Mrs. S S Kulkarni, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 11, Issue 2, (Series-V) February 2021, pp. 12-15

RESEARCH ARTICLE OPEN ACCESS

Comparative Analysis of PMSM and IM for Solar Water Pumping System

Prachiti Arun Indurkar[1], Mrs. S S Kulkarni[2], Dr. A.G.Thosar[3]
[1]*Student Department of Electrical Engg. Government College of Engineering, Aurangabad.*
[2]*Associate Professor Department of Electrical Engg. Government College of Engineering,Aurangabad.*
[3]*Professor Department of Electrical Engg. College of engineering Pune*

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.

KEYWORDS: Photovoltaic Array Generation, Boost dc-dc Converter ,Voltage Source Inverter, PMSM Permanent magnet synchronous motor , Induction motor.

Date of Submission: 07-02-2021 Date of Acceptance: 21-02-2021

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.

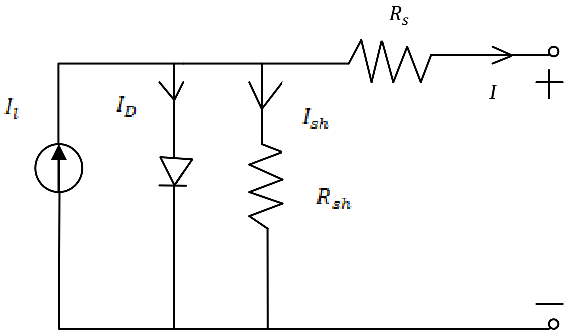
For pumping purposes it needs electric drive, before dc motors are used. But it has to take more maintenance due to deterioration brushes and commutator assembly. Induction Motor was meant for water pumping system because of its low cost and robustness [2]. But Induction motor gives high reactive demand 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. 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. It gives minimum harmonic distortion and gives more space vector voltage .

II. PV ARRAY MODEL



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

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

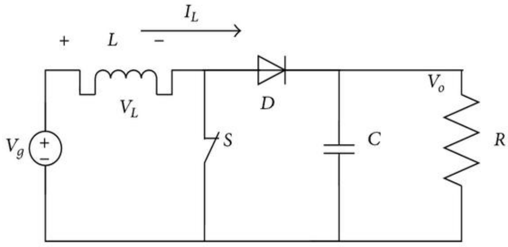
With $V_t = \frac{k \times T}{q}$

& $I_{sh} = \frac{V*\frac{N_p}{N_s}+I*R_s}{R_{sh}}$

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

III. BOOST CONVERTER MODEL

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.

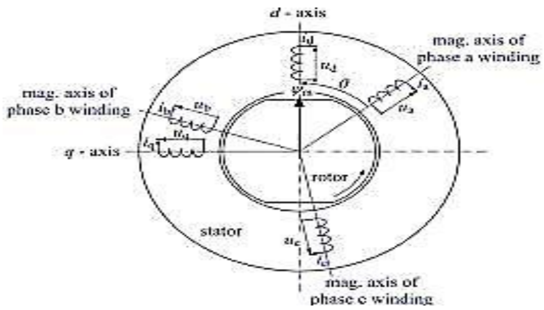
M= $\frac{V_o}{V_g} = \frac{1}{1-D}$

IV. 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.

V. 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.

$\lambda_{sa}, \lambda_{sb}, \lambda_{sc}$ 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.

$\lambda_{ra}, \lambda_{rb}, \lambda_{rc}$ 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,

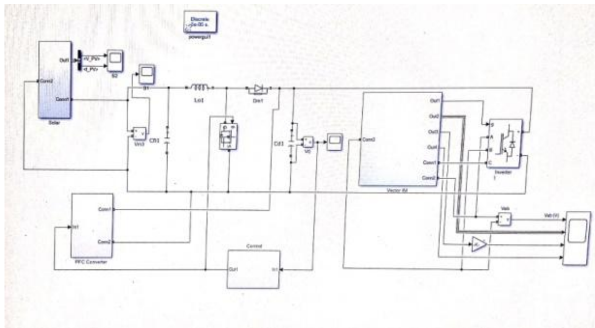
$[v_s] = [v_{sa}, v_{sb}, v_{sc}]$t

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

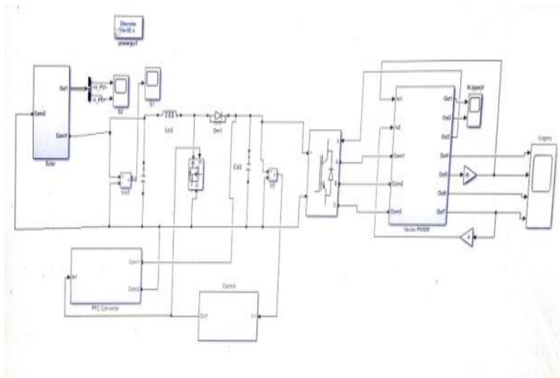
$[r_s] = [r_a, r_b, r_c]$t

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

VI. SIMULATION MODELLING OF SYSTEM WITH PMSM



VII. SIMULATION MODELLING OF SYSTEM WITH IM



VIII. SIMULATION RESULTS

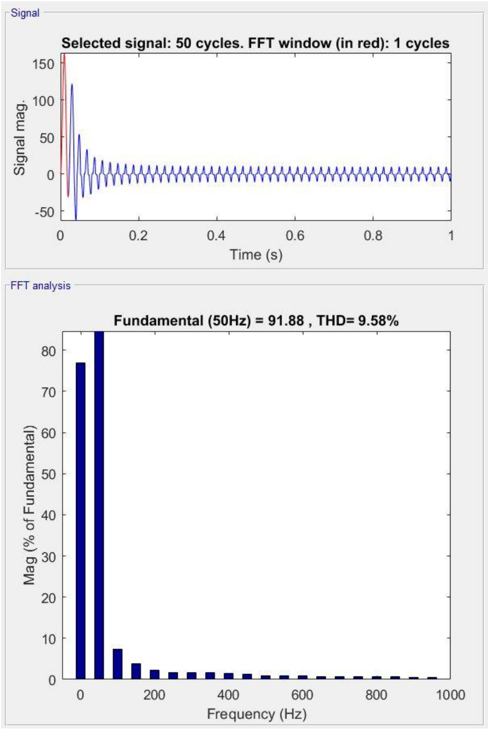


Fig shows FFT analysis when system is developed using Induction motor.

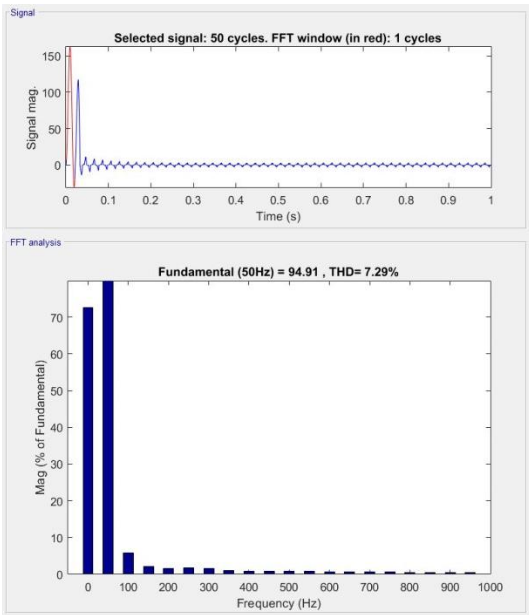


Fig shows FFT analysis when system is developed PMSM.

IX. CONCLUSION

In this way solar water pumping system is modelled by employing PMSM and IM.PMSM gives less maintenance higher efficiency. This system will efficiently irrigate for agriculture purpose or rising water level from lower potential to higher potential.

REFERENCES

[1]. K.Yoshikawa, “Silicon heterojunction solar cell with interdigitated back contacts for a photo conversion 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.