reaches the MPP. When dP/dV>0 and the operating voltage of PV array is perturbed in a specific direction, it known that perturbation moves the operating point of PV array to the MPP. P&O method will then continue to perturb the PV voltage in the same direction. When dP/dV<0, the perturbation moves the operating point of PV array away from the MPP and the P&O method reverses the direction of the perturbation. Although this method can out turn in oscillation of power output. It is referred to as a hill climbing method. Because, it depends on the rise of power against voltage below MPP and above MPP.

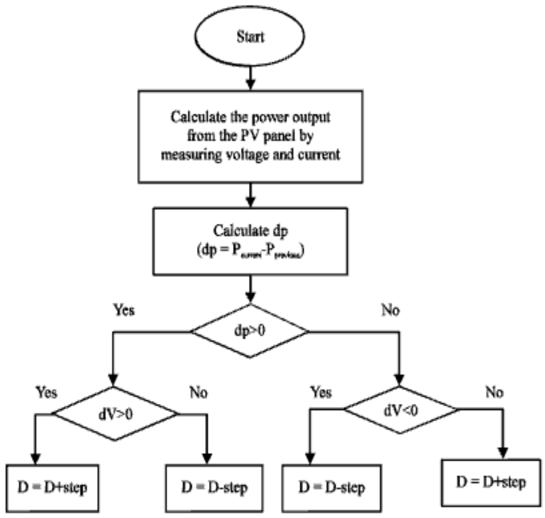

Fig 4. Structural outline of Perturb &Observe algorithm

V. Simulations and Results

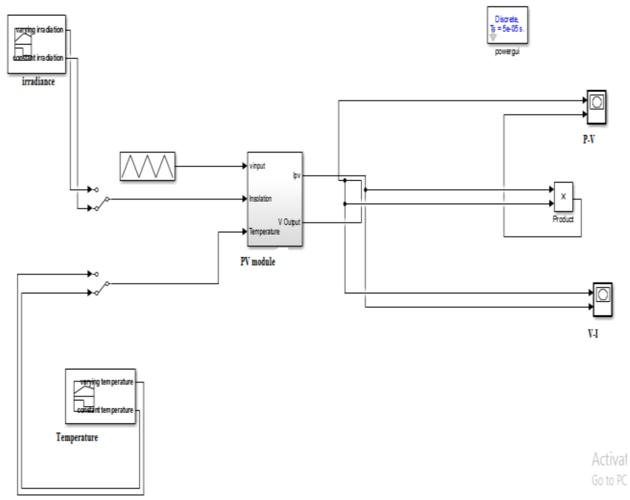

Fig 5. Modeling of PV array

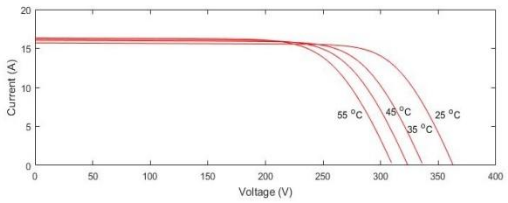

Fig 6. Voltage versus current curve at different irradiance

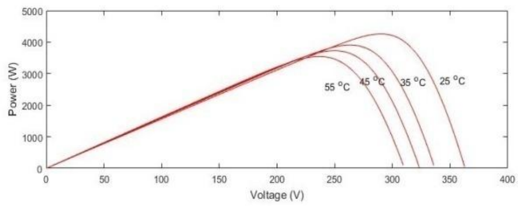

Fig 7. Power versus Voltage curve at different irradiance condition

Figure 6 and 7 shows the output of PV array at varying irradiance condition.

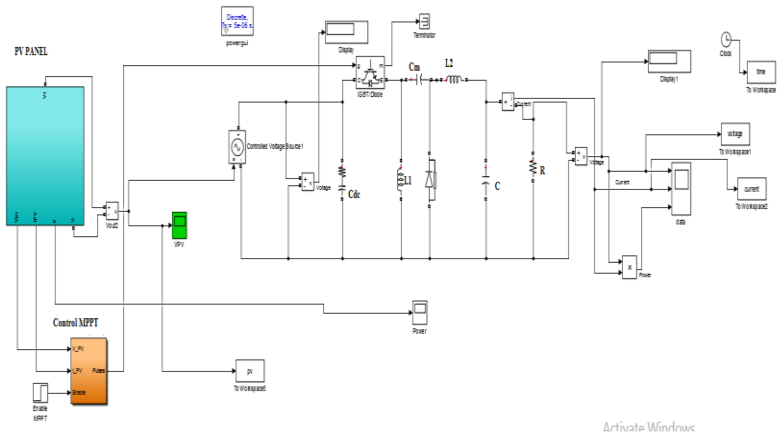

Fig 8. PV panel fed zeta converter

The following simulation results shows the output of zeta converter at various irradiance conditions. The figure below shows the comparison between INC algorithm and P&O algorithm.

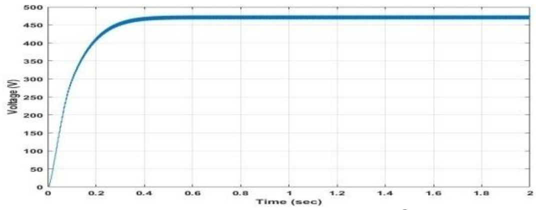

Fig 9. Output voltage for H=1000 W/m^2 of INC MPPT

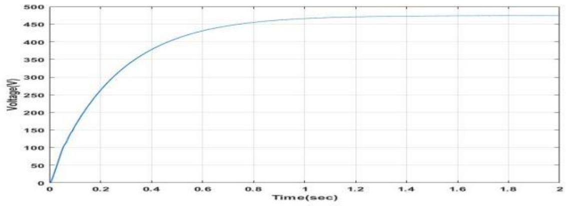

Fig 10.Output voltage for H=1000 W/m^2 of P&O MPPT

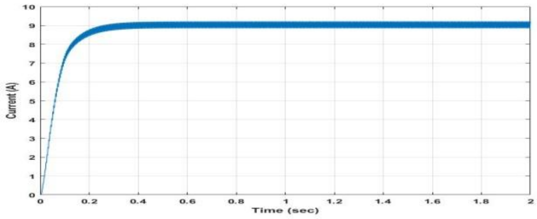

Fig 11.output current for H=1000 W/m^2 of INC MPPT

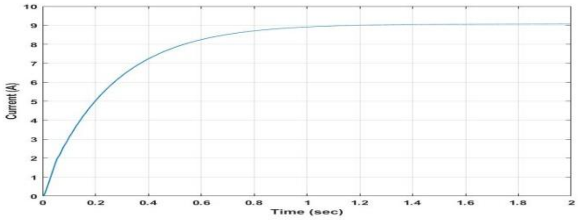

Fig 12. Output current for H=1000 W/m^2 of P&O MPP

The figure 9-10 and 11-12 indicates the performance of SPV fed zeta converter. The value of output voltage is 475 V and output current 9.1 A.

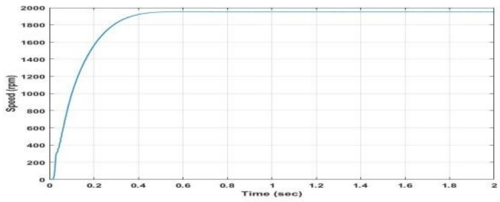

Fig 13. Output speed of SRM for H=1000 W/m^2 of INC MPPT

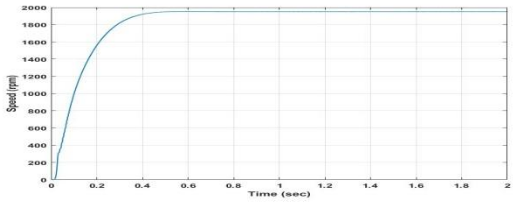

Fig 14. Output speed of SRM for H=1000 W/m^2 of P&O MPPT

The figure 13-14 indicates the performance speed of SRM at H=1000 W/m^2 irradiance. The value of speed=2000rad/sec.

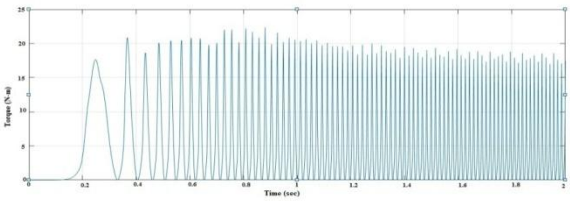

Fig 15. Output Torque of SRM for H=1000 W/m^2 of INC MPPT

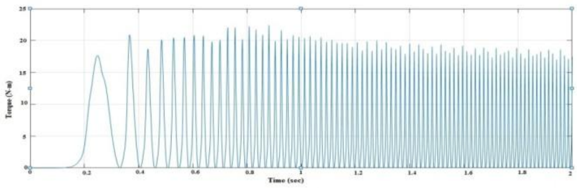

Fig 16. Output Torque of SRM for H=1000 W/m^2 of P&O MPPT

The figure 15-16 indicates the performance torque of SRM at H=1000 W/m^2 irradiance. The value of torque is 19.5 N-m.

The efficiency at different irradiance condition of the system

TABLE III. REGULATION AT VARIOUS % OF IRRADIANCE LEVEL

Irradiance W/m^2	**SPV Array Output P_{in}(W)**	**Torque T_e (N-m)**	**Speed ω (rad/sec)**	**P_{out}=(ω*T_e)**	**%η**
400	3800	16	193.71	3099.36	81.5
600	3978	16.56	193.71	3207.83	80.6
800	4100	17	198.95	3382.19	82.4
1000	4495	19.5	209.42	4083.69	90.8

VI. CONCLUSION

The Proposed system of SPV fed zeta converter employing SRM drive has smooth operation. Analysed the system with various irradiance level (H=400W/m^2,H=600W/m^2,H=800W/m^2,H=1000W/m^2). The P&O algorithm is simpler and linear than INC algorithm. The results have shown that the productivity of the structure is superior at increasing irradiance.

REFERENCES

[1] B.N. Singh, B. Singh, B.P. Singh, A. Chandra and K.Al-Haddad ,"Optimized performance of solar powered variable speed induction motor drive," Proc. of the International Conference on Power Electronics, Drives and Energy Systems for Industrial Growth(PEDES'96)held at New Delhi, 1996 pp, 58-66.

[2] K.Y.Lu, P.O.Rasmussen, S.J. Watkins and F. Blaabjerg, "A New Low-Cost Hybrid Switched Reluctance Motor for Adjustable-Speed Pump Applications,'' Proc. of IEEE 41st IAS Annual Meeting, held at 8-12 Oct. 2006, pp.849-854.

[3] S. Belliwali, A. Chakravarti and A.B. Raju, "Mathematical modelling and simulation of directly coupled PV water pumping system employing Switched Reluctance Motor,'' Proc. of IEEE PES Innovative Smart Grid Technologies - India (ISGT India), 1-3 Dec.2011, pp.no.386-390.

[4] Mahesh Krishnamurthy, Chris S. Edrington and BabakFahimi, "Prediction of Rotor Position at Standstill and Rotating Shaft Conditions in Switched Reluctance Machines," IEEE Transaction son Power Electronics vol. 21, no. 1, pp. 225-233, January 2006.

[5] Kim Jaehyuck and R.Krishnan, "Novel Two-Switch-Based Switched Reluctance Motor Drive for Low-Cost High-Volume Applications," IEEE Transactions on Industry Applications, vol.45, pp.1241-1248, July-Aug.2009.

[6] B. Singh and A.K. Mishra, "Canonical switching cell converter fed SRM drive for SPV array based water pumping," 2nd International Conference on Computing for Sustainable Global Development(INDIA Com), 11-13 March 2015, pp.932-937.

[7] N.Kishor, S.R.Mohanty, M.G.Villalva and E.Ruppert,"Simulation of PV array output power for modified PV cell model," Proc. of IEEE International Conference on Power and Energy (PECon), 2010,pp.533-538.

[8] D.Sera, L. Mathe, T.Kerekes, S.V. Spataru and R.Teodorescu, "On the Perturb-and-Observe and Incremental Conductance MPPT Methods for PV Systems," IEEE Journal of Photovoltaics, vol.3, no.3, pp.1070-1078, July 2013.

[9] R. Krishnan, Switched Reluctance Motor Drives: modeling, simulation, analysis, design and applications, CRC Press, 2001.