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Performance Analysis of a Matrix Converter FED Induction Motor Drive using Fuzzy Based SVM Modeling

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Abstract: Induction motor operated with inverter, harmonics will be in the supply. Especially, the odd harmonics are place crucial role to distort the operation of induction motor certainly. The presence of harmonics can reduce the performance of the machine. To overcome this drawback Matrix Converter (MC) can be used in place of inverter. MC is an AC-AC power converter that directly converts energy from input supply to output load without using any energy storage components. The output of the MC is fed as the input of Induction Motor (IM). In this work, the performance of the IM is analyzed by two modulation methods. The results were compared based on speed response, electromagnetic torque response, output voltage THD and input current THD. The proposed work is concentrated effectively at the design and modeling of Fuzzy Based Space Vector Modulation (FBSVM) to achieve a goal to require level of mall operation of induction motor due to input supply fed to it. The proposed FBSVM is also tested for loading condition due to disturbance and any other causes of faulty conditions i.e. increasing load form 5 to 8% on a test system.

Keywords: Fuzzy Based Space Vector Modulation, Matrix Converter, Induction Motor, Optimal Alesina and Venturini method (Optimal AV), Space Vector Modulation (SVM).

1. INTRODUCTION

Traditionally, DC motors were used for industrial applications despite the many advantages of the AC motors such as lower cost, low maintenance, robustness and reliability. The improvement in power switches and microprocessors technology has resulted in the development of AC-AC converters which basically transform the fixed frequency AC supply into a variable frequency, variable voltage source required by induction motor in industrial application [6-8]. The matrix converter allows to produce variable frequency and variable magnitude of the voltage from an AC source without using energy storage elements.

A first solution proposed by Venturini, it has the sinusoidal input and output waveforms with controllable input power factor and unrestricted output frequency. This algorithm has limitation that the voltage transfer ratio of 50%. The Optimal Alesina Venturini Method (Optimal AV) allows a maximum voltage transfer ratio of 86.6% and fully controlled input power factor [1-4]. A Fuzzy based SVM was proposed in this paper for the analysis of induction motor fed matrix converter. Fuzzy C-Means algorithm can able to fine tune the modulation index of matrix converter. [12]

2. MATRIX CONVERTER

MC is a new type of a direct AC-AC converter. MC is the combination of controlled semi-conductor switches that connects directly input phases with output phases. There are two fundamental rules for the operation of a matrix converter that arise from the voltage stiff input and current stiff output characteristics. No two input phases can be shorted together and no output phase can go open circuit [9-11]. The figure 1 shows the block diagram of MC fed IM.

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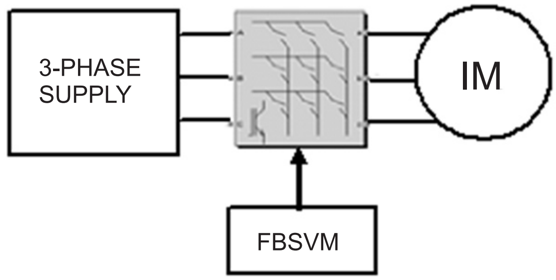


Figure 1: Matrix Converter with FBSVM

3. MODULATION METHODS FOR MATRIX CONVERTER

3.1. Fuzzy Based Space Vector Modulation (FBSVM)

This modulation technique applies the well developed Pulse width Modulation (PWM) strategies of converter to a MC modulation algoritham including Fuzzy C-Means algoritham. Synthesize the output voltage vectors from the input voltages and the input current vector from the output currents. The output voltages and input currents are controlled independently in FBSVM. he MC can equivalently represented as inverter and rectifier stages splitted by a fiction DC link this is done by dividing the switching functions into the product of rectifier and inverter switching function.

3.1.1. Fuzzy C-Means for SVM

The classification of modulation indexes are obtained in rectifier and inverter of MC was fine-tuned and clustered with help of Fuzzy *c*-Means. The fine-tuned modulation indexes (m_c, m_v) for purpose of SVM. The detailed algorithm with Fuzzy *c*-Means as follows [5]

Algorithm (step by step)

1. Fix "*c*" i.e. $2 \le c \le n$ and initialize partition matrix

$$\mathrm{U}^{(o)} \in \mathrm{M}_c \tag{1}$$

   Where U with "*c*" rows and "*n*" columns

2. Calculate the c centre vector, $v_1^{(r)}$ using following equation

$$\mathrm{V}_{ij} = \frac{\sum_{k=1}^{n} (\mu_{ik})^2 \, \mathrm{X}_{kj}}{\sum_{k=1}^{n} (\mu_{ik})^2} \tag{2}$$

   Where, $i = 1, 2, \ldots, c, j = 1, 2, \ldots, n$ μ_{ik} is the member ship function

3. Update $\mathrm{U}^{(r)}$ calculate updated characteristics function (for all i, k)

$$d_{ik} = \left[\sum_{\substack{i=0,1,\ldots,c \\ j=1,\ldots,m \\ k=1,\ldots,n}} (\mathrm{X}_{kj} - \mathrm{V}_{ij})^2 \right]^{\frac{1}{2}} \tag{3}$$

   X_{ik} is the input of SVM

   Find membership value of partition matrix element

$$\mu_{ik}^{r+1} = \left[\sum_{j=1}^{c} \left[\frac{d_{ik}^{r}}{d_{jk}^{r}} \right]^{\frac{2}{m^1 - 1}} \right]^{-1} \tag{4}$$

Where m^1 - weight factor

4. If max $[\mu_{ik}^{1} - \mu_{ik}^{0}] \le \varepsilon$ (tolerance level) stop; otherwise set r=r+1and return to stop.

   This fuzzy *c*-mean algorithm is used to fine tune the current modulation index m_c, voltage modulation index m_v.

Simulation Results: The performance of the Induction Motor analyzed and compared using two modulation methods based on Speed, Electromagnetic Torque, Input Current THD and Output Voltage THD. The MATLAB/Simulink of test system were shown in the Figure 2 to 6. The performance of IM tested with different torque levels (0 to 10 Nm), at each torque level input current THD, output voltage THD, Speed response and torque response with settling times were analyzed. Dynamical variation in load torque also tested on test system, torque and speed variations were analyzed. From the analysis, the MC fed IM with Fuzzy based SVM shows the best performance compare with the Optimal AV Method. The results were tabulated in Table 1.

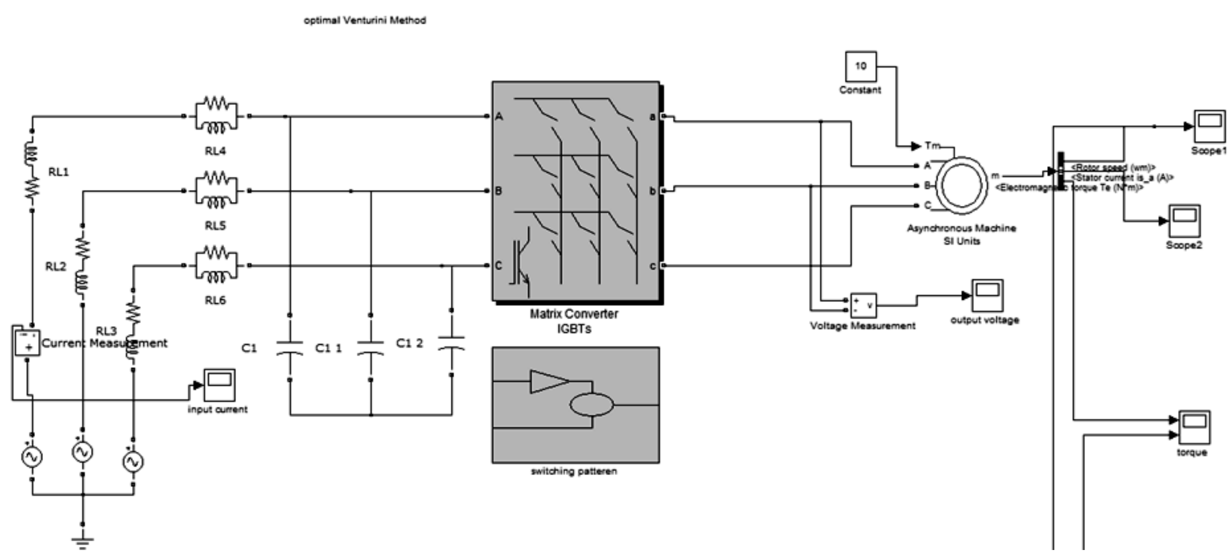


Figure 2: Simulation model of test system using Optimal AV Method

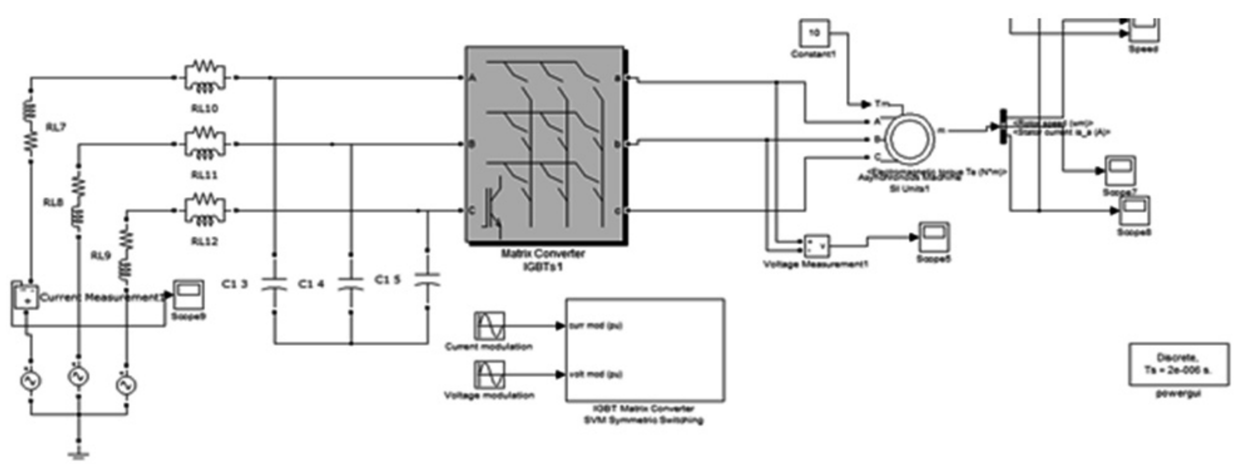
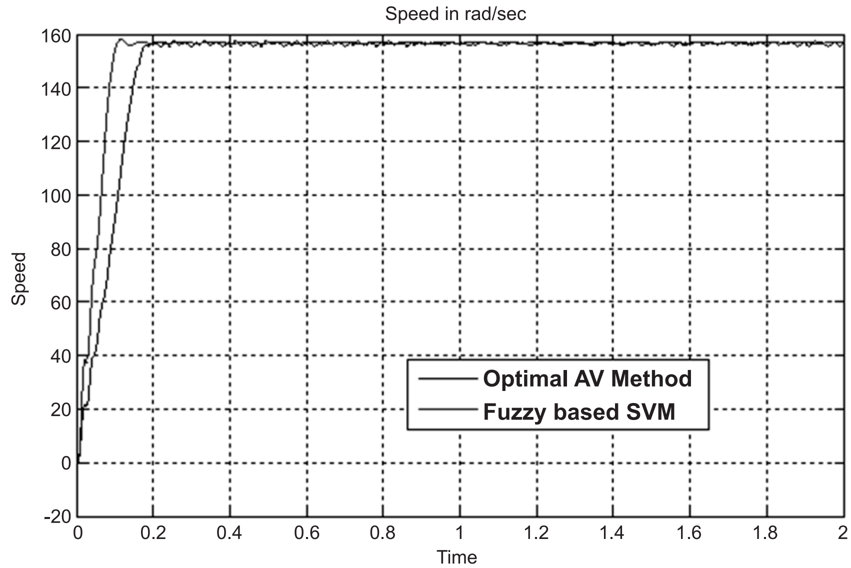


Figure 3: Simulation model of test system using Optimal AV Method


Speed in rad/sec
Speed
Time
160
140
120
100
80
60
40
20
0
-20
0
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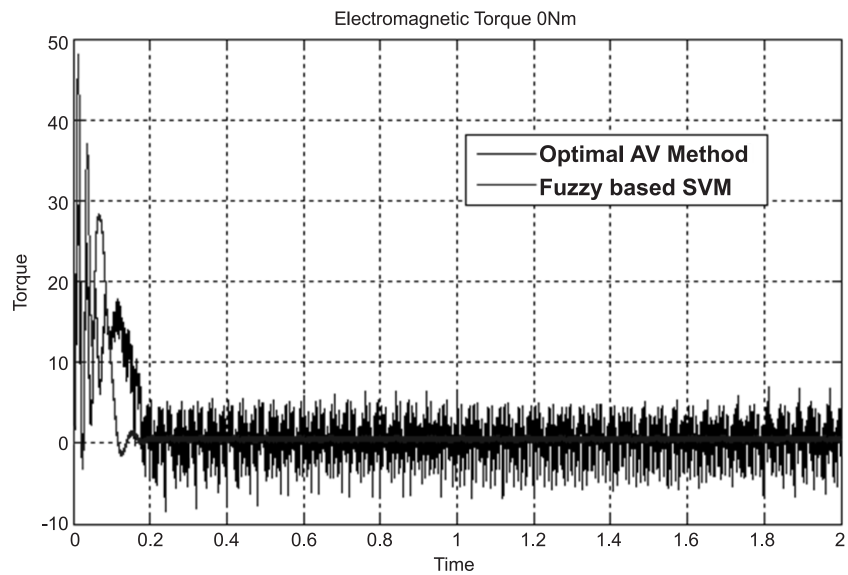
2
Optimal AV Method
Fuzzy based SVM

(A)


Electromagnetic Torque 0Nm
Torque
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50
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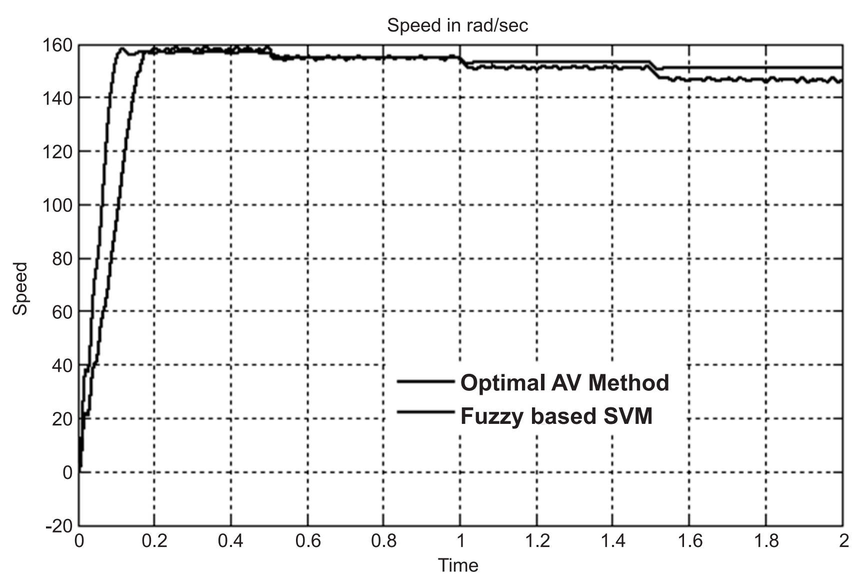
Optimal AV Method
Fuzzy based SVM

(B)


Speed in rad/sec
Speed
Time
160
140
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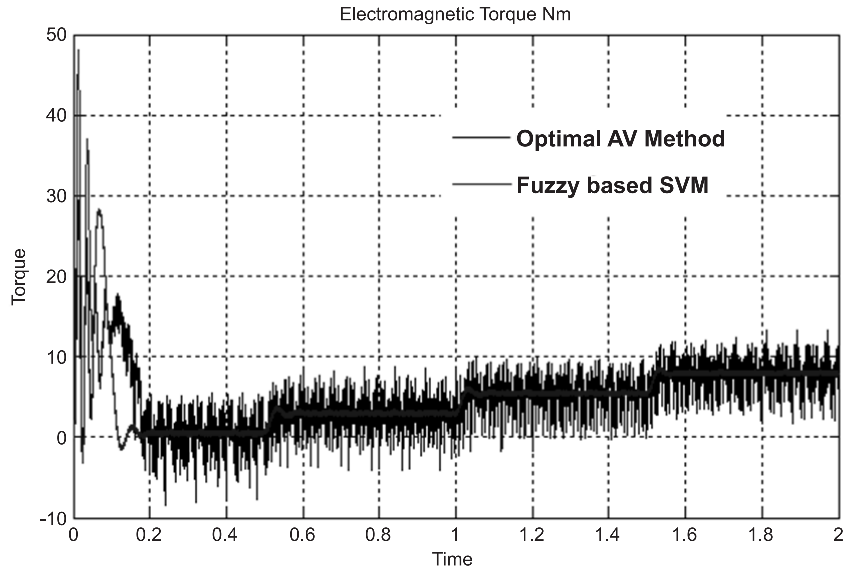
1
1.2
1.4
1.6
1.8
2
Optimal AV Method
Fuzzy based SVM

(C)



(D)

Figure 4: (A) Speed response of IM with load Torque 0 Nm, (B) Torque response of IM with load Torque 0 Nm (C) Speed response of IM with variable load Torque, (D) Torque response of IM with variable load Torque

Table 1
Simulation results of MC fed IM with two modulation method.

	Methods	*Tm = 0 N-m*	*Tm = 2.5 N-m*	*Tm = 5 N-m*	*Tm = 7.5 N-m*	*Tm = 10 N-m*
Input Current THD %	Optimal AV Method	123.9	109.29	94.35	79.78	68.4
	FBSVM	10.03	7.38	6.34	5.47	3.2
Output Voltage THD %	Optimal AV Method	43.73	45.49	46.24	46.5	46.67
	FBSVM	6.79	6.82	6.85	6.5	5.99
Settling time (seconds)	Optimal AV Method	0.2	0.3	0.4	0.5	0.7
	FBSVM	0.15	0.16	0.17	0.18	0.2

4. CONCLUSION

The MC fed IM simulation results were discussed in this paper. Based on the simulation results, FBSVM gives the best results compared with Optimal AV method. The FBSVM results input current THD as 3.20% and the output voltage THD as 5.99% at full load operation. The proposed FBSVM is tested for incremental load from 5 to 8% with loading conditions due to disturbance on the test system. The MC fed IM Drive was simulated successfully with FBSVM, obtained the best results.

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