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Comparison of PI and Fuzzy Logic Controller for the Speed Control of Switched Reluctance Motor

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ABSTRACT

Due to its simple structure and its reliability Switched Reluctance Motor (SRM) is becoming very popular. Usually, typical PI controller is used to regulate the speed of SRM.In the thesis, a PI controller and Fuzzy Logic Controller (FLC) is designed to control the speed of SRM drive. The performance of SRM with PI and Fuzzy Logic controller is analyzed in Matlab/Simulink platform. To prove the superiority of FLC, its performance is compared with typical PI controller. Performance of the switched reluctance motor has simulated and studied with typical PI and Fuzzy Logic Controller. From the simulationresults obtained, itshowed that FLC can improves the speed response of SRM drive withless settlingtime, less rise time as compared to typical PIcontroller. Finally, it is proven that FLC is suitable for SRM drive to achieve the smooth speed response over a wide range of speeds.

I. INTRODUCTION

The Switched Reluctance Motor (SRM) consists of salient poles on both stator and rotor.Thus it is called as double salient pole machine with no winding or permanent magnets on the rotor. In SRM stator poles are greater than rotor poles. Because of winding free rotor, SRM offers a low inertia, gives a good performance. It is also cheaper in cost and has high efficiency. Due to these features, it is used in industrial applications, but SRM suffers from high torqueripples and possesses anon-linear magnetism. Thesedrawbacks limit theSRM in manyapplications where the smooth response of the motor is required. Because of non-linear magnetic structure, conventional control schemes are inadequate to regulate the speed of SRM. Consequently, non-linear controllers are required to control SRM drive. Many controllers are discussed in literature [5-6]. In [4], acontrolleris designed based on feedback, to enhance the performance of SRM. A sliding mode controller is also developed in[6] to achievethesmooth control ofSRM undersuddenchanges ofload.But, it has ripples in speed because of its control unit which required high switching frequency. Fuzzy controllers are currently trending in engineering fields. These are intelligent and robust controllers, it accepts uncertainties in its inputs. Fuzzylogic controllers are used effectively. In which the system is not completely described by using mathematical modelling. In this paper, PI and FLC controller is used to get the smooth speed control of SRM under constant speed with variable load conditions.

II. SWITCHED RELUCTANCE MOTOR

A Switched Reluctance Motor is a singly excited, doubly- salient machine in which the electromagnetic torque is developed due to variable reluctance principle. Both stator androtor has salient poles but only stator carries winding. As in dc motor the SRM has wound field coils for stator windings. However the rotor has no attached coils or magnets. The projecting magnetic poles of salient pole rotor are made of soft magnetic material. When the excitationisgiventothestatorwindings,aforceiscreatedbyrotor'smagneticreluctance that bid to align the rotor pole with the adjacent stator pole. In order to preserve sequence rotation, the windings of stator pole switches in a sequential manner with the help of electronic control system so that the magnetic field of rotor pole was lead by the stator pole, pulling towards it.

The rotor pole is said to be "fully unaligned position" when the rotor pole is equidistant from the two adjacent stator pole. This position is called as maximum magnetic reluctance for the rotor pole. In aligned position the rotor poles are fully aligned with the stator poles, this position is called as minimum reluctance of rotor pole. Figure 1 illustrates the 8:6 SRM drive which consists 8 stator poles and 6 rotor poles.

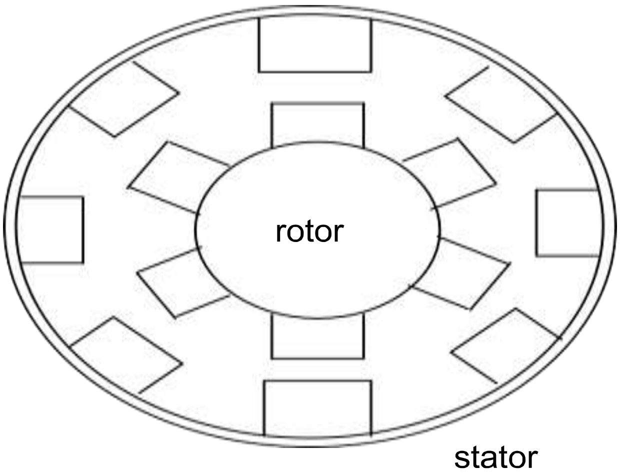

Figure1SRMwith8/6poles

Thevoltageequationof SRMisgivenby,

$V=ri + d\Psi / dt$ (1)

$\psi=Li=N\varphi$ (2)

Forr=0,

$V= Ldi/dt + i (dL/d\theta)(d\theta/dt)$ (3)

$V= Ldi/dt + i\, \omega(dL/d\theta)$ (4)

$T = ½\, i2\, dL/d\Theta$ (5)

Thisequationdeterminesthatthedevelopedtorquedependsonlyoncurrentmagnitudeand dL/dϴ direction but it is independent on current direction.

III. BLOCK DIAGRAM:

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 PIgives control signal to the converter according to the error signal. The speed of the motor is controlled bythe converterthrough proper excitation oftheir corresponding windings (Figure 2)

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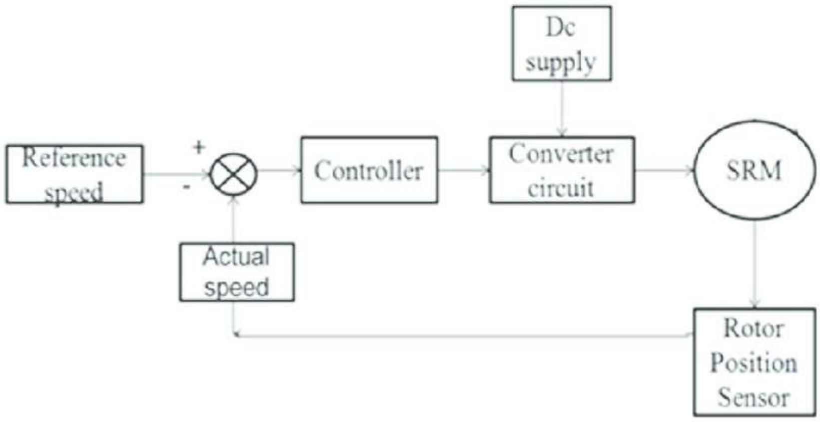

Figure2BlockdiagramofSRMspeed control.

Parametersof Motors:
InTable2parametersofthemotorsthatisusedfortheresearchworkaregiven.

Table2:Parameterof motorused.

Power(kw)	3.4 kw
Maximumcurrent	10 A
Speed	1500 RPM
Statorresistance	3.1 ohm
Inertia	.0089 Kg/m2
Unalignedinducatance	5.9e-3(mh)
Alignedinductance	23.6e-3(mh)
LoadRated	7 NM

IV. SPEED CONTROL OF SRM USING PIC ON TROLLER:

The combination of proportional and integral terms is essential to refine the speed of the response and also to eliminate the steady state error. By giving feedback to the converter the performance of the PI controller can be improved and it conquers the disturbances. The forced oscillation and steady state error can be eliminated in PI controller during theoperation of P controller and on-off controller respectively.

However, introducing integral mode has a negative effect on stability of the system and in speed response. So that speed response will not increase in PIcontroller. This problem can be detected by introducing derivative mode. It has the capability to predict the errors and to decrease the reaction time of the controller. If the speed response is not a criteria normally PI controllers are used.

The simulink model is designed for the speed control of switched reluctance motor using PI controller and their corresponding output waveform is shown in Figures 3.

Stator resistance is 3.1 ohms and inertia of the motor 0.0089Kg/m2. The value of the constants of the controller KP, Ki is dependent on the system to be controlled, so after tuning appropriately and testing for best condition, the values of the constant used for this analysis was obtained as follows:
ForPIcontroller,KP=1.01,Ki=0.5

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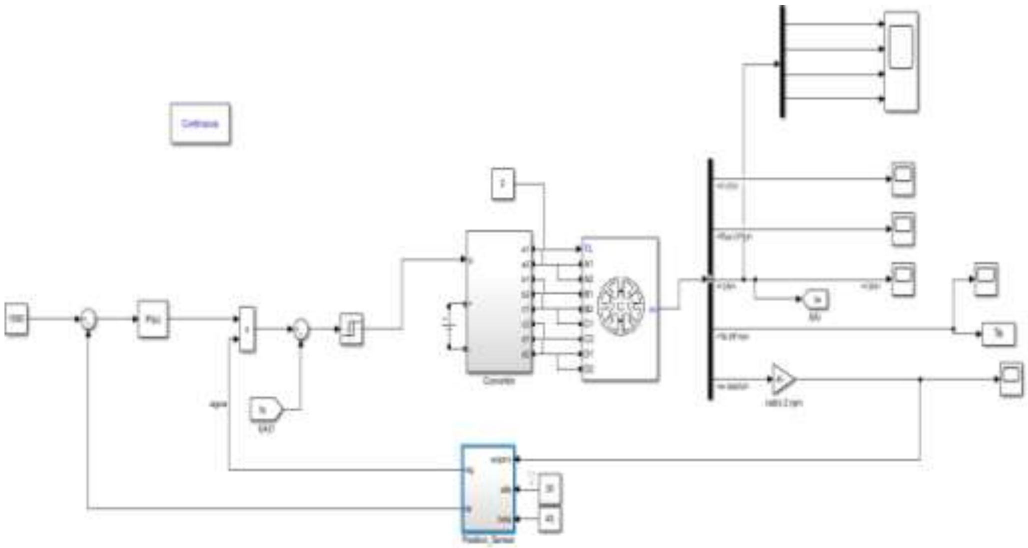

Figure3SimulationmodelusingPIcontroller

V. SPEED CONTROL OF SRM USING FUZZY LOGIC CONTROLLER:

Fuzzy logic was proposed by Lotfi Zadeh in 1965, it has various applications in all inventive fields. The merits of fuzzy logic controller are the clarification for a problem can be easily analyzed and the design of the controller can be implemented. The design of fuzzy logic system is not based on the mathematical model of process.

The four main stages in fuzzy logic controller fuzzification, rule base, inference mechanism and defuzzification. The fuzzification is nothing but it comprises the process of transpose crisp values into grades of membership forlinguistic terms of fuzzy sets. The transpose from a fuzzy set to a crisp number is called a defuzzification. The inference engine and the knowledge base were the components of an expert system. The knowledge base stores the factual knowledge of the operation of the concern experts. Fuzzy inference engine is the process of calculating from a given input to an output using fuzzy logic. In inference engine, If – Then type fuzzy rules converts fuzzy input to the output .

Mamdanitypefuzzylogiccontrollerismostc ommonlyusedinaclosedloopcontrolsystem, because it reduces the steady state error to zero.

Thedesigned fuzzyrules usedin this research are given in Table 1. Fuzzyrulebase system is constructed that connects the input variables to the output variable by means of if–then rules. Given particular values of the input variables, the degree of fulfillment of a rule is obtainedby aggregating the membership degrees of these input values into the respective fuzzy sets.. There are seven membership functions which are named as Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive medium (PM), Positive Big (PB).

The simulink model is designed for the speed control of Switched Reluctance Motor using Fuzzy logic controller and their corresponding waveform is shown in Figures (4-7).

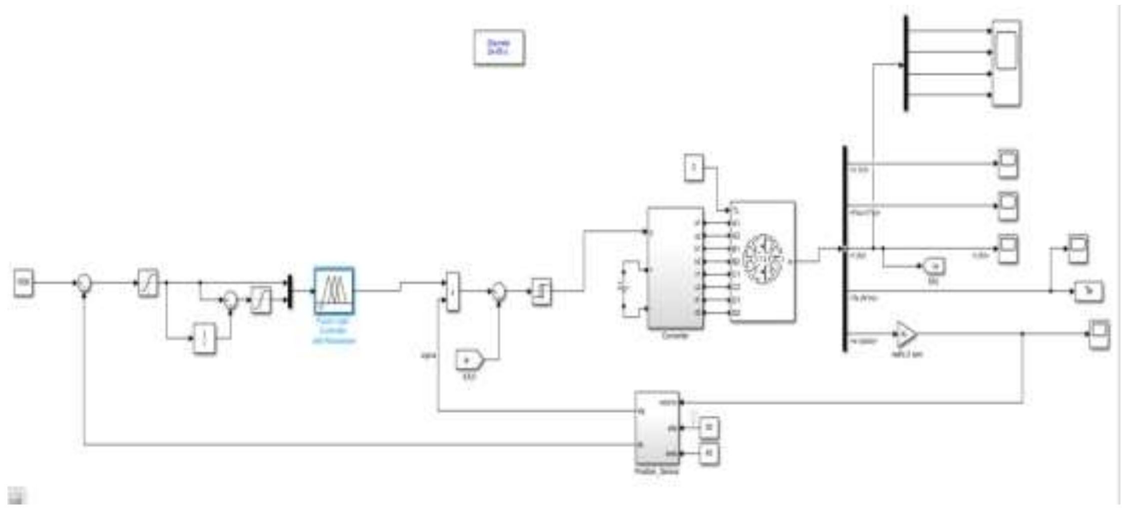

Figure4SRMwithfuzzylogiccontroller

TwoinputsaregiventoFLConeisspeederror(e),secondoneischangeinspeed error (de). The output of FLC is expressed as:
u (k)=F[e(k)−ce(k)]

Table2:RulebaseusedwiththeFuzzylogiccontroller

E/CE	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NM	ZO	ZO
NM	NB	NB	NB	NB	NM	ZO	ZO
NS	NM	NM	NM	NM	ZO	PS	PS
ZO	NM	NM	NS	ZO	PS	PM	PM
PS	NS	NS	ZO	PM	PM	PM	PM
PM	ZO	ZO	PM	PB	PB	PB	PB
PB	ZO	ZO	PM	PB	PB	PB	PB

ThemembershipfunctionsforerrorchangeinerrorofmotorspeedandoutputofSRMis depicted in figure given below:

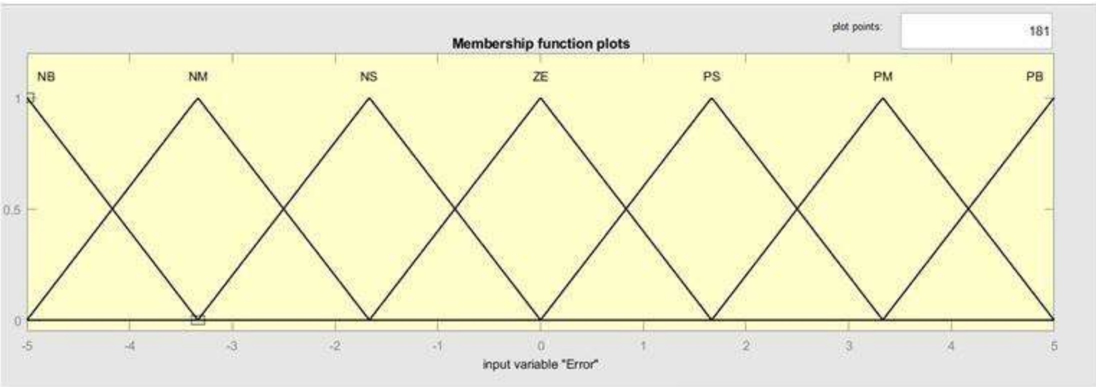

Figure5Errorplot

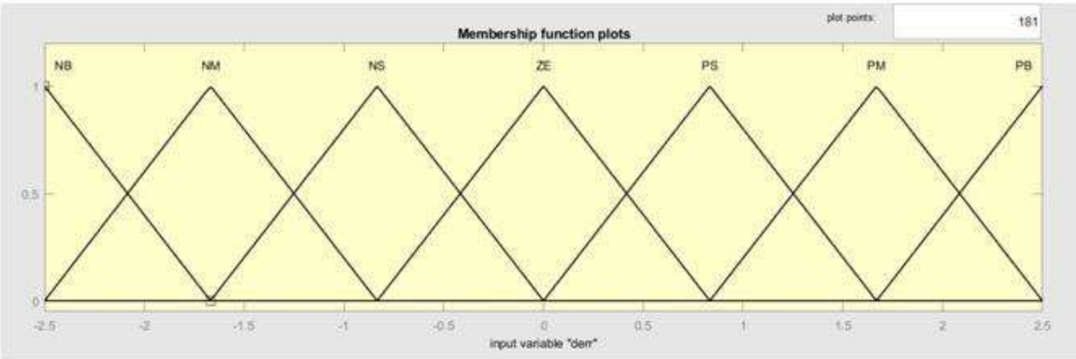

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Figure6Changeinerrorplot

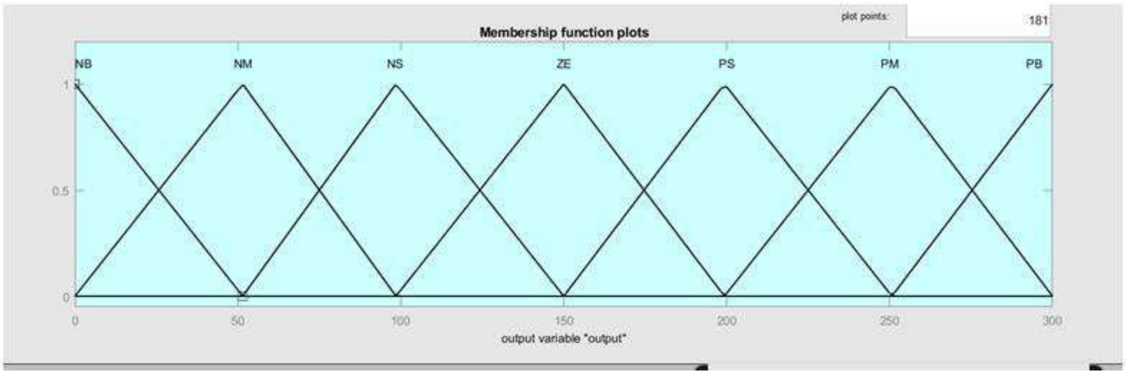

Figure7Controllingsignal

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VI. RESULTS

ThereferencespeedgiventotheSRMis1500RPMwithofnoload,halfloadand full load by using PI and Fuzzy Logic controller and the speed output compared with the reference speed and the results are shown below:

Table3:PlotbetweenSpeed(rpm)andtime(msec)atnoload,Halfload,Fullloadwith PI and Fuzzy controller

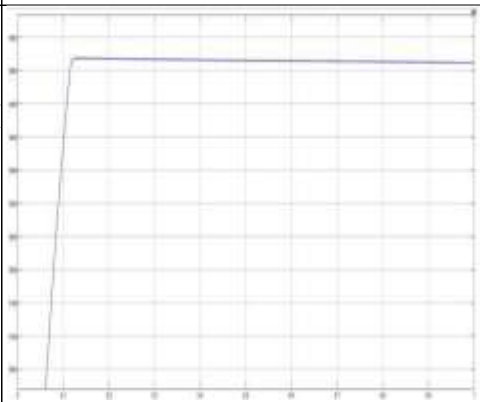
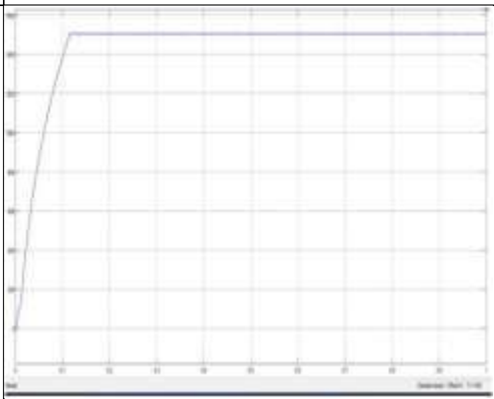
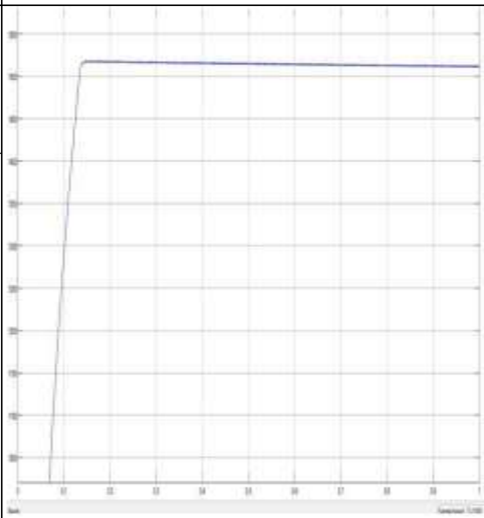
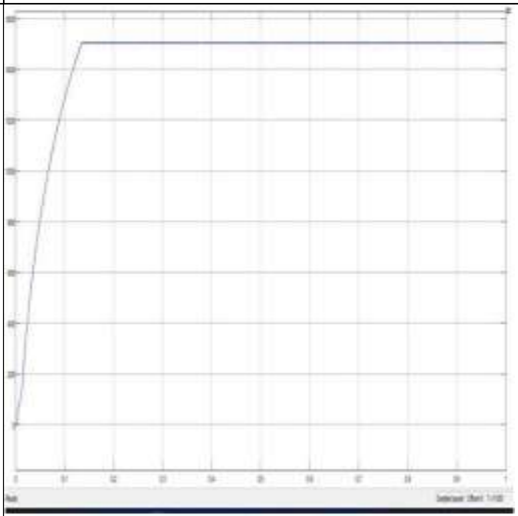
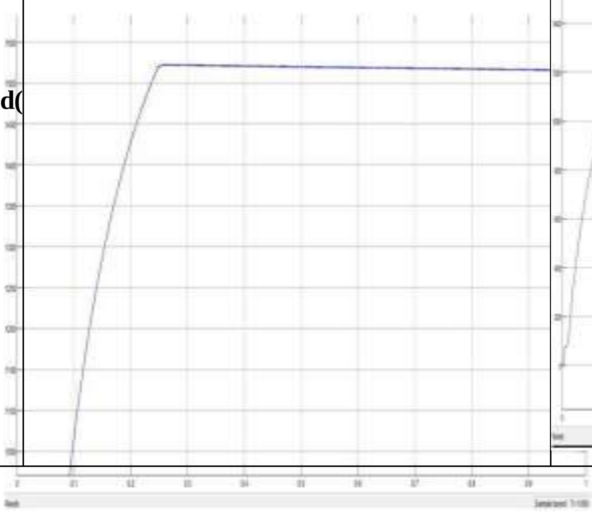
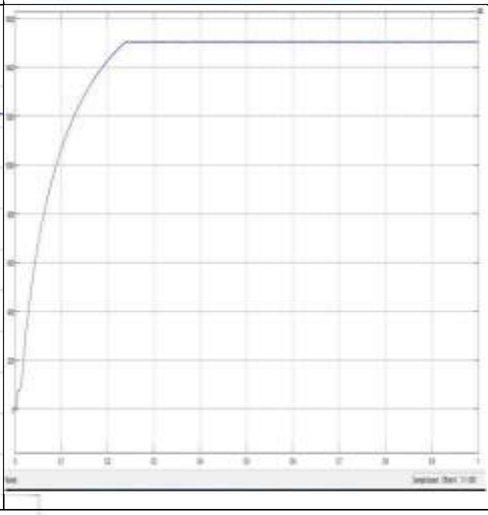
	PIController	**Fuzzycontroller**
No Load(0NM)		
Half Load (3.5 NM)		
Full Load(7NM)		

Table4:ComparisonbetweenparametersobtainedatdifferentloadsinPIandFuzzy Controller

Controller	**LOAD**	**Steadystateer ror (%)**	**Risetime (m sec)**	**Settlingtime (m sec)**
PIcontroller	0NM(noload)	1.2%	82.0	131
Fuzzycontroller	0NM(noload)	.33%	81.1	122
PIController	3.5NM (halfload)	1.13%	95.549	156
FuzzyController	3.5 NM (halfload)	.32%	93.89	140
PIController	7 NM (Fullload)	1.57%	158.387	247
FuzzyController	7NM (Fullload)	.33%	152.797	200

VII. CONCLUSIONS

Performance of the switched reluctance motor has simulated and studied with typical PI and Fuzzy Logic Controller. From the simulation results obtained, it showed that FLC can improves the speed response of SRM drive with less settling time, less rise time as compared to typical PIcontroller. Finally, it is proven that FLC is suitable for SRM driveto achieve the smooth speed response over a wide range of speeds.

Hence from the analysis of switched reluctance motor with PI and FLC we can say that the speed control of Switched Reluctance Motor is better in case of Fuzzy Logic Controller as compared with PI controller.

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