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Comparative Study of Speed Control of 8/6 Switched Reluctance Motor Using Pi and Fuzzy Logic Controller

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Abstract: This paper deals with the comparative study of speed control of 8/6 Switched Reluctance Motor using PI and Fuzzy Logic Controller. Nowadays the Switched Reluctance Motor has gained more and more attraction in industries. The speed of the Switched Reluctance Motor is controlled using both PI and Fuzzy Logic speed Controller in MATLAB/Simulink environment. The simulation result shows that Fuzzy Logic Controller is superior to PI controller.

Keywords: Switched Reluctance Motor (SRM), Fuzzy Logic Controller (FLC), PI Controller, and Speed Control

I. INTRODUCTION

In this paper the simulink model for the speed control of switched reluctance motor is done using two different speed controllers. The simulink model for this is designed using both the controllers separately and their performance result is compared. The Switched Reluctance Motor is an electric motor which runs by reluctance torque. These motors usually run at very high speed of 50,000 rpm which is to be controlled for industrial use. The speed controllers applied here are PI and Fuzzy Logic Controller. A PI Controller (proportional-integral controller) is a special case of the PID controller in which the derivative of the error is not used. Fuzzy logic controller is an intelligent controller which uses fuzzy logic to process the input. Fuzzy logic is a many valued logic which is much like human reasoning.

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II. SRM over view

The Switched Reluctance Motor has gained significant interest in the field of industrial drive. It has numerous advantages like simple and robust construction, reliability, low manufacturing cost, high starting torque, high efficiency, and high speed capacity. The stator has concentrated windings wound field coils and the rotor has no coils or magnets. The stator and rotor have salient poles; hence, the machine is a doubly salient machine. Switched Reluctance Motor is a highly nonlinear control plant and operates in saturation to maximize the torque output. The principle of operation is such that the motion is produced as a result of variable reluctance in the air gap between the rotor and the stator. When the voltage is applied to the stator phase, the rotor tries to rotate in the direction of minimum reluctance position producing reluctance torque. In order to achieve a full rotation of the motor, the windings must be energized in the correct sequence. The Switched Reluctance Motor operates in all the four quadrants and it is suitable to operate in hazardous areas also [1].

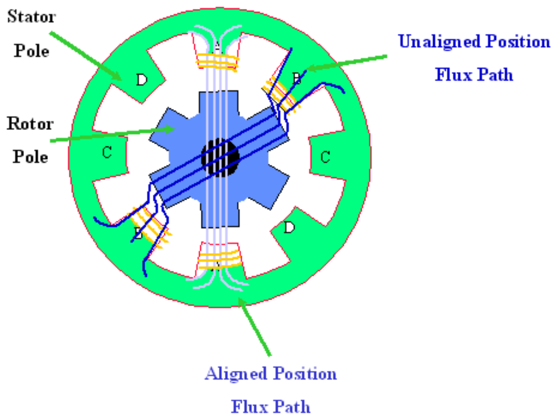

Fig. 1 Structure of 4 phase 8/6 SRM

The voltage equation for SRM is given by,

$V = r\,i + d\Psi / dt$

$\psi = Li = N\varphi$

For $r = 0$

$V = L\, di/dt + i\,(dL/d\theta)\,(d\theta/dt)$

$V = L\, di/dt + i\,\omega\,(dL/d\theta)$

$T = ½\, i^2\, dL/d\Theta$

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This equation shows that the torque developed depends only on the magnitude of current & direction of dL/dϴ but independent of direction of current [4].

III. BLOCK DIAGRAM OF SRM SPEED CONTROL:

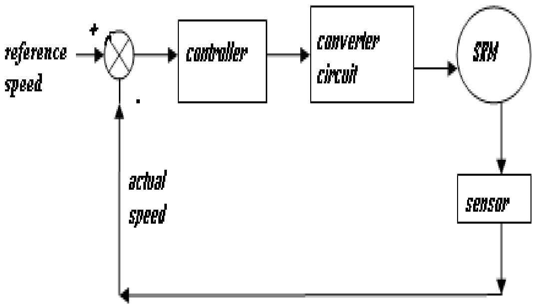

Fig. 2 Block diagram of SRM speed control

Fig. 2 shows the basic closed loop feedback control system for SRM. Here the position of rotor is sensed by the rotor position sensor and it provides its corresponding output to the error detector. Error detector compares reference speed and actual speed to generate error signal which is given to controller block. The controller either fuzzy or PI gives control signal to the converter according to the error signal. The converter thus controls the motor speed by exciting the corresponding windings [5].

IV. PI controller:

A PI Controller (proportional-integral controller) is a special case of the PID controller where the derivative of the error is not used. It is a generic control loop feedback mechanism widely used in industrial control systems. It generally calculates an "error" value which is the difference between a measured process variable and a desired set point and is denoted as Δ. The PI controller attempts to minimize the error by adjusting the process control inputs.The PI Controller contains proportional term (P) and integral term (I). Here P depends on the present error and I depend on the accumulation of past errors [7].

A. Proportional term:

The proportional term produces an output value which is proportional to the current value of error. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain.

The proportional term is given by:

$P_{out}=K_P\Delta$

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable. In contrast, a small gain results in a small output response to a large input error, and a less responsive or less sensitive controller. If the proportional gain is too low, the control action may be too small when responding to system disturbances.

B .Integral term:

The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. The integral in a PID controller is the sum of the instantaneous error over time and gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain (K_i) and added to the controller output.

The integral term is given by:

$I_{out}=K_I\int \Delta\, dt$

The integral term accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a pure proportional controller. However, since the integral term responds to accumulated errors from the past, it can cause the present value to overshoot the setpoint value.

The overall controller output is given by

$$K_P\Delta + K_I\int \Delta\, dt$$

Where Δ is the error or deviation of actual speed from the reference speed

V. FUZZY LOGIC CONTROLLER:

Fuzzy logic controllers are the one which is mainly used in system control for industries. This is mainly used when a non linear system is taken in to account. The fuzzy logic controller has the following main functions they are

- Fuzzification
- Inference Engine
- Rule base Design
- Defuzzification

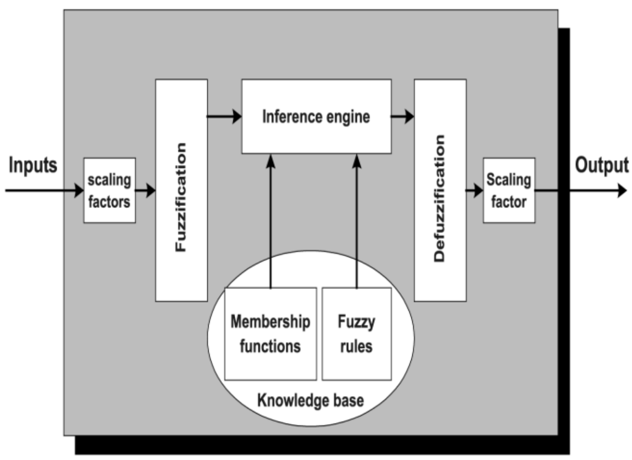

Fig. 3 Block diagram of Fuzzy Logic Controller system

A. Fuzzification

Fuzzification is the process of converting real scalar value in to membership fuzzy set values.

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The fuzzification process is done using fuzzifiers. Different types of fuzzifiers are used according to the application. In this paper Gaussian membership function is used for inputs and triangular membership function for output.

B. Inference Engine:

The fuzzy inference engine decides how to process rules using fuzzy input. The inputs for the fuzzy controller will be error and change in error. The control signals will vary according to error and change in error. Once the fuzzy controller receives input the rule base is evaluated [1].

C. Rule Base Design:

Basically a rule base is a linguistic controller, which is designed using IF THEN statements. Here we have two input conditions and one output response. Based on that, rules are designed for proper control of the system. The Fig 4 shows the rule base design for the speed control of Switched Reluctance Motor [6].

e/Ce	Z	PS	PM	PL	PVL
Z	VHS	VHS	VHS	HS	MS
PS	VHS	HS	HS	MS	LS
PM	VHS	HS	MS	LS	LS
PL	HS	MS	LS	VLS	VLS
PVL	MS	LS	VLS	VLS	VLS

Fig. 4 Rule data base for Fuzzy Logic Controllers

D. Defuzzification:

Defuzzification is the process of converting the degrees of membership of output linguistic variables with in their linguistic terms in to crisp values. There are number of defuzzification methods in use. The defuzzification method used in this paper is centre of area which will change the current of the controller accordingly.

VI. Simulations:

The simulink models designed for the speed control of Switched Reluctance Motor using PI and Fuzzy Logic Controller is shown Fig. 5, Fig. 6 and Fig. 7.

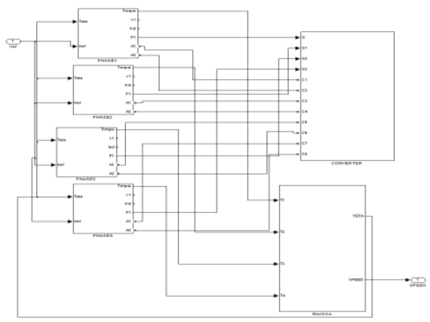

Fig. 5 Simulink Model for Speed Control

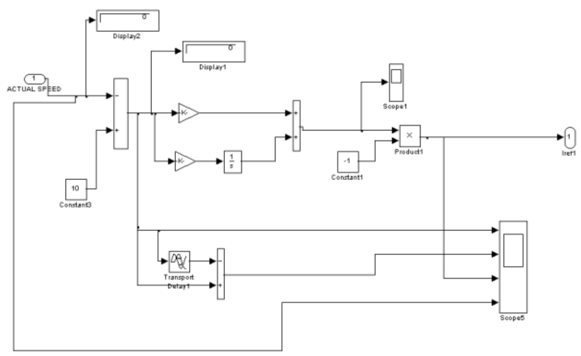

Fig. 6 PI Speed Controller Block

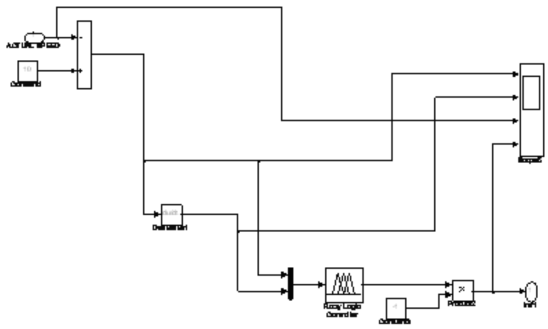

Fig. 7 Fuzzy Logic Speed Controller Block

VII. Dynamic simulation using MATLAB:

To verify the dynamic performance of the 8/6 SRM, the simulation is done using Matlab / Simulink environment. This choice was taken because this software has a good performance and satisfies all features required. Simulation was done based on the machine equations stated above. In this simulation asymmetrical bridge converter is used to drive the SRM. The dynamic performance characteristics are shown in the following figures.

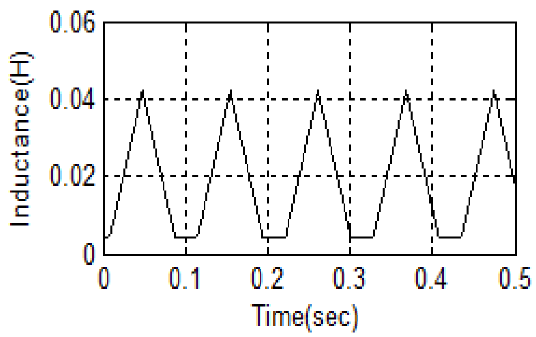

Fig. 8 Inductance profile from MATLAB simulation

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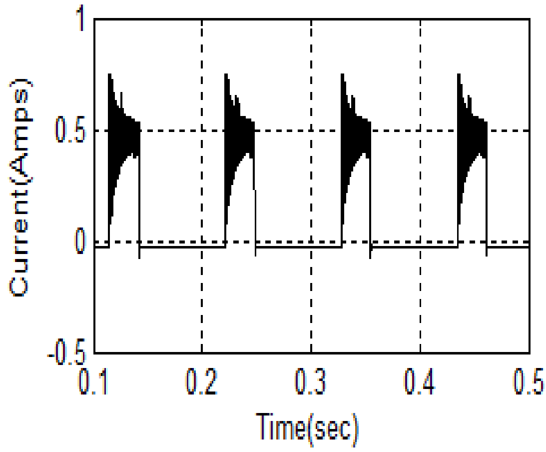


Fig. 9 Phase current from MATLAB simulation

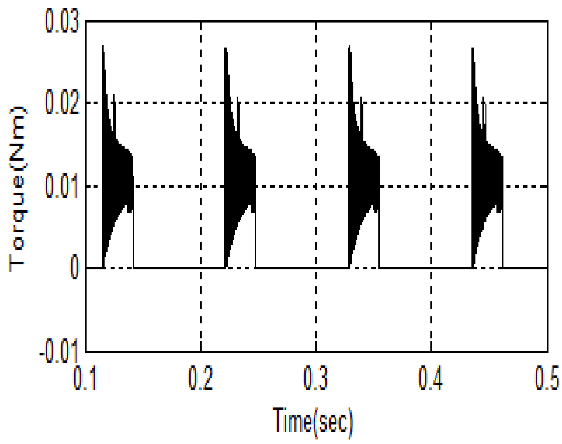


Fig. 10 Torque waveform from MATLAB simulation

VIII.Results and discussions:

A.FLC Simulation

The speed responses for 10 rad/sec and 100 rad/sec of SRM closed loop operation is shown in Fig. 10 and 11. When the reference speed is set to 10 rad/sec, the output speed is settled at 0.9 sec in PI controller, whereas in the FLC controller the output speed is settled at 0.03 sec.

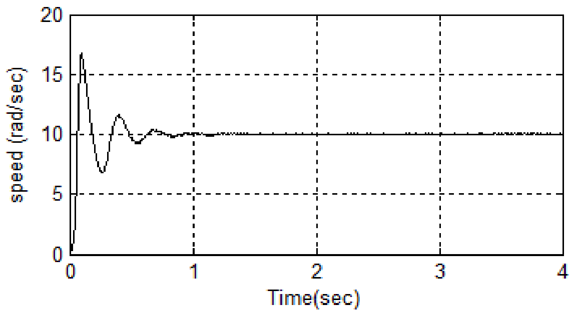
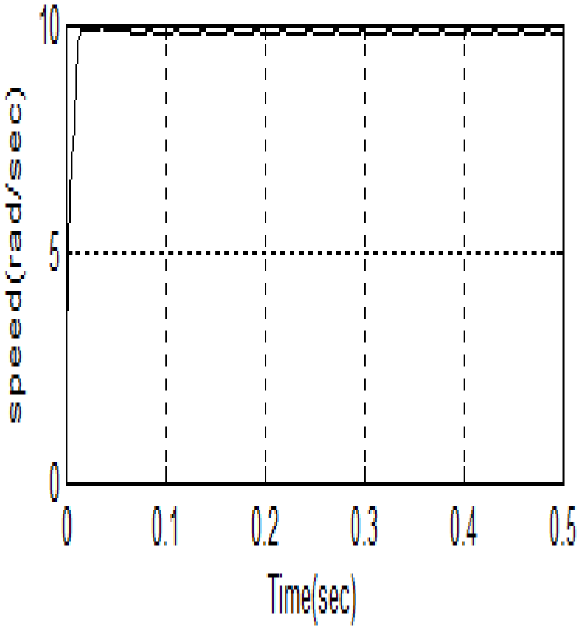


Fig 11 (a) Speed Response of PI controller for 10 rad/sec

Fig. 11(b) Speed
Resp



on

se of FLC for 10 rad/sec

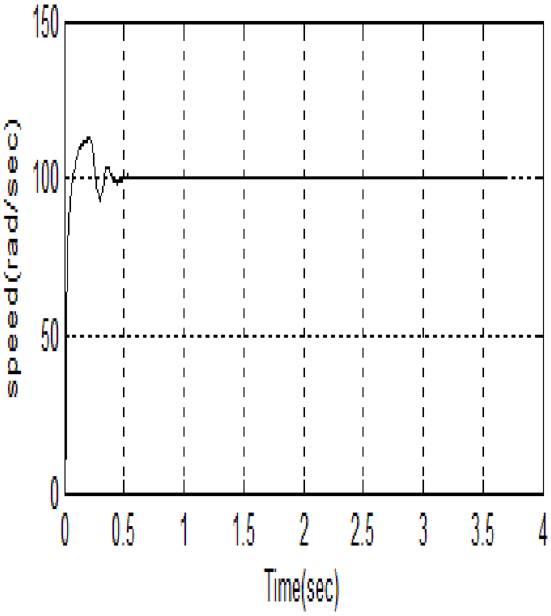


Fig. 12 (a) Speed Response of PI controller for 100 rad/sec,

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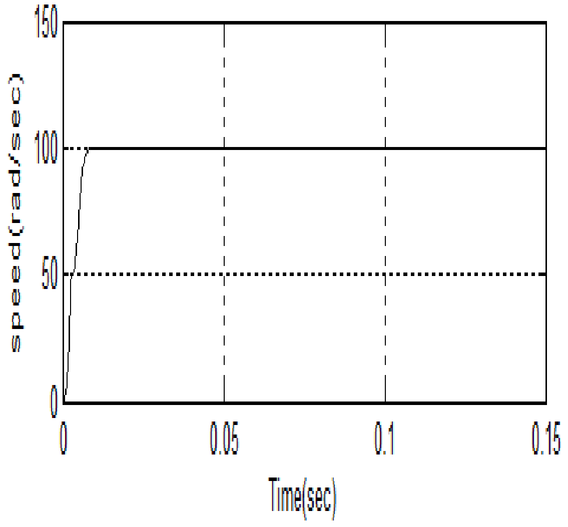

Fig. 12 (b) Speed Response of FLC for 100 rad/sec

By comparing the PI controller and Fuzzy Logic Controller, Fuzzy Logic Controller provides a better performance in term of overshoot limitation and fast response. Also fuzzy logic controller has numerous advantages like accurate, time saving and easy to design and cost effective. It is mainly used in the case where mathematical model for the system may not exist.

IX. CONCLUSION

The dynamic performances of SRM are predicted and the model is simulated using MATLAB/simulink environment. The speed control for SRM using Fuzzy logic controller has been design and implemented using both PI and Fuzzy Logic speed Controller. From the simulation results it can be concluded that Fuzzy Logic Controller performs well than PI controller.

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