ISSN: 2581-3404 (Online)
International Journal of Innovative Research in Technology and Management, Vol-4, Issue-3, 2020.

Utility Grid Interfaced Solar Water Pumping System Using PMSM Grid with Improved Power Quality

Ruchi Patel[1], Amol Barve[2], Sujeet Kumar Soni[3]

[1] **M.Tech Scholar, Department of Electrical and Electronics Engineering, LNCTE BHOPAL**
[2]**Asso. Professor, Department of Electrical and Electronics Engineering LNCT, Bhopal**
[3]**Assist. Professor, Department of Electrical and Electronics Engineering LNCT, Bhopal**

ABSTRACT

In this paper a PMSM water pumping system is proposed which is operated from PVA and utility grid in parallel. During no solar irradiation or low irradiation the utility grid supports the load connected to it. The PMSM is operated using sensor less field oriented control with speed estimator. The FOC scheme takes voltage and current feedback from the motor generating estimated speed of the machine using MRAS controller. The MRAS controller also generated estimated rotor angle theta for the operation of Parks and Clarks transformations. The FOC scheme is updated with DSM-PI controller which generates stable speed for PMSM rather compared to conventional PI controller. The model is developed in MATLAB software with comparative results.

Keywords: SWP PMSM; Sensor-less vector control; Utility grid; DSM –PI Controller, Sliding mode observer.

INTRODUCTION

Rising energy concerns have motivated the researchers to search for alternate energy solutions for reducing the utilization of conventional energy sources. Recently various applications have been identified where renewable energy sources (RES) can replace the use of conventional energy sources.

Water pumping is one of the potential areas utilizing large amount of fossil fuels and therefore, the utilization of RES for this application would reduce the emission of greenhouse gases and reduce the carbon foot print [1].

Due to its modular structure, declining installation cost, and zero operating cost, solar photovoltaic (PV) based power generation is gaining wider acceptability [2]. Although solar PV integrated water pumping system (WPS) presents a feasible solution, however, intermittent nature of solar energy limits its use for active hours only i.e. when solar insolation is available. For an effective utilization of WPS, this drawback needs to be resolved. Some of the solutions to this problem are connecting the battery energy storage at the DC link, use of pump storage and fuel cell as a storage medium. However, these solutions also have their flaws such as increased system complexity, cost and space requirement [3]. As the grid is an infinite source of energy, some of the existing work suggests the integration of utility grid to SWP system An integration to utility grid enhances the system utilization and improves the system reliability. Although some the existing literature focus on power factor correction, however, none of the existing work focuses on problems associated with the weak grid. As most of the water pumps are located at the radial end of the utility grid, these systems are exposed to various power quality (PQ) problems such as voltage sag, voltage swell, grid current distortion and grid voltage distortion. For the proper operation of SWP system, these issues need to be resolved. This work aims at mitigation of some of the above mentioned issues for proper operation of Water pumping system.

The salient features of presented work are highlighted as follows.

1. The solar water pumping system is integrated to the single phase utility grid to facilitate an uninterrupted water pumping independent of available solar insolation.

2. A double second order generalized integrator quadrature signal generator (DSOGI-QSG) control structure is implemented for filtering the distorted grid voltage and to extract its fundamental component.

3. The PQ issues such as voltage sag, voltage swell, grid current distortion and grid voltage distortion, are mitigated so that the presented system follows the IEEE standard for PQ in grid connected system.

4. To improve the system reliability and to reduce the system cost, a sensor-less vector control technique is implemented for controlling the speed of the PMSM.

II SYSTEM ARCHITECTURE AND CONTROL

The system configuration of grid integrated solar water pumping system using PMSM drive is shown in Fig 2.1. This system comprises of a solar PV array, a boost converter for maximum power point tracking (MPPT), a voltage source inverter to drive the motor, another boost converter for power factor correction (PFC) and a PMSM coupled to pump. The speed of the PMSM is regulated using sensor-less vector control technique.

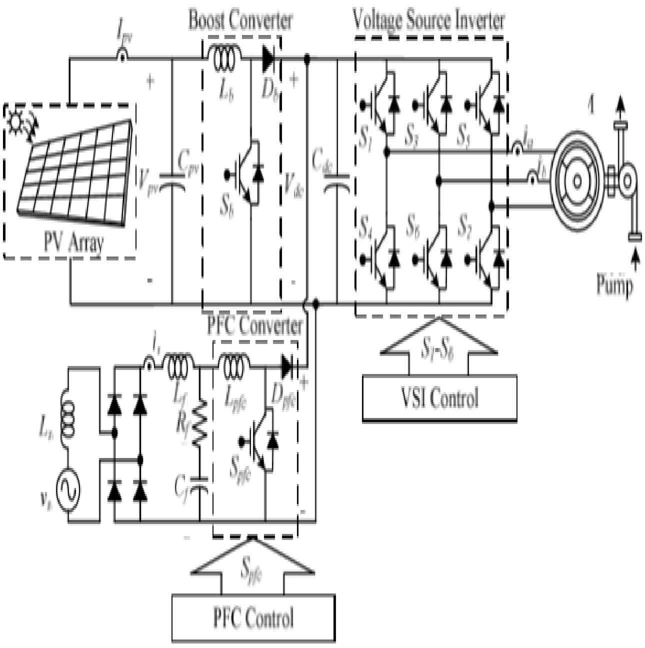

Fig. 2.1 Proposed system configuration

An incremental conductance (INC) algorithm is utilized for MPPT through change in duty ratio of switch Sb. The grid is feeding the DC link using PFC converter. The UPF is maintained at AC mains through proper switching of switch Spfc. A RC filter (R_f, C_f) and an interfacing inductor (Lf) are used for removing switching harmonics and current ripples, respectively.

2.2 SYSTEM CONTROL

The control of proposed Water pumping system is divided into three parts. First one is MPPT control using INC MPPT algorithm. Second one is speed control of PMSM using sensor-less vector control technique as shown in Fig. 2.2. A back electromotive force (EMF) based technique is used for speed and position estimation. Third one is power flow control from utility grid. This is achieved using unit vector template (UVT) technique. For proper operation even during distorted grid voltage conditions, first the grid voltage is filtered using DSOGI-QSG as shown in Fig. 2.3. The DSOGI-QSG removes the harmonic component and DC offset.

The transfer function for DSOGI-QSG is written as,

$$D_{DSOGI}=\frac{v_f(s)}{v_s(s)}=\frac{c_1c_2\omega^2s^2}{\left(s^2+c_2\omega s+\omega^2\right)\left(s^2+\omega^2\right)+c_1c_2\omega^2s^2}$$
$$Q_{DSOGI}=\frac{qv_f(s)}{v_s(s)}=\frac{c_1c_2\omega^3s}{\left(s^2+c_2\omega s+\omega^2\right)\left(s^2+\omega^2\right)+c_1c_2\omega^2s^2}$$

Equation no.2.1

The filtered voltage is divided with the peak voltage for the generation of unit template. The unit template is multiplied with the voltage regulator output for the generation of reference current. The sensed and reference currents are compared for generating the gating pulses for Spfc.

The sensor less control technique implements the FOC algorithm by estimating the position of the motor without using position sensors. Figure 2.3 is a simplified block diagram of the position estimator function. Motor position and speed are estimated based on measured currents and calculated voltages.

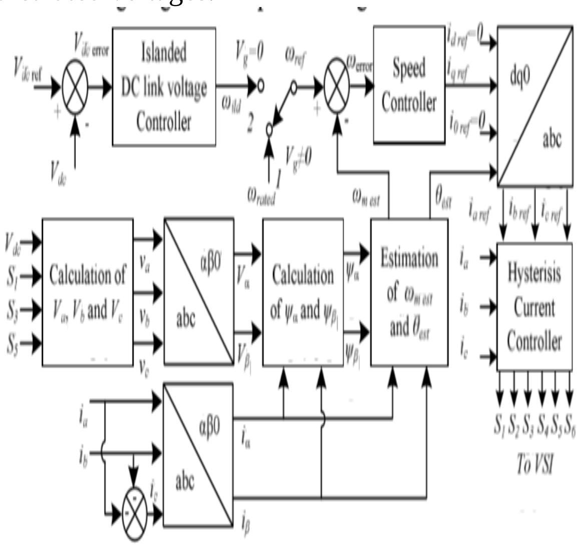

Fig. 2.2 Sensor-less field oriented control scheme of PMSM

2.3 PI and Dual sliding mode PI controller

In a normal PI controller the gains are fixed at one particular value. Distinctly in DSM-PI controller gain values are constantly changed according to the error generated.DSM-PI controller is used to derive current signal from speed error input. This DSM-PI controller continuously monitors and gains of proportional and integral gains respectively and consequently the response time is minimized. The main advantage of this scheme is settling time of the speed-time response is reduced with reduction in oscillations and disturbances.

A PI controller has proportional and integral gains fixed at one particular value, which remains constant even for higher value or lower value of error. Whereas in DSM-PI

Controller the values of gains and are variable w.r.t. the error generated. If the speed error is high, value of gains and are increased and if it's low the gain values are decreased so as to reduce the settling time.

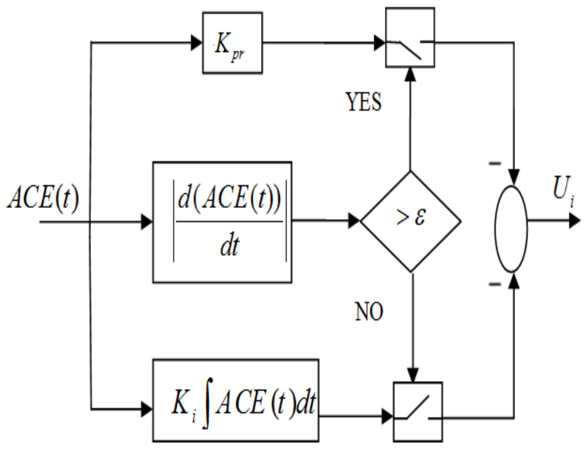

Fig. 2.3 Dual PI Controller

2.4 Hysteresis current control Method:

Hysteresis current control is a method of generating the required triggering pulses by comparing the error signal with that of the hysteresis band and it is used for controlling the voltage source inverter so that the output current is generated from the filter will follow the reference current waveform is shown in Figure 2.4

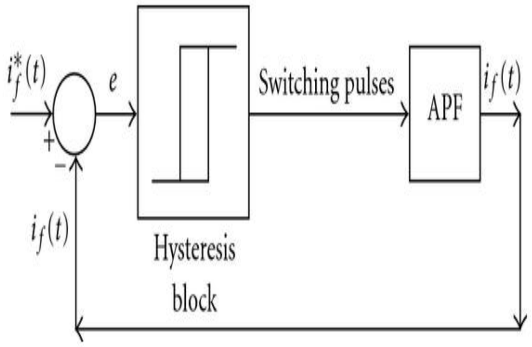

Figure.2.4 Hysteresis Control

This method controls the switches of the voltage source inverter asynchronously to ramp the current through the inductor up and down, so that it follows the reference current. Hysteresis current control is the easiest control method to implement in the real time.

Figure 2.5 illustrates the ramping of the current between the two limits where the upper hysteresis limit is the sum of the reference current and the maximum error or the difference between the upper limit and the reference current and for the lower hysteresis limit, it is the subtraction of the reference current and the minimum error. Supposing the value for the minimum and maximum error should be the same. As a result, the hysteresis bandwidth is equal to two times of error .

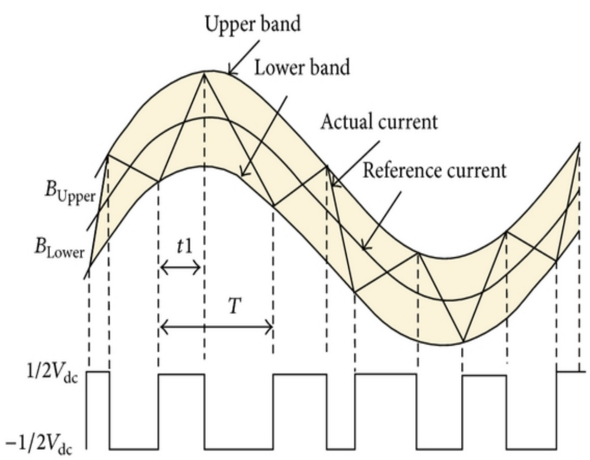

Figure. 2.5 Hysteresis Band

CHAPTER-III

SIMULATION RESULT AND DISCUSSION

The complete design related to the project is created in Matlab& Simulation using Sim Power System Toolbox and thereby analysis the different MPPT Technique. .This designing is conducted in two stage stages:-

1 .Grid interfaced PV-INC MPPT system with PI Controller Using for PMSM Motor Drive.

2. Grid interfaced PV-INC MPPT system with Dual sliding mode- PI Controller Using for PMSM Motor Drive.

3.1 Simulation model parameter:

Parameter	**Value**
Irradiation	1000
Temperature	30
Voltage of PV Array	300V
Current of PV Array	8 Amp
Boost Voltage of PV Array	600V
Inductor(L)	1milli hennery
Capacitor (Cin)	47 micro farad
Capacitor (Cout)	2200micro farad
PWM Switching Frequency	10000

3.2: Proposed test system with PVA connected to grid

Grid interfaced PV-INC MPPT system with PI Controller Using for PMSM Motor Drive is shown in fig. no. 3.1. The PFC circuit connected to grid and PVA for higher voltage generation with low ripple. The PVA uses incremental conductance method as MPPT for control of the PFC converter connected to it. The grid connected PFC converter uses voltage-oriented control for the control of output voltage. The below are the MPPT method and voltage-oriented control models.

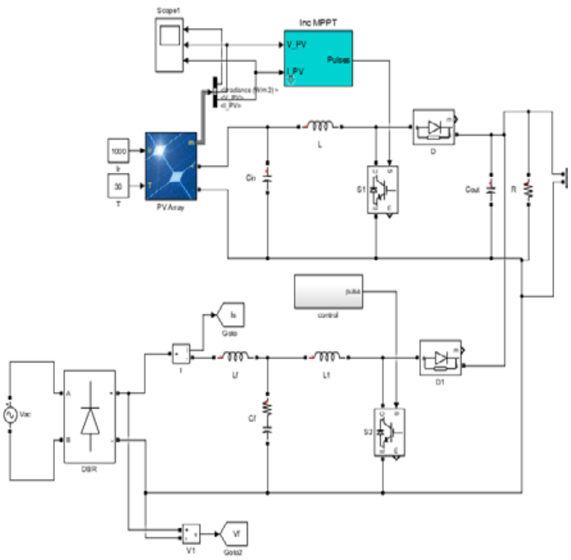

Fig. : 3.1 proposed test system with PVA connected to grid

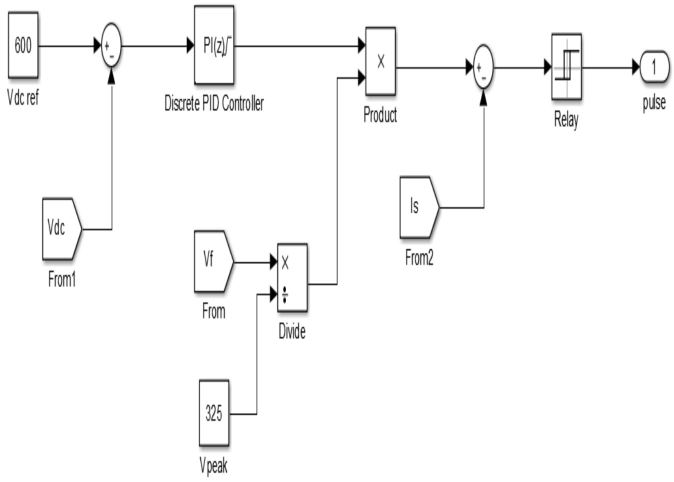

Fig. : 3.3 DC-DC booster converter controller of the grid connection

.

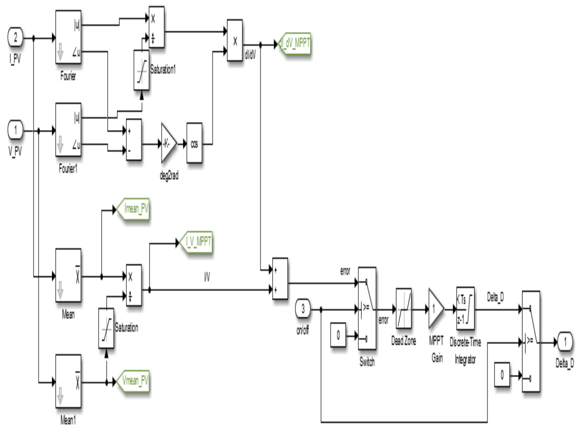

Fig.: 3.2 Incremental conductance MPPT method modeling

In the shown in fig.3.3 controller the reference DC voltage taken is 600V which is maximum value of 440Vrms line to line voltage. The 600V is given as input to the sensor less FOC of PMSM drive for water pumping operation. The below is the modelling of water pumping system with PMSM drive using sensor less FOC

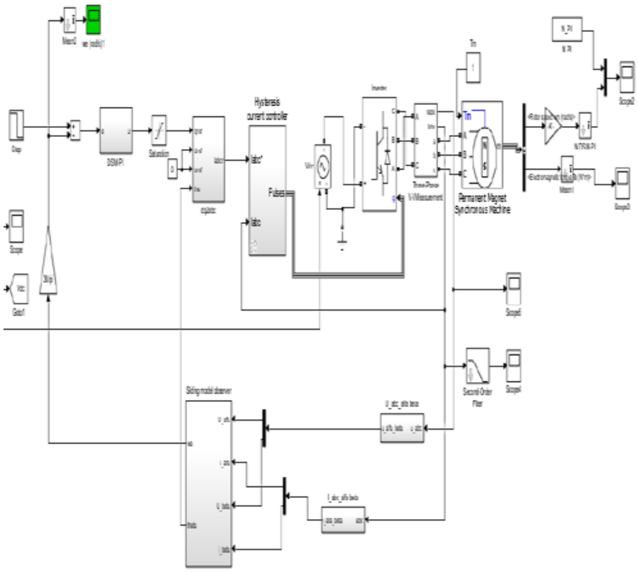

Fig.3.4 FOC scheme with MRAS control for speed control of PMSM

The shown in figure 3.5 the reference speed (1500rpm), estimated speed and measured speed comparison.

ISSN: 2581-3404 (Online)
International Journal of Innovative Research in Technology and Management, Vol-4, Issue-3, 2020.

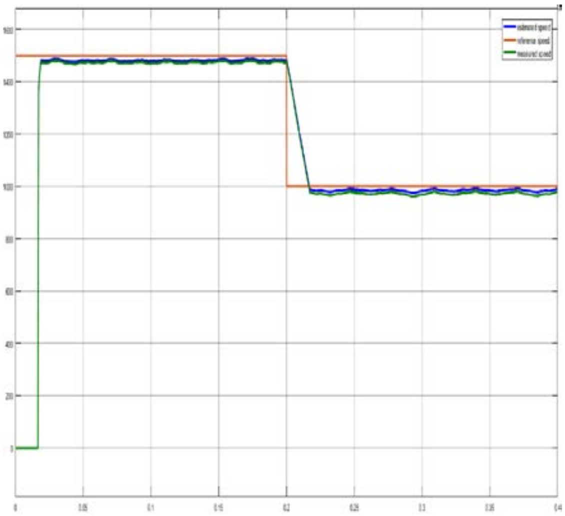

Fig. 3.5 Speed of the machine compared with reference value.

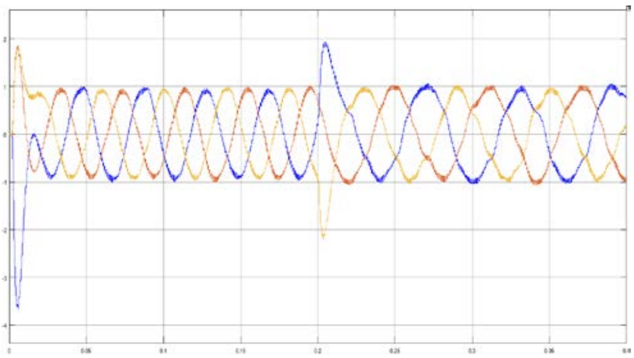

Fig. 3.6 Voltages and currents of PMSM

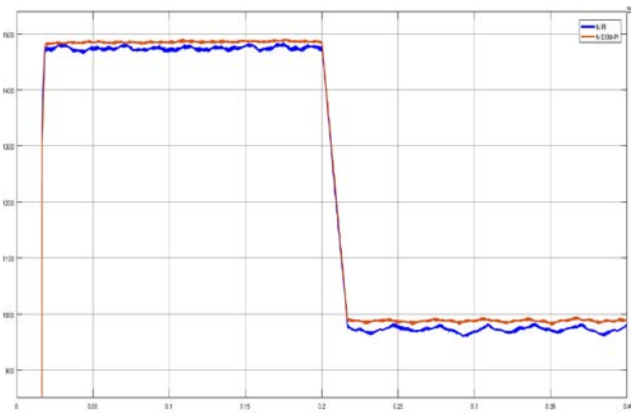

Fig. 3.7 Speed comparison of PMSM with PI and DSM-PI controller

3.2 HORMONICS ANALYSIS BETWEEN PI-CONTROLLER &DSM-PI CONTROLLER

The comparison the THD of the DSM-PI controller is less as compared to PI controller during 1500rpm reference value. This is shown in figure 3.8 and 3.9.

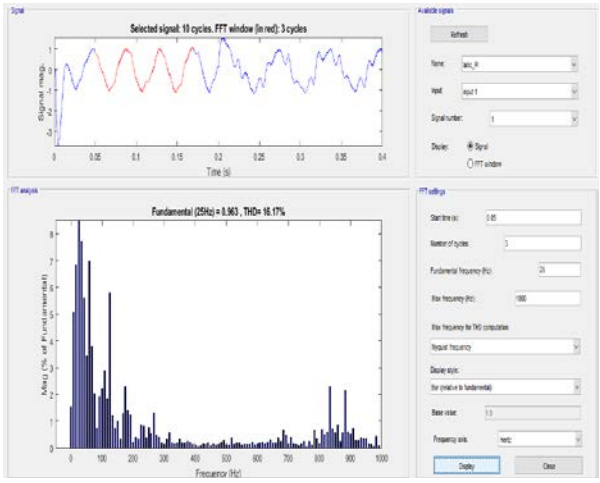

Fig. 3.8 THD analysis of PMSM stator current with PI controller

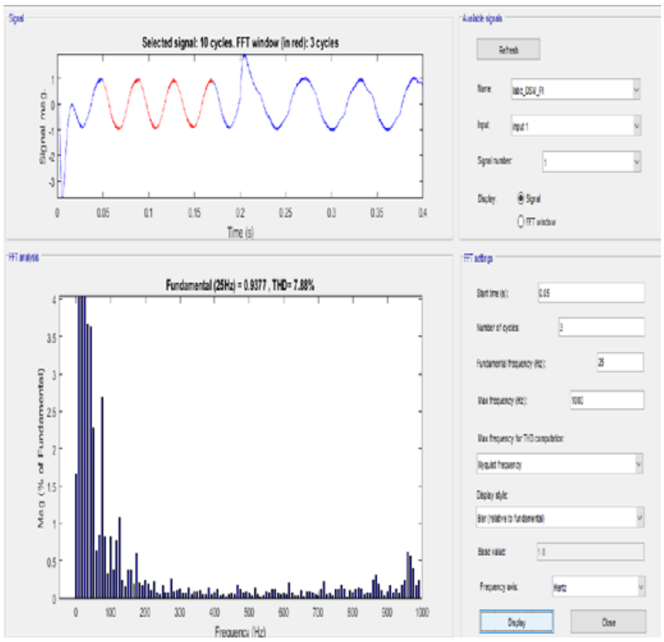

Fig. 3.9 THD analysis of PMSM stator current with DSM-PI controller

CONCLUSION & FUTURE SCOPE

As per the graphs generated with comparison of PI and DSM-PI controller of the FOC structure operating PMSM it can be considered that the test system with DSM-PI controller is more stable. The speed comparison denotes that measured value of the DSM-PI controller has less disturbance and precise value generation. The THD of the FOC system with PI controller is recorded at 16.17% where the DSM-PI controller is recorded at 7.88% at 1500rpm reference. However the power sharing from PVA and grid is constant with respect to change in solar irradiation in both the models. The FOC controller can further be updated by optimization controller for better performance of the machine with exact speed generation and with least ripple. The THD can be further reduced below 5% with more stabilized control system with faster response rate. The inverter can be replaced with multi-level inverter topologies for reduction of THD in the stator current of the machine.

REFERENCE:

[1] M. A. Elgendy, B. Zahawi and D. J. Atkinson, “Assessment of Perturb and Observe MPPT Algorithm Implementation Techniques for PV Pumping Applications,” IEEE Trans. Sust. Energy, vol. 3, no. 1, pp. 21-33, Jan. 2012.

[2] S. Jain, R. Karampuri and V. T. Somasekhar, “An integrated control algorithm for a single-stage PV pumping system using an open-end winding induction motor,” IEEE Trans. Ind. Elect., vol. 63, no. 2, pp. 956-965, 2016.

[3] A. Khiareddine, C. Ben Salah and M. F. Mimouni, “Strategy of energy control in PVP/battery water pumping system,” Proc. International Conference on Green Energy, Sfax, 2014, pp. 49-54.

[4] P. García, C. A. García, L. M. Fernández, F. Llorens and F. Jurado, “ANFIS-based control of a grid-connected hybrid system integrating renewable energies, hydrogen and batteries,” IEEE Trans. Ind. Info., vol. 10, no. 2, pp. 1107-1117, May 2014.

[5] I. Ducar and C. Marinescu, “Increasing the efficiency of motor-pump systems using a vector controlled drive for PMSM application,” International Symposium on Fundamentals of Electrical Engineering (ISFEE), Bucharest, 2014, pp. 1-5.

[6] A. B. C. S. B. Slama and A. Chrif, “Efficient design of a hybrid (pv-fc) water pumping system with separate mppt control algorithm,” lJCSNS International Journal of Computer Science and Network Security, vol.12, pp. 53-60, January 2012.

[7] R. Kumar and B. Singh, “Grid interfaced solar PV based water pumping using brushless DC motor drive,” IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), Trivandrum, 2016, pp. 1-6.

[8] R. Kumar and B. Singh, “Brushless DC motor-driven grid-interfaced solar water pumping system,” IET Power Electronics, vol. 11, no. 12, pp. 1875-1885, Oct. 2018.

[9] B. Singh and S. Murshid, “A Grid-Interactive Permanent-Magnet Synchronous Motor-Driven Solar Water-Pumping System,” IEEE Trans. Ind. Appl., vol. 54, no. 5, pp. 5549-5561, Sept.-Oct. 2018.

[10] T. Esram and P. L. Chapman, “Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques”, IEEE Trans. Energy Conv., vol. 22, no. 2, pp. 439-449, June 2007.

[11] IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, IEEE Standard 519, 1992.

[12] F. Blaabjerg, R. RTeodorescu, M. Liserre, and A.V.Timbus, “Overview of Control and Grid Synchronization for Distributed Power Generation Systems,” IEEE Trans. Ind. Electron., vol. 53, no. 5, pp 1398-1409, Oct. 2006..

[13] E. Radziemska, and E.Klugmann “Photovoltaic Maximum Power Point Varying with Illumination and Temperature”, in Journal of Solar Energy Engg., vol. 128, no. 1,pp.34-39

[14] D. P. Hohm and M. E. Ropp, “Comparative Study of Maximum Power Point Tracking Algorithms”, Progress in Photovoltaics: Research and Applications, 11, pp. 47-62, 2003.

[15] Chia-HsiChang ; Yu-Hui Lin ; Yaow-Ming Chen; Yung Ruei Chang 'Simplified Reactive Power Control for Single-Phase Grid-Connected Photovoltaic Inverters' Industrial Electronics, IEEE Transactions on Volume: 61 Issue: 5, 2286 - 2296 ,2014.