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# Speed Control of Matrix Converter Based Pmsm Drive System

U. Poovizhi
Student, EEE Dept
Meenakshi college of Engineering
Chennai, India

V. Srividhya
Asst.Professor, EEE Dept
Meenakshi college of Engineering
Chennai, India

Dr. Neena Ramesh
Professor, EEE Dept
Meenakshi college of Engineering
Chennai, India

***Abstract*—This project presents speed control of matrix converter based PMSM drive system. The speed of PMSM drive system can be controlled by using fuzzy logic controller, the speed of PMSM varies by changing the load which creates a drop in voltage. The matrix converter which compensates the drop and given to the PMSM. The simulations are carried out in the MATLAB Environment.**

***Keywords*— Matrix converter, fuzzy logic control, permanent magnet synchronous motor.**

## I. INTRODUCTION

The permanent magnet synchronous motors are becoming more popular nowadays compared to other ac motors. The advantages of PMSM including high torque, high efficiency, high power and low noise. The high performance drive systems used for drive PMSM in robotics and many other applications. The conventional PI controllers and proportional integral derivative controllers have been widely utilized as speed controllers in PMSM drive systems. For good results d-q axis reactance parameters of the PMSM should be known exactly, but it is difficult and conventional fixed gain PI and PID controllers are very sensitive to the step change and load disturbance [3]. To overcome this problem other speed controller has been adopted.

This paper describes the Rejection of Voltage Disturbance for Matrix Converter Using Fuzzy Based PMSM Drive System. The Matrix converter is a device used to convert the voltages ac to ac directly. The main advantage of matrix converter is, it does not have any storage element. Here fuzzy logic control is utilized for the speed control process to obtain the good results.

## II. PERMANENT MAGNET SYNCHRONOUS MOTOR

The Permanent Magnet Synchronous motor is a rotating electric machine where the stator is a classic three-phase stator like that of an induction motor and the rotor has permanent magnets.The use of a permanent magnet to generate a substantial air gap magnetic flux makes it possible to design highly efficient PM motors.

Fig 1 shows the block diagram of fuzzy based PMSM drive system where the matrix converter which converts the AC to AC voltage directly where the input voltage is 230 V. The matrix converter converts 230 V to 170 V.

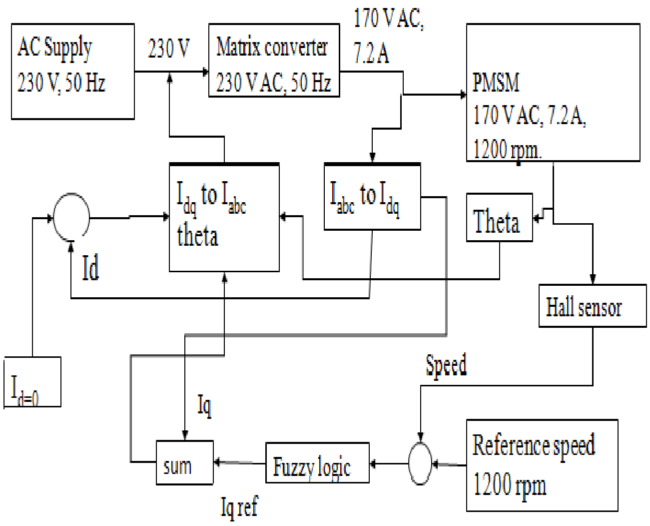


Fig.1. General Block Diagram of Fuzzy Based PMSM Drive System.

The output current of matrix converter is transformed from abc to dq(Park Transformation and vice versa. Here $i_d$ is taken as 0 because Flux is zero. And $i_q$ can be taken as torque. The output current of matrix converter is 7.2 A. by varying the load of PMSM the speed varies, the matrix converter which compensates the drop and given to the motor.

### *A. Mathematical Modeling of PMSM*

In d-q reference frame, the nonlinear differential equations:

$$T_e = \frac{3}{2}\frac{P}{2}\left[\lambda_m . i_q - (L_d - L_q).i_d.i_q\right] \quad (1)$$

$$\frac{d(i_d)}{dt} = \frac{v_d - r_s.i_d + \omega_r.L_q.i_q}{L_d} \quad (2)$$

$$\frac{d(i_q)}{dt} = \frac{v_q - r_s.i_q - \omega_r(L_d.i_d + \lambda_m)}{L_q} \quad (3)$$

$$\frac{d(\omega_{rm})}{dt} = \frac{T_e - T_L - B\omega_{rm}}{J} \quad (4)$$

$$\omega_r = \frac{P}{2}\omega_{rm} \quad (5)$$

$$\omega_r = \frac{d\theta}{dt} \tag{6}$$

$T_L$ is the load torque, B is the viscous friction, J is the moment of inertia, $v_d$ and $v_q$ represents d-q axes stator voltages, $i_d$ and $i_q$ is the d-q axes stator currents, $L_d$ and $L_q$ are the d-q axes inductances, $\omega_r$ represents electrical velocity of the rotor, $\lambda_m$ is the flux linkage due to rotor magnets linking the stator, $T_e$ is the motor torque, $\omega_{rm}$ is the mechanical velocity of the rotor, $r_s$ is the per phase resistance.

Here the output voltage of matrix converter is 170 V and output current is transformed from abc to dq.

$$\begin{bmatrix} i_q \\ i_d \\ i_0 \end{bmatrix} = \frac{2}{3}\begin{pmatrix} \cos\theta & \cos(\theta-120) & \cos(\theta+120) \\ \sin\theta & \sin(\theta-120) & \sin(\theta+120) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{pmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{7}$$

And again dq to abc transformation takes place.

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \frac{2}{3}\begin{pmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta-120) & \sin(\theta-120) & 1 \\ \cos(\theta+120) & \sin(\theta+120) & 1 \end{pmatrix}\begin{bmatrix} i_q \\ i_d \\ i_0 \end{bmatrix} \tag{8}$$

## III. MATRIX CONVERTER

It consist of nine bidirectional switches which needs commutation to minimize the losses and to produce desired output voltage with high quality input and output waveforms.

The output side quantities of matrix converter are transformed into a direct and quadrature reference frame rotating at the electrical angular speed of the PMSM rotor with the d-axis aligned with the rotor flux vector.

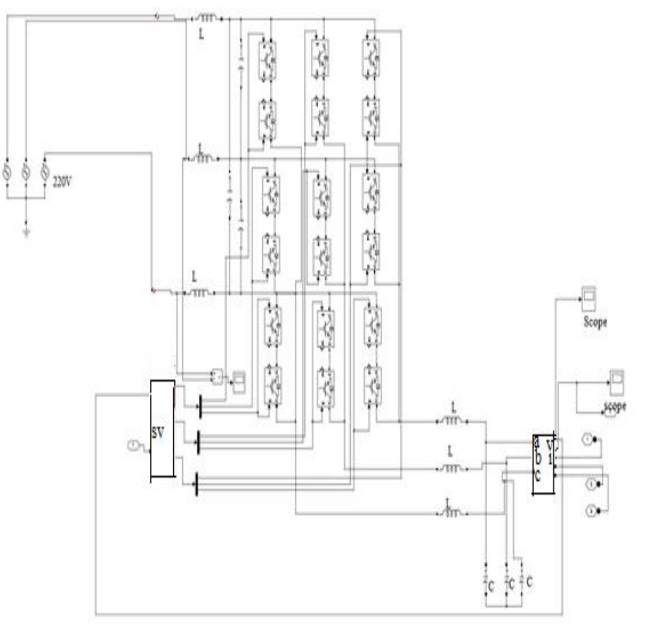

Fig.2. Matrix Converter Containing Nine Bidirectional Switches

### A. *Operation and Control of the Matrix Converter*

The voltages $v_{an}$, $v_{bn}$, $v_{cn}$ at the output terminals are related to the input voltages $v_{Ao}$, $v_{Bo}$, $v_{Co}$ by the equation.

$$\begin{bmatrix} v_{an} \\ v_{bn} \\ v_{cn} \end{bmatrix} = \begin{pmatrix} S_{Aa} & S_{Ba} & S_{Ca} \\ S_{Ab} & S_{Bb} & S_{Cb} \\ S_{Ac} & S_{Bc} & S_{Cc} \end{pmatrix}\begin{bmatrix} v_{Ao} \\ i_{Bo} \\ i_{Co} \end{bmatrix} \tag{9}$$

The input phase currents are related to the output phase currents by the equation

$$\begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \begin{pmatrix} S_{Aa} & S_{Ab} & S_{Ac} \\ S_{Ba} & S_{Bb} & S_{Bc} \\ S_{Ca} & S_{Cb} & S_{Cc} \end{pmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{10}$$

### B. *Switching States of Matrix Converter*

Three phase voltages can be divided into six areas according to their instantaneous magnitudes, which are called input voltage areas. In each area, there are eight input current modes $K_a, K_b, K_c$.

$$S_{Kj}(t) = \begin{cases} 1, \text{ switch } S_{Kj} \text{ closed} \\ 0, \text{ switch } S_{Kj} \text{ open} \end{cases} \tag{11}$$

where $K = \{A,B,C\}$, $j = \{a,b,c\}$ and $S_{Ka} + S_{Kb} + S_{Kc} = 1$

The equations which represents the switching states of matrix converter. The output current of matrix converter is 7.2 A.

TABLE I. SIMULATION PARAMETER RATINGS OF MATRIX CONVERTER

| Simulation Block | System Block | Parameter value |
|---|---|---|
| Matrix converter | LC filter<br>L-Inductance<br>C-capacitance<br><br>Bidirectional Switch<br>Internal resistance<br>Snubber resistance | <br>20e-3 H<br>1000e-6 F<br><br><br>1e-3 Ω<br>1e5 Ω |

## IV. FUZZY LOGIC CONTROL

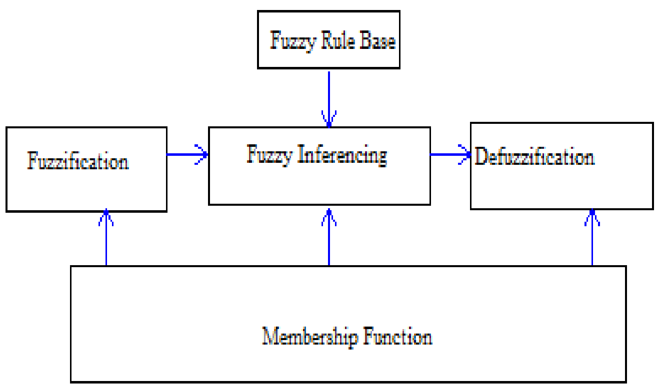


*Fig.3. Fuzzy Logic Control*

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A matrix converter-based permanent magnet synchronous machine (PMSM) with fuzzy logic drive system to overcome the unflavored impact introduced by digital filter and guarantees the drive performance under input disturbance conditions.

Three fundamental operations charactering a fuzzy system are

1. Fuzzification of input crisp values.
2. Fuzzy inference.
3. Defuzzification of fuzzy output.

***Fuzzification*** is a process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. Here change of error ce (k) and Error e(k) can be taken as two input variables to the fuzzy controller

$$e(k) = \omega_r^*(k) - \omega_r(k) \qquad (12)$$

$$ce(k) = e(k) - e(k-1) \qquad (13)$$

Where $\omega_r(k)$ is the actual speed and $\omega_r^*(k)$ is the Reference speed

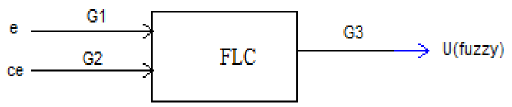


Fig.4. FLC control process

e(k) and e(k) are converted fuzzy variables E(k) and CE(k) by using the membership function

$$E(k) = G1*e(k) \qquad (14)$$

$$CE(k) = G2*ce(k) \qquad (15)$$

$$U(k) = G3*u(k) \qquad (16)$$

***Inference and Rule-Base*** is explained using IF-THEN rule statement between input and output functions. Mamdani method is used for FIS.

***Defuzzification*** is used to calculate the crisp value, Centroid Method is used in Defuzzification. The crisp value obtained is U(k).

The output of fuzzy logic controller is $i_{qref}$ which is calculated by integrating u(k) as in equation

$$i_{qref}(k) = i_{qref}(k-1) + u(k) \qquad (17)$$

TABLE II. MEMBERSHIP FUNCTION TABLE

| | Error "e" | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Change of error "ce"** | | NB | NS | NS | Z | PS | PM | PB |
| | NB | NB | NB | NB | NB | NM | NS | Z |
| | NM | NB | NB | NB | NM | NS | Z | PS |
| | NS | NB | NB | NM | NS | Z | PS | PM |
| | Z | NB | NM | NS | Z | PS | PM | PB |
| | PS | NM | NS | Z | PS | PM | PB | PB |
| | PM | NS | Z | PS | PM | PB | PB | PB |
| | PB | Z | PS | PM | PB | PB | PB | PB |

Where Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM) , Positive Big (PB).

## V. SIMULATION AND ITS RESULTS

The matrix converter input voltage is 230 V, which converts ac to ac voltage, the output voltage is 170 V. Under loading condition the speed of PMSM varies which creates a drop in voltage. The matrix converter which compensates the drop and given to the PMSM.

The main advantage of matrix converter is to compensate the drop and to maintain the speed of PMSM.

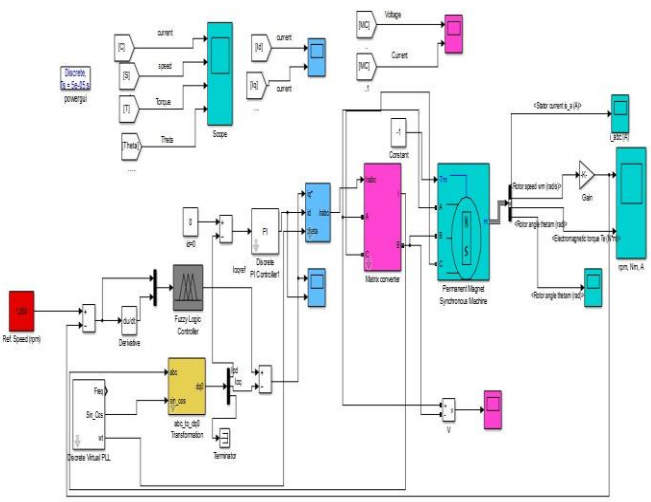

*Fig.5. Simulation Block Diagram of Fuzzy Based PMSM* Drive System

### *A. Under Rated Load Condition*

The output voltage of Matrix converter (170 V) with respect to Input voltage 220 V and the frequency is 50 hz. The peak voltage is constant 170 V .

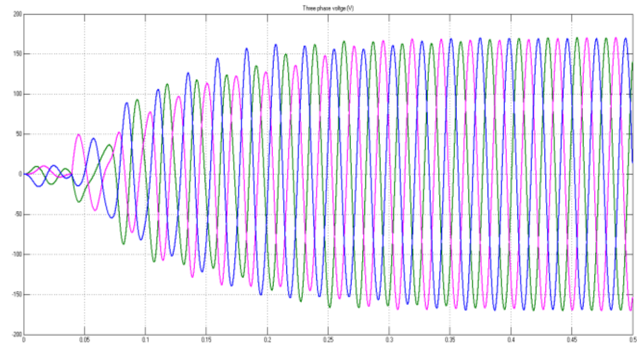

Fig. 6 Matrix Converter Output Three Phase Voltage.

The output current of Matrix converter (7.2 A) with respect to Input voltage 220 V and the frequency is 50 hz . The peak current is 7.2 A which is constant.

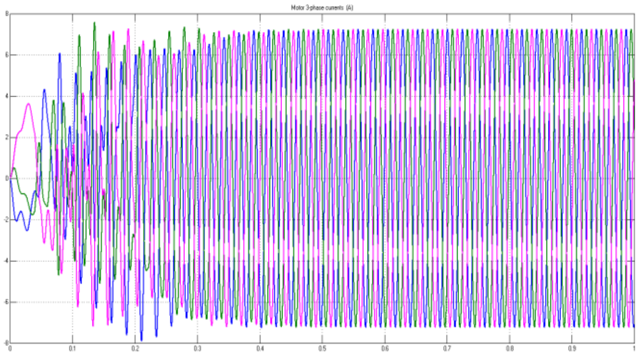

Fig. 7 Matrix converter output current

The graph shows the output speed of PMSM by using fuzzy logic control is 1258 rpm. The settling time for the speed of 1258 rpm is 0.3

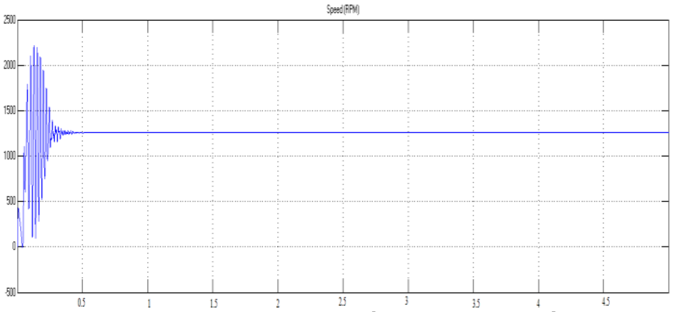

Fig. 8 Permanent Magnet Synchronous Motor Speed

The graph shows the output Torque of PMSM here for using fuzzy logic control we get the constant torque of -1 Nm. The Settling time for the torque is 0.32 sec .

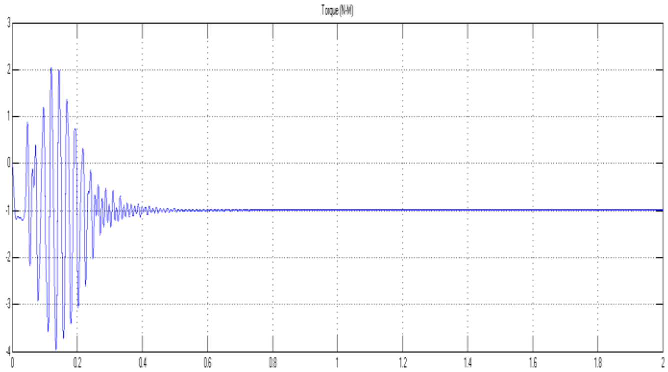

*Fig.9 Torque Graph for Permanent Magnet Synchronous Motor*

The graph shows the $I_d$ and $I_q$ current after comparing to the reference current. $I_d$ =1.2 A and $I_q$ =7.7 A. The output waveform is sinusoidal. The settling time is 0.3 sec, after the settling the current is constant.

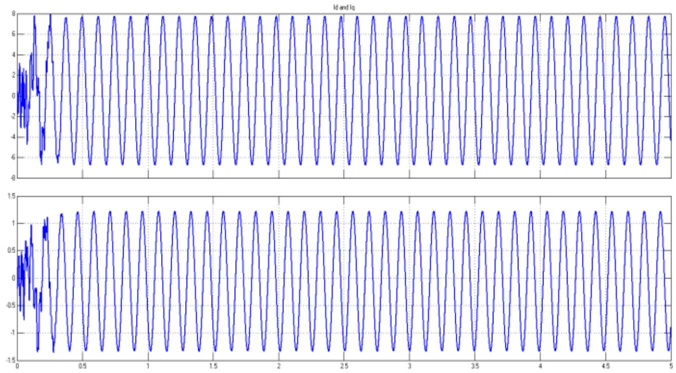

Fig.10. $I_d$ and $I_q$ After Comparing to the Reference Current.

TABLE III. SIMULATION RESULTS OF PMSM DRIVE SYSTEM

| **Parameters** | **Obtained Results** |
|---|---|
| Speed<br>Voltage<br>Current | 1258 rpm<br>170 V<br>7.24 A |
| $I_d$<br>$I_q$ | 1.22 A<br>7.75 A |

TABLE IV. SIMULATION PARAMETERS OF MATRIX CONVERTER BASED PMSM DRIVE SYSTEM

| **Simulation Block** | **System Block** | **Parameter value** |
|---|---|---|
| PMSM | Stator phase resistance<br>Armature inductance<br>Frequency<br>Inertia<br>pole pairs | 1.66 Ω<br>0.02875 H<br>50 Hz<br>0.0001051Kgm$^2$<br>2 |
| Membership values | NB<br>NM<br>NS<br>Z<br>PS<br>PM<br>PB | -1.8 to -0.2<br>-0.8 to 0.8<br>0.2 to 1.6<br>-1.667to -0.3334<br>-1 to 0.3334<br>-03334 to 1<br>0.3334 to 1.666 |

By increasing the load the speed of the PMSM varies with respect to the load, the advantage of the matrix converter is to compensate the voltage and current drop and given to the motor.

## VI. CONCLUSION

This project presents speed control of matrix converter fed PMSM drive system. The speed of PMSM can be controlled by using fuzzy logic controller, the speed of PMSM varies by increasing the load which creates the drop in voltage and current of matrix converter. The matrix converter which compensates the drop and given to the PMSM. The simulation results proven that the speed of PMSM can be controlled by using matrix converter based fuzzy logic control.

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