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Speed Control of Asymmetrical Six Phase Induction Motor based Fuzzy Logic Controller

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Abstract - *Ac electric drives for both synchronous and induction take great interests by researchers and industrialist especially last type due to there is effortlessness for speed regulation, ruggedness, and high power to weight ratio etc…three phase drives was the conventional types that covered wide range of industrial and transmitting application .but with rising power demand and development in power electronics device and control schemes conventional induction motor drives could not be able to overcome all requirements in different fields , that's leads to think to create an other types of drivers having more than three phase (five, six ,seven and nine etc.) .six phase induction motor drive become one of these type used for many application instead of three phase type rising systems dependability, efficiency and flexibility in control process . [1]*

Key Words: multi-phase drives, six phase drive, induction motor, six phase inverter, anfis…

1. INTRODUCTION

Since last five decades many advances have been founded in conventional variable speed drive where three phase IM used to drive load in many fields like factory, vehicle, marine ship and propulsion ship. These loads are limited within many hundreds of kilo watt, for application more than one mega conventional drives lose their ability to face accident may have happened like faults, increasing load, stress on power electronics device [2]. A new generation of machine multi-phase induction motor drives have been presented to beat the last problem. the word multi refer to any number more than three introduced many advantages in drive system such as falling the pulsating torque, reducing total harmonics distortion in rotor circuit, reducing current stress on each phase at same value of voltages, improving reliability and efficiency [3,4], application with dissimilar load and operation state need to adjust speed for these drives, different methods used to regulate motor speed such as volt/hertz control, varying poles number in stator ,adjusting supply voltage. These methods can be implemented using one of the following techniques like PID controller or its derivative, Artificial Neural Network (ANN) fuzzy logic controller (FLC), or adaptive neuro fuzzy controller (ANFIS). Each one of them characterized by properties differs from others where PID is sensitive to any change of circuit so it need to know the exact parameter of system, while fuzzy logic controller (FLC) gave fast response with approximate mathematical model of system, and artificial neural network depends on volume of training data. Anfis controller represent a combination both last schemes with their properties.

1.1 Equivalent Circuit for six phase induction motor

Mathematical model of six phase induction motor drive will be represent according to how their winding construct. In this work asymmetrical IM consisting of double stator winding with shift angle = 30o electric degree will be studied. Figure (1) shown asymmetrical six phase induction motor

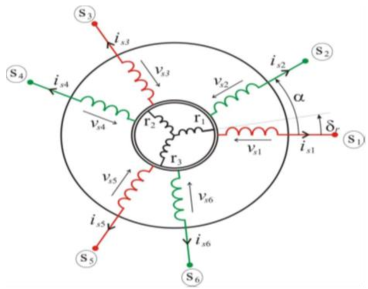


Fig -1: asymmetrical six phase induction motor

Like conventional IM six phase motor many thoughts must be must be considered to symbolize a mathematical model of machine:

1- Machine circuit not saturated
2- No core losses
3- The temperature does not effect on circuit parameter value
4- Uniformly distribution winding

From figure above it can be realize double set of three phase stator winding between them (30 degree) so it can be representing the model of machine by the same equations that for conventional motor surrounded the rotor winding. Stator and rotor voltage equation of motor will be written in synchronous reference frame

The double stator equation written below

$V_{qst1}=R_{qst1} I_{qst1}+ [w\lambda]_{dst1}+P \lambda_{qst1}$ …………... (1)

$V_{dst1}=R_{dst1} I_{dst1}- [w\lambda]_{qst1}+P \lambda_{dst1}$ ……………. (2)

$V_{dst2}=R_{dst2} I_{dst2}+ [w\lambda]_{qst2}+P \lambda_{dst2}$ ……………. (3)

$V_{dst2}=R_{(dst2)} I_{dst2}- 〖w\lambda〗_{(qst2)}+P \lambda_{(dst2)}$ ……………. (4)

The rotor equation written below

$V_{qr}=R_{(r)} I_{qr}- 〖\Delta w\lambda〗_{(dr)}+P \lambda_{(qr)}$ ……………. (5)

$V_{dr}=R_{(r)} I_{dr}- 〖\Delta w\lambda〗_{(qr)}+P \lambda_{(dr)}$ ……………. (6)

The equation of stator flux linkage also written as below

$\lambda_{(qst1)}=L_{11} I_{qst1}+ 〖aL_m〗_{(I_{qst1}+I_{qst2})}- aL_{dq} I_{dst2}+ 〖L_m〗_{(I_{qst1}+I_{qst2}+I_{qr})}$ ………………. (7)

$\lambda_{(dst1)} =L_{11} I_{dst1}+ 〖aL_m〗_{(I_{dst1}+I_{dst2})}- aL_{dq} I_{qst2}+ 〖L_m〗_{(I_{dst1}+I_{dst2}+I_{dr})}$ …………… (8)

$\lambda_{(qst2)}=L_{12} I_{qst2}+ 〖aL_m〗_{(I_{qst1}+I_{qst2})}- aL_{dq} I_{dst1}+ 〖L_m〗_{(I_{qst1}+I_{qst2}+I_{qr})}$ …………… (9)

$\lambda_{(dst1)}=L_{12} I_{dst1}+ 〖aL_m〗_{(I_{dst1}+I_{dst2})}- aL_{dq} I_{qst1}+ 〖L_m〗_{(I_{dst1}+I_{dst2}+I_{dr})}$ …………. (10)

The equation of rotor flux likage also written as below

$\lambda_{(dr)}=L_{1r} I_{dr}+ 〖L_m〗_{(I_{dst1}+I_{dst2}+I_{dr})}$ …………… (11)

$\lambda_{(qr)}=L_{1r} I_{qr}+ 〖L_m〗_{(I_{qst1}+I_{qst2}+I_{qr})}$ …………… (12)

Where

(a) = N1/N2

N1= number of turns of the first set of stator winding

N2= number of turns of the second set of stator winding

L_m is mutual inductance between stator and rotor

L_{dq} is mutual inductance between stator windings sets

Reference [5]

1.2 Volt/hertz speed control (scalar control)

In industrial application speed control of motor is one of the most important consideration to improve machine performance. Conventional induction and multi-phase motor rotate at constant speed near synchronous speed (Ns) due to their operation at constant frequency and voltage. When motors are loaded speed will be decrease under normal condition, volt-hertz (v/f) strategy is one of these methods implemented to achieve controlling process, this mean than the ratio of v/f must be constant for any speed. Keeping the flux of machine constant, so with any change of frequency (increase) without changing voltage, motor may operate at saturation region. Although it cannot increase voltage of supply feeding motor without rising frequency. this control scheme is appropriate for medium and high power applications.by implementing scalar controller for both open or closed loop controller maximum torque of machine will remain its value but at different slip. Figure (2) shows motor (torque –speed) characteristic using (v/f) control strategy [6]

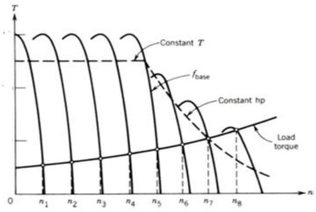


Fig -2: motor (torque –speed) characteristic using (v/f) control strategy

2. PID controller for speed regulator

Several strategies for closed loop control system used to regulate induction motor speed, a proportional –integral-derivative (PID) scheme is one of many industrial control systems. this type of supervisor used to reduce the steady state error, and reaches to preferred set point of system, by modifying parameter construct this controller (P, I, D), each one can be deducing in terms of time. Where P deals with current error, I with accretion of error and D with estimation of error. By summing these parameters. By summing these manipulated variable (MV). As shown in figure (3) with different weighted values a control block constructed which connects to plants. [7]

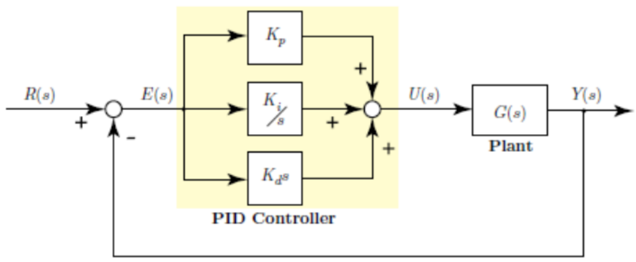


Fig -3: block diagram of PID controller connected with plant

3. Adaptive neuro-fuzzy controller (ANFIS)

ANFIS can be define as a combination of both fuzzy logic systems with artificial neural network with ability to modify it self. In this state anfis let parameters change automatically to match with membership function. At the state when input data loaded to control system (fuzzy inference system(FIS)) generates. To create particular network scheme enabling searching and taming parameters using "back propagation gradient descent (GD) method alone or in combination with Least Squares Estimates (LSE)."[8]

4. Simulation results

After building six phase induction motor (6PIM) using equation (1-12) a dual three phase inverters connected with model as shown in figure (4) driving using (SPVWM) technique, a complete model of drive system was appeared [4]

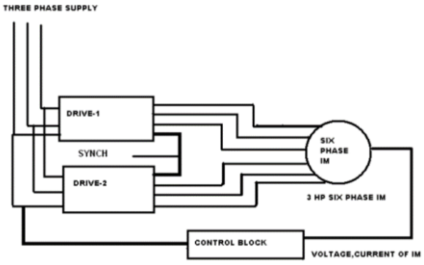


Fig -4: six phase IM drive

Drive runs free without any control circuit the motor output signal can be shown as figure below shows motor torque at value 12N.M

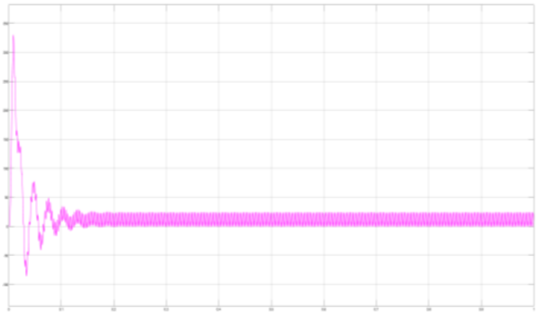


Fig -5: motor torque

Fig -6: motor speed 1477 RPM

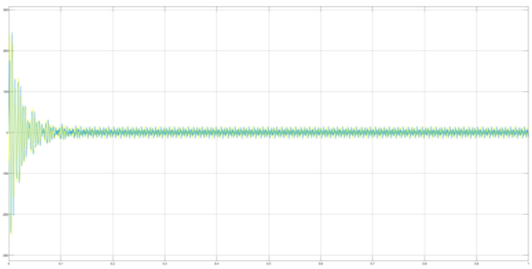


Fig -7: rotor current

V/F control strategy used to adjust motor speed using two different method of controller first (PID) and second (ANFIS) where an investigating and comparison between two strategy used for different speed values.

By implementing anfis with two input one output nodes, and training system the structure and surface of system and sugeno input output membership can be show in figures below

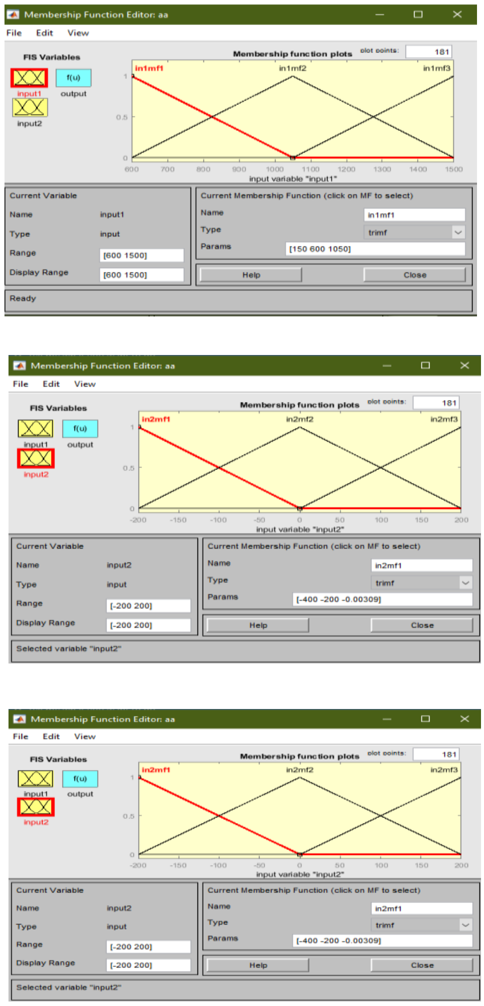


Fig -8: rules structure of two input one output anfis

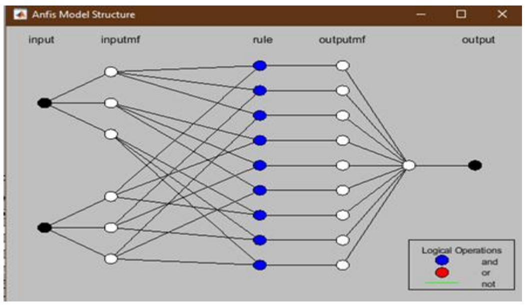


Fig -9: anfis structure

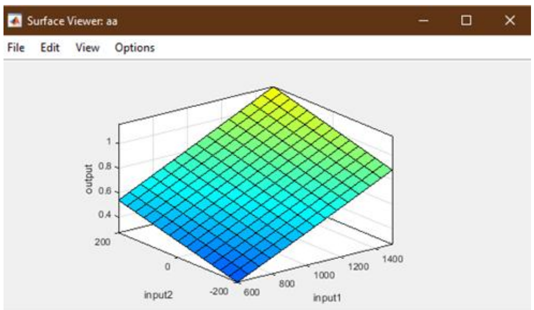
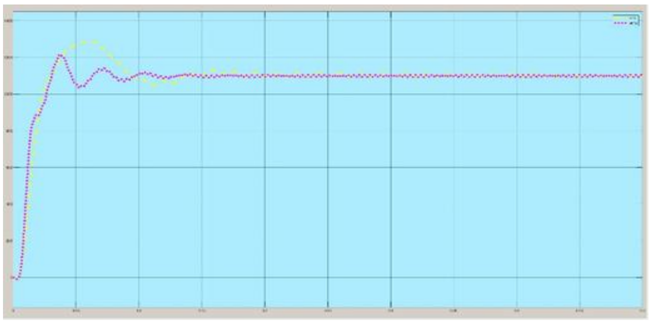
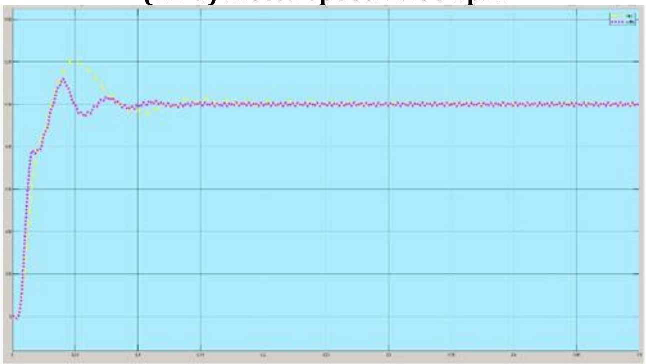


Fig -10: anfis structure surface

The results of speed controller for both anfis and PID are showing in figure below to simply the comparison between them

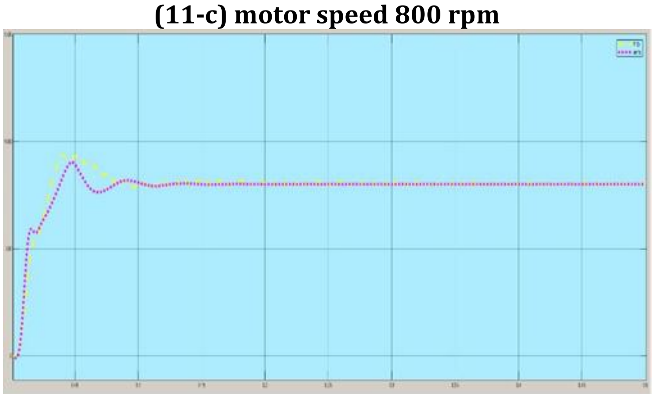


(11-a) motor speed 1100 rpm



(11-b) motor speed 1000 rpm

(11-c) motor speed 800 rpm



(11-d) motor speed 700 rpm

Fig -11: speed control results for both PID and ANFIS controller, yellow line symbolized PID, and pink represented ANFIS controller

By investigating the previous figures showed motor speed for PID control strategy .a comparison made between then deals with performance quality to show the best method for different speed, the chosen parameter related to rising time (tr) maximum over shoot (MOS) and steady state error (SSE)

Table -1: system performance for PID control scheme

speed	tr	MOS	SSE
1100	0.019	1290	1.09%
1000	0.0194	1205	1.2%
800	0.0208	936	1.25%
700	0.0285	810	1.43%

The same steps are implemented on anfis controller to make comparison for different speed of motor using adaptive neuro fuzzy (anfis)

Table -2: system performance for anfis control scheme

speed	tr	MOS	SSE
1100	0.0191	1215	0.00054%
1000	0.0194	1120	0%
800	0.0252	902	0%
700	0.0212	780	0%

3. CONCLUSIONS

Using mathematical equation, an asymmetrical six phase induction motor drive was built, a results of motor presented at load 12 N.M to show its characteristics. To regulate motor speed there are many strategies used to control speed but in this research Volt –hertz scheme has been implemented to make motor runs at different slip at same value of torque. Using two unlike control strategies proportional integral derivative (PID) and an adaptive neuro fuzzy logic controller (ANFIS) the mentioned scheme performed. from results it can be seen by comparing them the second controller gave a better performance than the first where anfis improve motor performance by reducing both steady state error and maximum over shoot while reduction rise time by PID happening by smaller value than anfis. Due to last results it can be conclude that the first suggested controller can advance drive performance in different value of speed

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BIOGRAPHIES

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