IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Review on Solar Water Pumping System Employing PMSM

Prachiti Arun Indurkar, Mrs. S. S. Kulkarni, Dr. A.G.Thosar

M.tech Student, Associate Professor, Professor
Department of Electrical Engineering,
Government College of Engineering, Aurangabad, India

Abstract: This paper proposes solar water pumping system that gives better full load efficiency by employing permanent magnet synchronous motor (PMSM). PMSM has the ability to maintain full torque at low speeds. The system uses a Photovoltaic Generator, boost dc-dc converter, three phase VSI, three phase permanent magnet synchronous motor and a pump. Boost converter which is controlled by using Fuzzy logic in order to obtain Maximum power point tracking. Direct torque control space vector modulation is designed to inverter for supplying the PMSM to control motors torque.

***Index Terms* - Photovoltaic Array Generation, Boost dc-dc Converter, MPPT FLC(Fuzzy Logic Control) Voltage Source Inverter, PMSM (Permanent magnet synchronous motor, water pumping, Direct Torque Control (DTC-SVM).**

I. Introduction

In recent years, as there is increase in call of supply, renewable energy sources are used owing to exhaustion of the non - renewable energy resources. Because of renewable sources there comes the problem of global warming as well as carbon foot printing .To reduce such problem sustainable energy such as green sources are used .To fulfill day to day needs of human life it gives an excellent solution whereas renewable sources are available abundantly. The best form of above resources that exist easily is solar energy [1]. The installing cost of such solar system is economical .The applications by using solar PV panel is solar water pumping that has been raised. Solar water pumping is compensations to that area where there is no grid connection or power supply is disrupted at some interval of time. Solar water pumping would help activities of industry, domestic as well as for agriculture purposes.

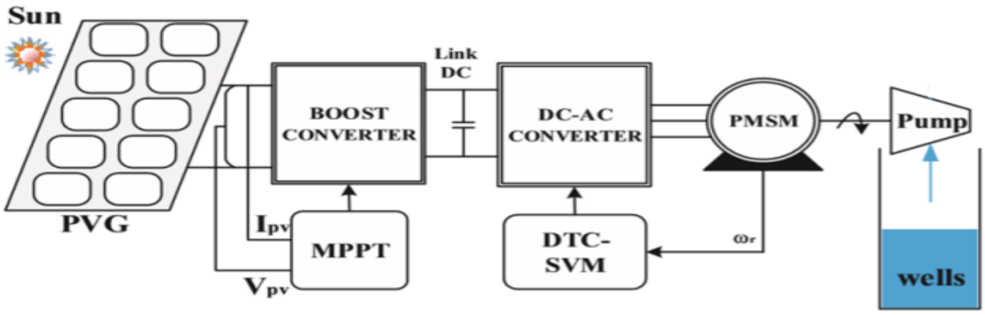
For pumping purposes it needs electric drive, before dc motors are used. But it has to take more maintenance due to deterioration brushes and commutator assembly. Induction Motor was meant for water pumping system because of its low cost and robustness [2]. But Induction motor gives high reactive demand and lower efficiency making it incompetent for this purpose.

Lesser efficiency needs high valued size of solar PV array. To figure out all these issues Permanent magnet synchronous motor offers an excellent result. PMSM gives a solution to the low maintenance because of presence of permanent magnet present on it rotor side and winding on its stator. For water pumping PMSM use 20 % less power as that of Induction motor use [3]. PMSM has high power density than Induction motor having same rating as there is no stator power devoted to magnetic field production [3]. Because of absence of magnetizing current PMSM operates at high power factor. This motor is categorised by full torque control at zero speed and smooth rotation over whole speed range. It also gives fast acceleration and deceleration. Hence this motor drive makes fairly practical for solar water pumping system.

Solar panel has nonlinear elements as it maximum point depends on climatic conditions. As solar irradiation changes and load varies it optimum operating point also varies. To ensure that there is not variation in maximum operating point, MPPT is used and later it controls duty cycle of converter connected next to it [5]. Different MPPT methods like incremental conductance perturb and observe, methods originated from optimization techniques such as, grey wolf optimization, genetic algorithm, neural network, fuzzy logic [4]. Among all Fuzzy is bite complex but possessing excellent tracking even at lower irradiation. The inverter by using the vector mode by FLC direction of rotor flux controls the torque and speed. Scalar control is inferior to Vector control strategy.

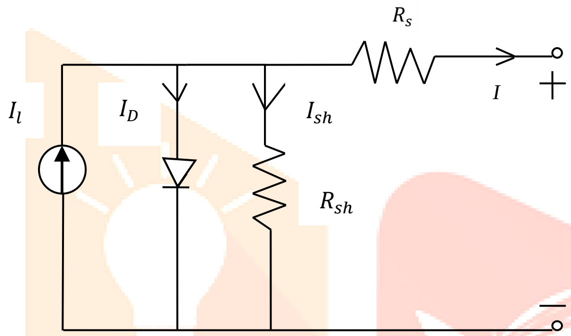
The work undertaken is to rise the productivity of solar water pumping by using PMSM, for controlling the inverter feeding in ac drives .DTC become more popular than other FO control. DTC is simple and it gives good dynamic and high efficiency but its drawback is, it produces high torque, flux ripples, variable switching frequency .The (DTC-SVM) is progressive technique used in variable frequency drive. It gives minimum harmonic distortion and gives more space vector voltage. Paper is structured as follows: proposed system, modelling of PV array, the design of fuzzy logic methodology for MPPT, modelling of PMSM, the speed control by DTC-SVM.

II. Proposed System



This work comprises of PVG connected to dc-dc boost converter in which its duty cycle is controlled with Fuzzy logic controller to ensure MPPT. The inverter by vector mode controls the torque and speed given to permanent magnet synchronous motor. The speed control of PMSM achieves fast dynamic response and high accuracy by using DTC SVM which offers more voltage space vector.

2.1 Modelling of PV array



I_{ph} = [I_{sc} + K_i (T – 298)] × I_r/ 1000
I_{rs} module reverse saturation current,
$I_{rs} = I_{sc}$ / [exp (q.V_{oc}/ $N_s$knT) – 1] ……….. (1)
I_o module saturation current ,
$I_o = I_{rs}(\frac{T}{T_r})^3 \exp[\frac{q*E_{go}}{nk}(\frac{1}{T} - \frac{1}{T_r})]$…………..…. (2)

Where, K_i = short circuit current of cell.
T=operating temperature (K).
q =electron charge.
V_{oc}= open circuit voltage.
N_S= no. of cell in series.
n = ideality factor .
I_{sc} =Short circuit current.
I_r =solar irradiation (W/m^2).
Output current of module is

$$I = N_P*I_{ph} - N_p*I_o *[\exp(\frac{\frac{V}{N_S}+I*\frac{R_S}{N_P}}{n*V_t}) - 1]-I_{sh} \ldots. (3)$$

With $V_t = \frac{k \times T}{q}$

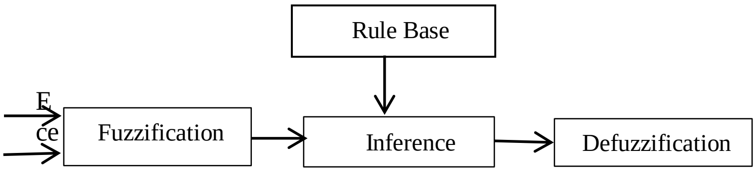
& $I_{sh} = \frac{V*\frac{N_P}{N_S}+I*R_S}{R_{sh}}$

Where,
N_p=no. of PV module connected on parallel
R_s = *series resistance* Ω
R_{sh} = *shunt resistance* Ω
V_t=diode thermal voltage (V)

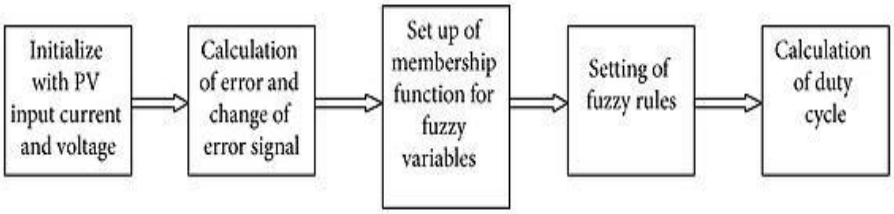
2.2 Modelling of MPPT with fuzzy

The fuzzification block is used for processing the input signals and gives them a fuzzy value. Rule Base allows a linguistic description of the variables that are to be controlled. The inference mechanism is used for making an interpretation of the data taken in with the rules and the membership functions. Conversion of fuzzy data into non-fuzzy data from the inference system is done by defuzzification block.

The proposed fuzzy logic block diagram is shown below.



Where, e is the error.
ce is the change in the error
ΔD is the duty ratio.
The flow chart for calculation of duty cycle is shown where voltage and current are the input.



The equation related with the error signal are given below

$E\,(K) = \frac{\Delta I}{\Delta V} + \frac{I}{V} = \frac{\Delta P}{\Delta V} = \frac{\Delta P}{\Delta I}$ ……………. (1)

CE $(K) = (K) - E\,(K-1)$,

$\Delta I = (K) - (K-1)$,

$\Delta V = (K) - (K-1)$,

$\Delta P = (K) - (K-1)$,

C (K) = C (K-1) + ΔC (K).

Where, CE (K) input defines the movement of the operating point.
(ΔC) is output variable in the duty cycle
K is sample times.

2.2.1 Membership Functions

Figure demonstrates the graphical membership function of error signal.

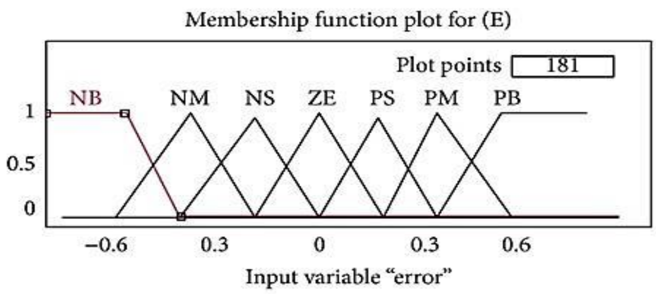


Figure demonstrates the graphical membership function of error change.

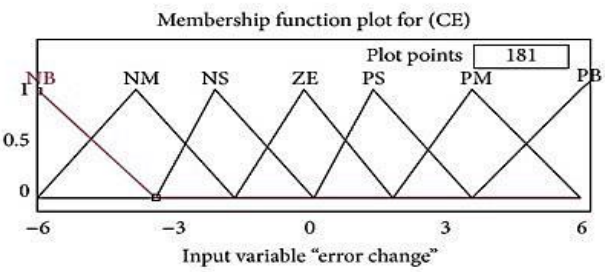
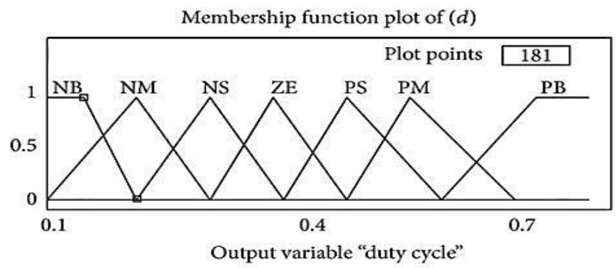


Figure demonstrates the graphical membership function of duty cycle.

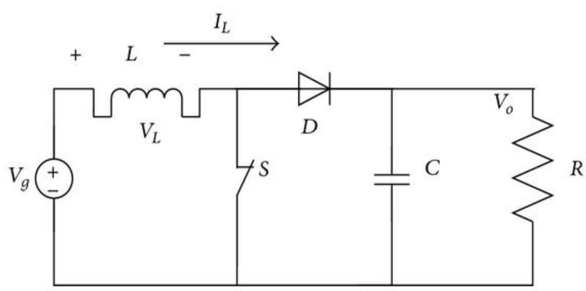


Twenty five rules are used for FLC as shown.

e/ce	NB	NS	ZE	PS	PB
NB	ZE	ZE	PB	PB	PB
NS	ZE	ZE	PS	PS	PS
ZE	PS	ZE	ZE	ZE	NS
PS	NS	NS	NS	ZE	ZE
PB	NB	NB	NB	ZE	ZE

3. Operation of Boost Converter

It takes voltage as input and boosts it at output terminal. Fig shows diagram of Converter.



Where. L is boost converter,
C is the filter capacitor,
V_g is dc input voltage.
S is switch here it is Mosfet.
R is the load.
D is the diode.
The converter mainly works on two modes of operation.

The capacitor is charged when switch is open by input voltage .By way of switch is shut the current flows through switch by inductor connected in between. Magnetic field is created on inductor getting it polarity. Inductor does not allow sudden change of current in the circuit ,so as the switch is open it act as voltage source and the outer capacitor is charged to a higher level voltage.

$M=\frac{V_o}{V_g}=\frac{1}{1-D}$

4. Modelling of VSI

The apparent power is given by,

$S_{VSI}=\sqrt{P^2+Q^2}$ ………………… (1)

Q is reactive power
P is real power
The RMS current through VSI is given by,

$I_{VSI}=\frac{KW*10^3}{\sqrt{3}\,V_m}$ …………………… (2)

Vm is mean voltage.
DC bus voltage is given as,

$V_{DC}=\frac{2*V_{LL}\sqrt{2}}{\sqrt{3}}$…………………… (3)

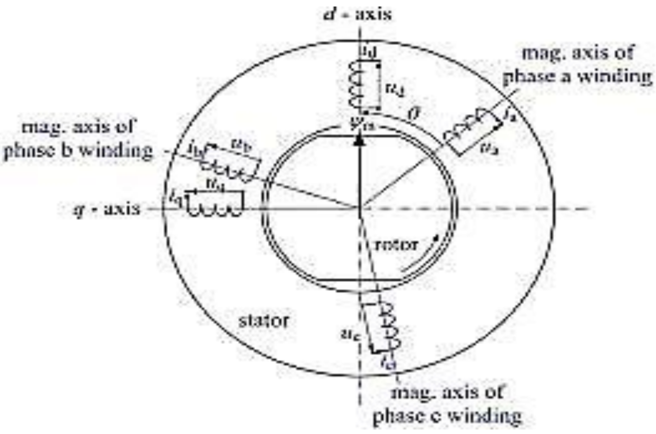
Centrifugal water pump modelled as,

T_P= K w^2

K is the proportionality constant,
w is the angular velocity,
Tp is the torque.

5. Modelling of PMSM

Figure illustrations cross sectional outlook of three phase permanent magnet synchronous motor with d-q rotating reference frame. Inductance varies as rotor angle changes. For that purpose d-q equivalent circuit is used.



The voltage equation in is given by,

$v_s = r_s i_s + \frac{d\lambda_s}{dt}$

Where r_s are the resistance of the stator winding, v_s are three phase stator voltage, i_s are three phase stator current, λ_s are stator flux linkage . They are represent as stationary reference frame as variable fixed to the stator ,

$v_s = \{ [v_{sa}(t) + a\, v_{sb}(t) + a_2 v_{sc}(t)] \}$ ……..... (1)

$i_s = \{ [i_{sa}(t) + a\, i_{sb}(t) + a_2 i_{sc}(t)] \}$………...(2)

$\lambda_s = \{ [\lambda_{sa}(t) + a\, \lambda_{sb}(t) + a_2 \lambda_{sc}(t)] \}$……... (3)

Where a and a_2 are operator for orientation of stator windings.

$a = e^{\frac{j2\pi}{3}}$ and $a_2 = e^{\frac{j4\pi}{3}}$

v_{sa}, v_{sb}, v_{sc} are stator instantaneous phase voltage .

i_{sa}, i_{sb}, i_{sc} are stator instantaneous phase current.

λ_{sa}, λ_{sb}, λ_{sc} are stator instantaneous stator flux linkages given by,

$\lambda_{sa} = L_{aa} i_a + L_{ab} i_b + L_{ac} i_c + \lambda_{ra}$…………..…. (4)

$\lambda_{sb} = L_{ab} i_a + L_{bb} i_b + L_{bc} i_c + \lambda_{rb}$……………... (5)

$\lambda_{sc} = L_{ac} i_a + L_{bc} i_b + L_{cc} i_c + \lambda_{rc}$……………….. (6)

Where L_{aa}, L_{bb}, L_{cc} are self-inductances with respect to a, b and c phase of stator. L_{ab}, L_{bc}, L_{ac} are mutual inductances.

λ_{ra}, λ_{rb}, λ_{rc} are flux linkages with respect to change in rotor angle.

Mutual inductances are expressed as

$L_{ab} = L_{bc}$……………………………………..... (7)

$L_{aa} = L_{ls} + L_o - L_{ms} (\cos 2\theta)$…………………….…… (8)

$L_{ab} = L_{ba} = \frac{1}{2} L_o - L_{ms} (\cos 2\theta)$………………….... (9)

Where L_{ls} is leakage inductance.

L_o is average inductance .

$L_o = ½ (L_q + L_d)$……………………………..…. (10)

L_{ms} is the inductance fluctuation

$L_{ms} = ½ (L_q - L_d)$ ………………………..…. (11)

Flux Linkages are expressed as,

$\lambda_{ra} = \lambda_r \cos\theta$…………………………….... (12)

$\lambda_{rb} = \lambda_r \cos\theta(\theta - 120)$ …………………. (13)

$\lambda_{rc} = \lambda_r \cos\theta(\theta + 120)$ ……………..…… (14)

Inductances are shown in matrix form.

$L_{ss} = L_{ls} + L_o - L_{ms}\ (\cos 2\theta)$ -.5L_o-L_{ms} cos2(θ-$\frac{\pi}{3}$).5L_o- L_{ms} cos 2(θ+$\frac{\pi}{3}$) -.5L_o -L_{ms} cos 2(θ-$\frac{\pi}{3}$) L_{ls} + $L_o L_{ms}$ cos 2(θ-$\frac{2\Pi}{3}$) -.5L_o-L_{ms} cos 2(θ-Π) - .5L_o - L_{ms} cos 2(θ+$\frac{\pi}{3}$) - .5L_o - L_{ms} cos 2(θ+Π) L_{ls} + L_o –L_{ms} cos 2(θ+$\frac{2\pi}{3}$)…………………..…………..(15)

$[v_s] = [r_s]\,[i_s] + d/dt\,[\lambda_s]$ ……………….. (16)

Where,

$[v_s] = [v_{sa}, v_{sb}, v_{sc}]$t

$[i_s] = [i_{sa}, i_{sb}, i_{sc}]$ t

$[r_s] = [r_a, r_b, r_c]$ t

$[\lambda_s] = [\lambda_{sa}, \lambda_{sb}, \lambda_{sc}]$ t

5.1 Park's Transformation

The time-varying such as current, voltage, phase inductances, flux linkages and stator quantities are converted by using Park's transformation to a d-q axis frame.

$[v_{dq0}] = [T_{dq0}(\theta_r)]\,[v_s]$ …………………..… (1)

$[i_{dq0}] = [T_{dq0}(\theta_r)]\,[i_s]$ ………………….. (2)

$[\lambda_{dq0}] = [T_{dq0}(\theta_r)][\lambda_s]$ ………………… (3)

Where $[v_{dq0}] = [v_d v_q v_0]$………………..... (4)

$[v_{dq0}]=[T_{dq0}(\theta_r)][r_s][T_{dq0}(\theta_r)]^{-1}[i_{dq0}]+$

$[T_{dq0}(\theta_r)]\ p\ [T_{dq0}(\theta_r)]^{-1}[i_{dq0}]$

$r_s[i_{dq0}] = [T_{dq0}(\theta_r)][r_s][T_{dq0}(\theta_r)]-1[i_{dq0}]$…. (5)

$v_d = R_s i_d - \omega_r\lambda_q + \frac{d\lambda d}{dt}$……………………… (6)

$v_q = R_s i_q - \omega_r\lambda_d + \frac{d\lambda d}{dt}$ ……………… (7)

$\lambda_{d\lambda} = L_d i_d + \lambda_f$ ……………………….. (8)

$\lambda_q = L_q i_q$

$V_d = R_s i_d - \omega_r L_q i_q + (L_d i_d + \lambda_f)$……… (9)

$V_q = R_s i_q - \omega_r L_q i_q + (L_q i_q)$………… (10)

The developed torque is given by

$T_e = 1.5(P/2)(\lambda_d i_q - \lambda_q i_d)$ ……………… (11)

The mechanical Torque equation is

$T_m = T_l + B\omega_m + J(d\omega_m/dt)$ ……………... (12)

$V_q = R_s i_q - \omega_r L_q i_q + (L_q i_q)$

$V_d = R_s i_d - \omega_r L_q i_q + (L_d i_d + \lambda_f)$

$\omega_m = ([(T_e - T_l - B\omega_m)/J]\ dt$

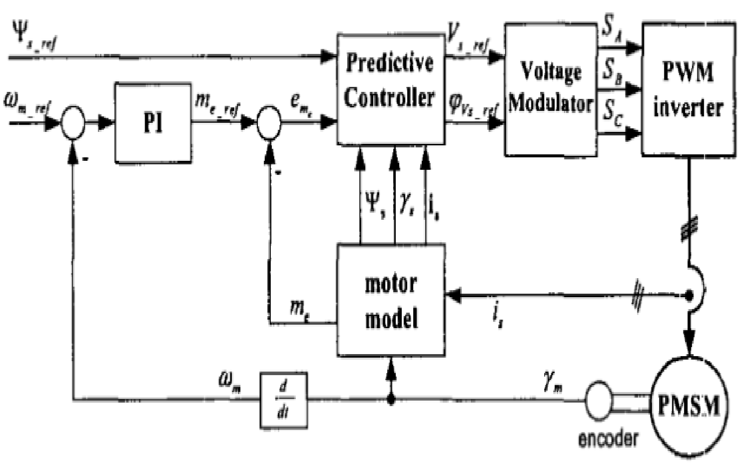
$\omega_m = \omega_r\ (2/P)$

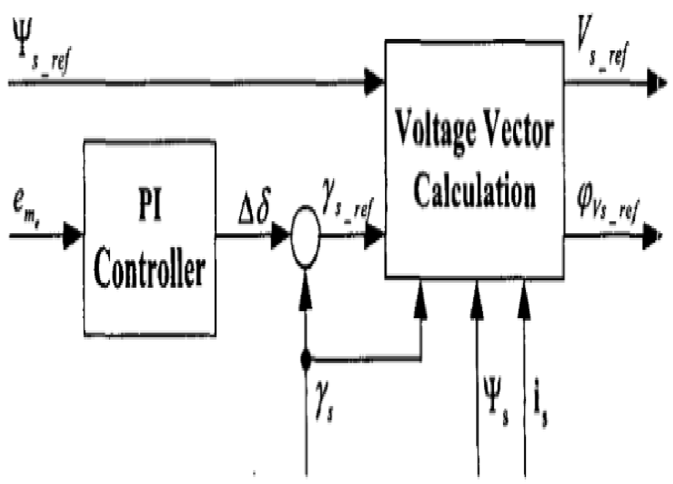
ω_r is the rotor electrical speed.

ω_m is the rotor mechanical speed.

5.2) SPEED AND TORQUE CONTROL (DTC-SVM)

The block diagram of torque and speed control (DTC-SVM) given to VSI helping PMSM is shown in figure below.





e_{m_e} is the experimented torque error

Ψ_{s_ref} reference stator flux amplitude

$v_{ref} = [V_{ref}, \varphi_{vref}]$ is calculated founded on stator resistance r_s, $\Delta\delta$, i_s, Ψ_s and γ_s as

$V_{ref} = \sqrt{{v_{s\alpha\_ref}}^2 + {v_{s\beta\_ref}}^2}$ ………………… (1)

φ_{vref} = arctan $\frac{v_{s\beta\_ref}}{v_{s\alpha\_ref}}$ ……………………….. (2)

Where, $v_{s\alpha\_ref} = \frac{\Psi_{s\_ref}\cos(\gamma_s+\Delta\delta)-\Psi_s \cos\gamma_s}{T_s} + r_s i_{s\alpha}$

$v_{s\beta\_ref} = \frac{\Psi_{s\_ref}\cos(\gamma_s+\Delta\delta)-\Psi_s \cos\gamma_s}{T_s} + r_s i_{s\beta}$

T_s is the sampling time.

III. RESULTS AND DISCUSSION

In this way solar water pumping system is modelled by employing PMSM .It is reliable, simple, requires less maintenance and gives higher efficiency. This system will efficiently irrigate for agriculture purpose.

REFERENCES

[1] K.Yoshikawa, "Silicon heterojunction solar cell with interdigitated back contacts for a photoconversion over 26%" Nature Energy ,vol 2, Mar. 2017.

[2] M. Kolhe, "Performance analysis of a directly coupled PV water-pumping system,"IEEE Trans. on energy conversion ,vol 19,Sept. 2004.

[3] T.Brinner,"Induction versus pm motors for electric submersible pump field & laboratory comparisions,"IEEE Trans. on ind. Appl.,,Jan./Feb.2014.

[4] T.Esram, "Comparison of PV array MPPT,"IEEE Trans.on energy conversion,vol 22,no 2, Jun. 2007.

[5] J.Caracas,"Implementation of a high-efficiency,high-lifetime & low cost converter for an autonomous PV water pumping system,"IEEE Trans. on ind. Appl.,vol 20,Jan/Feb 2014.

[6] S.Kulkarni , "Mathematical modeling and simulation of pmsm , " Intern. Jour. of Electronics & Electrical Engg., vol.1, no.2, Jun.2013.

[7] K. Sudheer , "Comparative study of pmsm and IM based on DTC method, "Intern. Jour. of Engg. research & appl. ,vol. 1,Issue 3,May 2014.