International Journal of Engineering & Technology, 7 (4.19) (2018) 139-143

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Intelligent Speed Controller for Four Phase Switched Reluctance Motor

G.Mahalakshmi[1*], D.Maladhi[2], G.Manochitra[3], T.Bhavatharini[4], T.Nandhakumar[5]

[1 2 3 4 5] Department of Electrical and Electronics Engineering, Sri Krishna college of Engineering and Technology, Coimbatore
**Corresponding Author E-mail: [1]mahalakshmig@skcet.ac.in*

Abstract

This paper examines the performance of Fuzzy logic controller with conventional PI controller speed control of four phase Switched Reluctance motor. Switched Reluctance motor has acquired attentiveness in Adjustable speed drive .Because of its less manufacturing and operating cost, fault tolerant capacity ,and high efficiency ,this motor is gains considerable attention. SRM is anyway somewhat hard to control, due to its nonlinear attributes. The dynamic execution anticipated from a variable speed drive incorporates least torque swell, low consistent state blunder, diminished speed overshoot, adaptation to non-critical failure and lessened speed wavering. Rather than linearizing the plant for particular working condition and afterward outlining a direct controller, a straightforward drive framework has been created. The controlled framework incorporates an inward current loop and external speed loop. Winding current and turn on ,turn off angles are utilized as control factors.

Keywords: *Switched Reluctance motor, hysteresis current controller, proportional integral controller, fuzzy logic controller, variable speed drives*

1. Introduction

Lately there has been an extraordinary request in industry for flexible speed drives. Exchanged Reluctance drives have a few exceptional highlights that make them appealing for scope of variable speed applications which incorporates
1 .High productivity over an extensive variety of torque and Speed.
2.High torque capacities at low operational velocities.
3.Simple and tough development.
4.Fault tolerant, four-quadrant task.
5. Reasonable for extraordinary condition activity.
The electromagnetic torque conveyed by the SRM is a non-straight capacity of stator current and rotor position. Correct and steady control of stator current and rotor position is the essential need of adjustable speed drive. Using PI controller and Hysteresis current controller this consistent control is connected and execution of the SRM drive made strides. J.A. Domínguez-Navarro, J.S. Artal-Sevil, H.A. Pascual, J.L. Bernal-Agustín(2018) proposed Fuzzy logic control strategy for SRM where power and its change are given as input and turn on angle and turn off angles are the outputs of the fuzzy. But the control has to be improved in the proposed method[1]. Xiu Jie, Xia Changliang(2007) compares the performance with PID controller, and the results shown have less blow out and less settling time.Proposed controller gives better results compared to the conventional PID controller[2]. N. Abut, b. Cakir, n. Inanc, a. B. Yildiz, m. Z. Bilgin(1997) propsed FLC for SRM in which Reduced torque ripple and less acoustic noise is obtained.
The prosed method is Experimentally tested with the prototype and simulation result have been proved[3]. Ali Maleki Majid Valianpour Ashkan Mohammadi Saeed Darabi(2012) conducted study on hybrid PID like Fuzzy logic Controller which is composed of a PI type fuzzy controller and a derivative operator.The proposed controller is straight forward than a FLC with three inputs and 7x7x7 rule bases. The proposed FLC has small speed ridge and invariable torque waveform[4]. Results of the study conducted by Gaber. El -saady, El-Noby A. Ibrahim and, M. Abuelhamd (2017) specified that the Adaptive hybrid PD-fuzzy logic controller designed can be used in pick and place industrial applications where wide range of different loding conditions is applied[5]. Ahmed Tahour,HAmsa Abid,Abdhel Ghani Aissiaoui ,and Mohamed Abid (2006), identified a controller which is used to designed a system with unknown model. Also zero steady stare error and quick response can be achieved by this method[6]. Shun-Chung Wan, Yi-Hua Liu, Chia-Cheng Lee(2009) stated that auxiliary hierarchy and computational many-sided quality of the controller can be lessened by decreasing the quantity of fuzzy sets without losing the framework execution and solidness[7].
Tarik UNLU, Ali UYSALA(2017) proposed a real time Fuzzy logic controller in which SRM's speed ca be controlled at different speeds and Variable load conditions[8]. Monitoring the Motor conditions like steady state and Transient conditions can also analyzed in the proposed hardware implementation.
M. Divandari and B. Rezaie(2016) proposed a fuzzy logic current compensator for reducing the peak of radial force and reduced acoustic noise[9].
Speed ripple and torque dwell also reduced by injecting extra current inclusion with each phase current. In another study presented by , Hady E. Abdel-Maksoud1, Mahmoud M. Khater1, Shaaban M. Shaaban1 Gamal M (2017), it is revealed in comparison with the conventional PI controller, the proposed controller improve the operation of motor in speed tracking mechanism[10] .A review of different torque ripple control techniques has been given in [11].

2. Switched Reluctance Motor

In each period of SRM, electromagnetic torque is created by the inclination for the attractive circuit to shape an arrangement of least resistance. Despite the fact that different blends of stator and rotor pole numbers are conceivable, the regularly utilized are 8/6,6/4. The quantity of stages is critical, with respect to a more prominent number of stages there will be smoother torque changes starting with one stage then onto the next, the more noteworthy the quantity of stages, the littler the torque swells. Speed of pivot relies upon the normal torque following up on the rotor, which thus relies upon the greatness of stage streams. The course of turn can be changed by energizing the stages in the invert succession. For instance, excitation of stages in the grouping 1-2-3-4-1 will give turn the counter clockwise way. The excitation of stage in the arrangement 4-3-2-1-4 will give turn clockwise way. The machine can likewise give regenerative braking.

3. PI Controller

It's a combination of Proportional and Integral controller where proportional term considers the current size of the error and the integral term considers the history of errors.
The control action is characterized by the equation given below:
$Y(t)=Kc\ i(t)+1/Ti \int i(t)\ dt$ (1)
Ziegler-Nichols Tuning is utilized to tune the PI controller in this Switched Reluctance Motor drive circuit.
(a) kevlar mat

4. Schematic form of Switched Reluctance motor drive

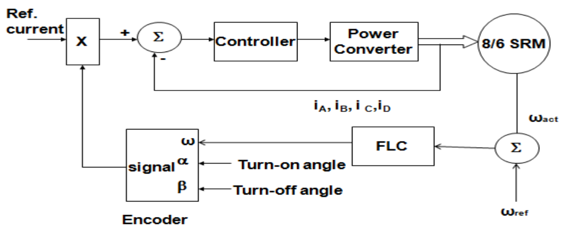

Fig. 1: Schematic form of the system

Schematic form of the 4phase 8/6 Switched Reluctance Motor drive circuit is shown in Fig1.The controller used here is Proportional –Integral (PI) controller and hysteresis current controller. Asymmetric converter that consists of two IGBT's and two diodes feeds the four phase SRM. Switching of the converter can be accurately made by the encoder attached to the rotor. The torque produced by the motor can be influenced by the switching angles. In the outer speed loop , actual speed of the motor is measured by position sensor and gives phase current reference as the output according to the rotor position and commutation logic. In the inner current loop, the four, phase currents from the converter output is compared with the reference current and it is applied to the controller. The phase currents are independently controlled by the hysteresis current controller or PI controller which generate IGBT's drive signals by comparing measured current with the references.

5. Simulation of PI and Hysteresis Controller fed SRM

Simulation of the SRM drive is done by MATLAB Simulink R2014a Software. Schematic diagram of PI/Hysteresis current controller based Four phase SRM drive is shown in Fig (2).Source Voltage of 240 volts is applied for the circuit. Switching angles of the converter are kept constant at 45 deg and 75 deg, respectively, for the entire speed range. Hysteresis band for the current controller is chosen as +-10 A .Current reference is set at any value. The regulator input is step input to start the SRM. Load characteristics will decide the acceleration of SRM. SRM torque has a very high torque ripple value which is due to the changeover of the currents from one phase winding to the next.

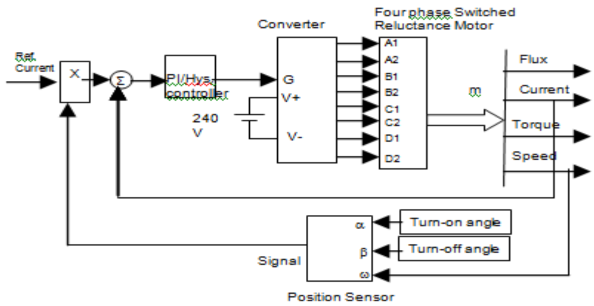

Fig. 2: Schematic diagram of PI /Hysteresis current controller based 8/6 SRM

6. Simulation Results of PI/Hysteresis Controller

Speed and torque responses of Hysteresis current controller based four phase Switched Reluctance Motor is shown in fig (3) & fig (4) respectively.

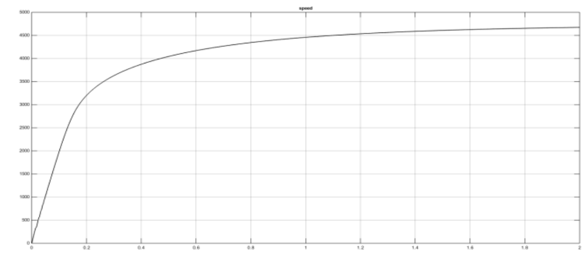

Fig. 3: Speed Response

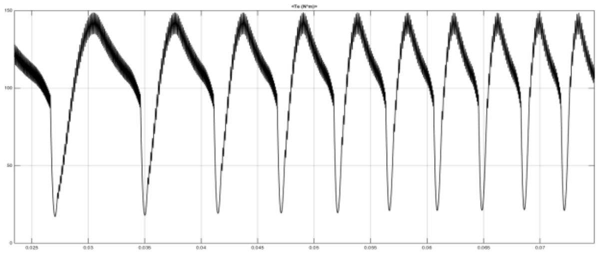

Fig. 4: Torque Response

From the Torque response characteristics it can be concluded that torque dip was more during the commutation from one phase to another.
Speed and torque responses of PI controller based Four phase Switched Reluctance Motor is shown in fig (5) & fig (6) respectively

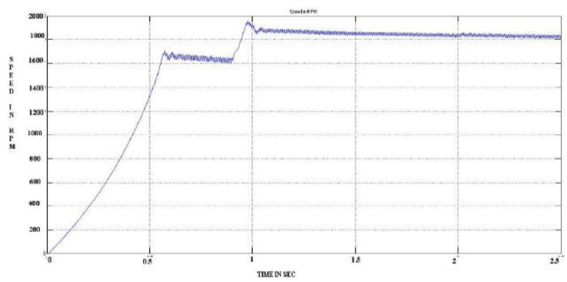

Fig. 5: Speed Response

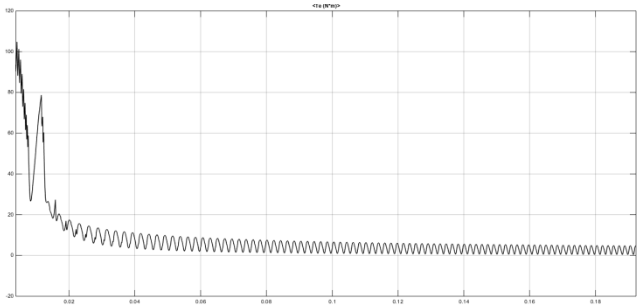

Fig. 6: Torque Response

PI controller was tuned Using Ziegler-Nichols method and the gain was also adjusted such that the performance of response is improved. The K_i value was tuned to 16.61 and the Kp value tuned to 0.65 and the gain is set to 1.

7. Basic Concepts of Fuzzy Logic Controller

For a complex, non-linear and non-specific defined process , Fuzzy Logic controller(FLC) has been used for which Quality based control techniques are impractical.

A fuzzy set is expressed by fuzzy variable which in turn explained by a membership function µ.Basic shape of FLC with SRM is shown in Fig.

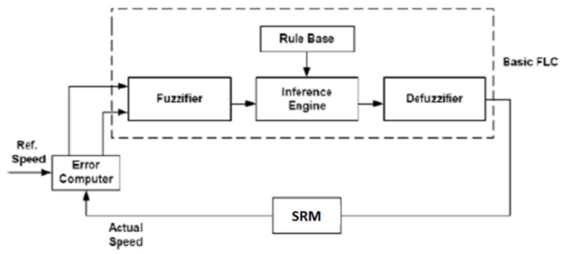

Fig. 7: Basic shape of FLC with SRM

Reference Settling:

For the four phase's current hysteresis control,current settling is determined. Actual speed is compared with the reference speed and based on the Error and change in error ,FLC produces current reference output. Estimated difference between the observed value of the quantity and the true value has its least value when the motor speed has supposed value ,+200 rad/sec and it is transposed to

-200rad/sec. So

$E=\omega_{ref}-\omega=(-200)-(+200)=-400$rad/sec.

Hence for Error Membership function, range of +600 to -600 has been chosen.

In the other direction maximum value,+400 is obtained. For the nominal current of SRM ,torque obtained is 250N-m.Hence we can calculate the maximum absolute value for change in Error(CE). CE=E ω(k)-E ω(k-1)

$= (\omega_{ref} - \omega(k))-(\omega_{ref} - \omega(k-1))$

$=-(\omega(k)- \omega(k-1)) =-\Delta \omega$

$J(\Delta\omega/\Delta t)=\tau$

$\Delta\omega=(\Delta t/J)\ \tau$

$CE=(\Delta t/J)\ \tau=(0.1/0.02)*250$

$=1.3$

Hence for Change in Error(CE) ,the range of +1.5 to -1.5 has been chosen.

From the results obtained from the PI controller the inceptive limits for the domain of antecedents (error, change in error) and Consequent (output) were the following:

E=-600 to +600 rad/sec

CE=-1.5 to +1.5 rad/sec

Output=-200 to 200

Seven membership functions that are used to represent the E,CE, Output are designed for the system and shown below.

Membership functions of Fuzzy Controller

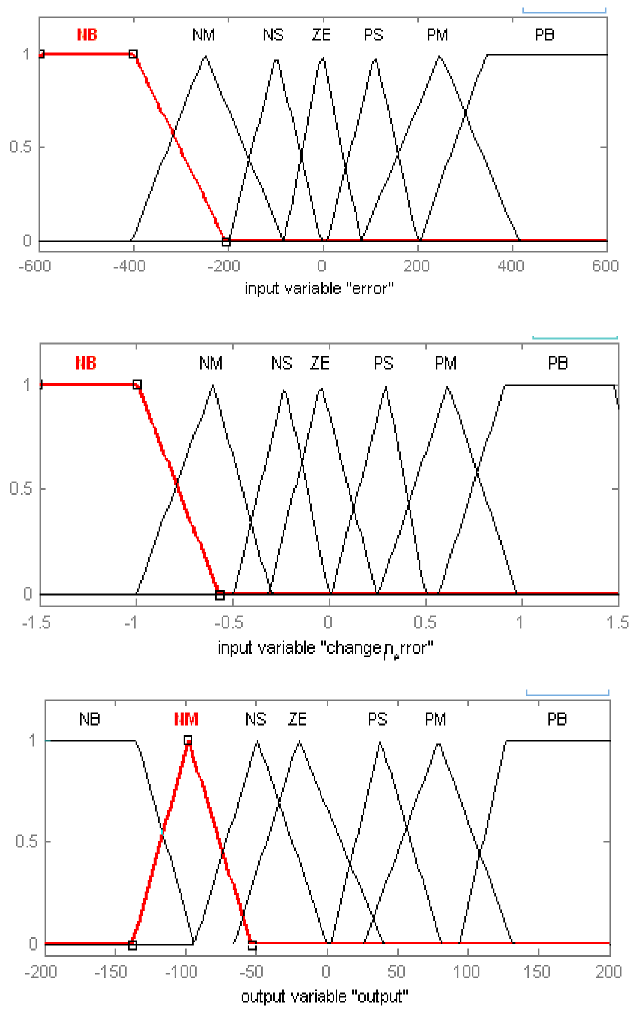

Fig. 8: Membership functions of Fuzzy Controller

8. Simulation Diagram of Proposed Speed Control of SRM with FLC:

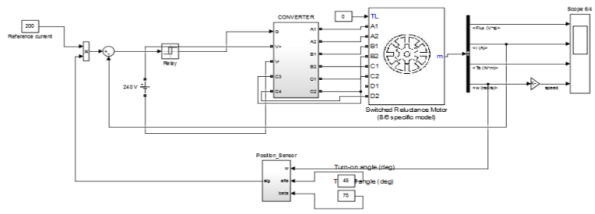

Fig. 9: Simulation diagram of proposed method

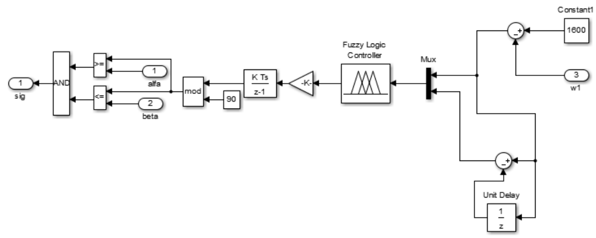

Fig. 10: MATLAB simulation diagram of Fuzzy controller Block

Fuzzy Interpretation:

IF-THEN patterns are used to form the fuzzy rules. NEGATIVE,ZERO, POSITIVE are used as adjectives to

represent the error and change in error. Two input conditions Error and Change in error and the output is output response .49 possible rules are generated for the system to get the optimum output . Rules are given in Table 1
Fuzzy Interpretation table is shown in Table 1

Table 1: Fuzzy Interpretation

ce/e	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	NZ
NM	NB	NB	NM	NM	NS	Z	PS
NS	NB	NM	NM	NS	Z	PS	PM
Z	NM	NM	NS	Z	PS	PM	PM
PS	NM	NS	Z	PS	PM	PM	PB
PM	NS	Z	PS	PM	PM	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

Motor Specifications for MATLAB simulation is shown in Table 2

Table 2: Four phase SRM Specification used in Simulation

Power	75kW
Stator resistance	0.05ohm
Inertia	0.05 kg.m.m
Friction	0.02 N.m.s
Unaligned inductance	0.67e-3
Aligned inductance	23.6e-3
Maximum current	450
Maximum flux linkage	0.486

9. Simulation Results and Discussion

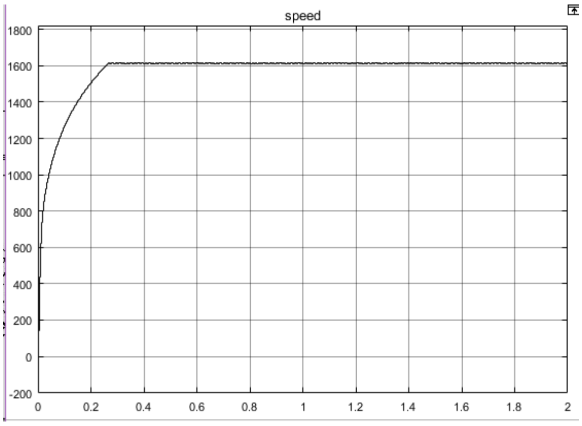

Fig. 11: Speed Response

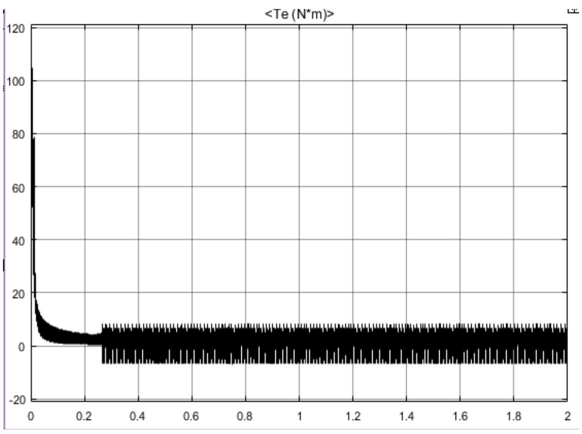

Fig. 12: Torque response

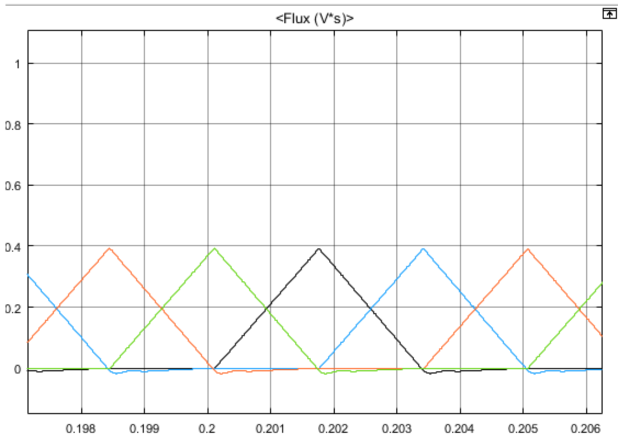

Fig. 13: Flux linkage characteristics

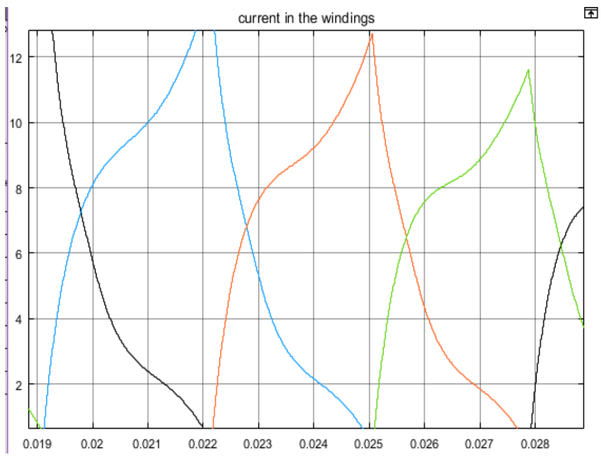

Fig. 14: Phase winding current characteristics

From the Fig(11) ,it can be concluded that the speed can be controlled to the desired value or set point value. Torque ripple produced by the four phase SRM is also less compared to the Conventional controller as shown in Fig(12). Phase winding currents are shown in Fig(14)
Performance comparison of fuzzy, conventional PI, Hysteresis controller is given in Table 3.
Reference Speed =1600rpm,T_L=0Nm,time=2 sec

Table 3: Performance comparison

Controller	Hysteresis controller	Conventional PI controller	Fuzzy Controller
Settling time	1sec	1 sec	0.25sec
Torque ripple Coefficient	1.75	1.384	0.5

Analysis has been done in settling time of speed response and torque ripple coefficient for the three types of controllers and are given in Table 3. From the results, it is concluded that the settling time of motor and ripples produced in the motor is less in Fuzzy logic controller .Authentication of high level performance of fuzzy logic controller is evidenced by the performance given in Table 3.

10. Conclusion

The Proposed fuzzy logic controller as has been employed for the speed control of Switched Reluctance motor. Its results are compared with the conventional PI controller and Hysteresis controller based SRM. Speed can be controlled to the set point value and the torque ripples also minimized in the proposed system. These outcomes likewise affirmed that the transient torque and current never surpass the greatest allowable esteem.

References

[1] J.A. Domínguez-Navarro, J.S. Artal-Sevil, H.A. Pascual, J.L. Bernal-Agustín(2018) ,Fuzzy-Logic strategy control for switched reluctance Machine, Thirteenth International Conference on Ecological Vehicles and Renewable Energies (EVER). European Union.

[2] Xiu Jie, Xia Changliang(2007), An Application of Fuzzy Logic Controller for SwitchedReluctance Motor Drive" Proceedings of the 26th Chinese Control Conference July 26-31, 2007, Zhangjiajie, Hunan, China,50-53

[3] S.Sheeba Rani, V.Gomathy and R.Geethamani, "Embedded design in synchronisation of alternator automation" in International Journal of Engineering and Technology(IJET) , Volume No.7, pp 460-463, April 2018

[4] Ali Maleki Majid Valianpour Ashkan Mohammadi Saeed Darabi(2012) ,Hybrid PID-Like Fuzzy Logic Speed Drive of Switched Reluctance Motor, 2012 11th International Conference on Environment and Electrical Engineering,

[5] Gaber. El -saady, El-Noby A. Ibrahim and, M. Abuelhamd(2017),Hybrid PD-Fuzzy Position Controller for Linear Switched Reluctance Motor with Online Fuzzy Logic Gain Scheduling of PD, 2017 Nineteenth International Middle East Power Systems Conference (MEPCON), Menoufia University, Egypt,830-838.

[6] Ahmed Tahour,HAmsa Abid,Abdhel Ghani Aissiaoui ,and Mohamed Abid (2006), Acta Electrotechnica,vol47,No.3,124-131.

[7] Shun-Chung Wan, Yi-Hua Liu, Chia-Cheng Lee(2009) , A Modified PI-Like Fuzzy Logic Controller for Switched Reluctance Motor Drive, International Journal of Engineering & Technology IJET-IJENS Vol: 10 No: 05,1366-1379

[8] Tarık UNLU, Ali UYSALA(2017), Real-Time Fuzzy Logic Control of Switched Reluctance Motor, International Journal of Intelligent Systems and Applications in Engineering, 5(3), 135-139

[9] M. Divandari and B. Rezaie(2016) ,Fuzzy Logic Control of Switched Reluctance Motor Drives, New Applications of Artificial Intelligence,Chapter3,IN THE open science,

[10] Hady E. Abdel-Maksoud1, Mahmoud M. Khater1, Shaaban M. Shaaban1 Gamal M (2017) , Adaptive Fuzzy Logic PI Control for Switched Reluctance Motor Based on Inductance Model, International Journal of Intelligent Engineering and Systems, Vol.10, No.4, 41-49.

[11] G.Mahalakshmi, Dr.C.Ganesh "A Review of Torque Ripple Control Strategies of Switched Reluctance Motor", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 4688-4692.