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ANALYSIS OF NONLINEAR SPEED-TORQUE PERFORMANCE OF SRM WITH FUZZY BASED NONLINEAR CONTROLLER

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ABSTRACT: By the use of linear controller the analysis of performance of SRM is not sufficient because of stator inductance of stator winding of SRM is function of rotor position, so here proposed to be design the nonlinear controller i.e. fuzzy based controller which converge the comparison analysis of SRM based on speed error and its change with respect time domain specification. Neural network and fuzzy logic technique are unique technique in which process the information specify by mathematical equation and compare with linear model of SRM. Arificial Neural Networks technique along with PI and Fuzzy PI has been implemented to design the controller to increase their performance. The comparison results give the more idea about the performance of SRM.

Keywords: reluctance motor, fuzzy logic controller, PI controller, membership function, FLPI controller .

I.INTRODUCTION:

Switched reluctance motor is named as for produce the variable reluctance followed by it require switching inverter to drive it. In SRM both stator an rotor have salient pole hence the motor is doubly salient machine and stator as well as different magnetic reluctance along various radial axis. Generally most nonlinear system are characterized by certain parameter which complicate their control as well as to improve their performance.SRM are very nonlinear in nature due to their operation with high magnetic saturation condition. It produces high nonlinear reluctance torque between stator and rotor when the stator winding is energized. Secondly phase flux linkage and instantaneous phase torque are nonlinear function of phase current and rotor position. By controlling the instantaneous phase current, torque of SRM can be regulate.

The **switched reluctance motor** (**SRM**) is a type of reluctance motor, an electric motor that runs by reluctance torque. Unlike common DC motor types, power is delivered to windings in the stator (case) rather than the rotor. This greatly simplifies mechanical design as power does not have to be delivered to a moving part, but it complicates the electrical design as some sort of switching system needs to be used to deliver power to the different windings. With modern electronic devices this is not a problem, and the SRM is a popular design for modern motors. Its main drawback is torque ripple. The principle of operation, Controlling Techniques,

II.PRINCIPLE OF OPERATION

The SRM has wound field coils as in a DC motor for the stator windings. The rotor however has no magnets or coils attached. It is made of soft magnetic material (laminated-steel protuberances).

When power is delivered to the stator windings, the rotor's magnetic reluctance creates a force that attempts to align the rotor with the powered windings. In order to maintain rotation, adjacent windings are powered up in turn. As the stator does not turn, the switching of power from winding to winding may be difficult to arrange in a fashion that is properly timed to the movement of the rotor - brushes could be used, but this would eliminate most of the advantages of the design. Instead, in modern designs a high-power electronic switching system is used, which also offers advantages in terms of control and power shaping.

A.Electromagnetic system equation of SRM

Generally in SRM configuration ,there are one or more phases excited. During a phase exciting the voltages u is applied to SRM phase and the resulting current which depending upon derivative of flux linkage ψ for that particular phase of SRM and the relative equation are as follows.

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$$\frac{d\omega}{dt} = \frac{1}{j} \cdot [T_e - T_i - B.\omega_r]$$

$$u = R.i + \frac{\partial \psi(i,\theta)}{\partial i}.\frac{di}{dt} + \frac{\partial \psi(i,\theta)}{\partial \theta}.\omega_m \quad (1)$$

The above equation (1) can be rewritten to:

$$\frac{di}{dt} = \frac{1}{\frac{\partial \psi(i,\theta)}{\partial i}}.\left[u - R.i - \frac{\partial \psi(i,\theta)}{\partial \theta}.\omega_m\right] \quad (2)$$

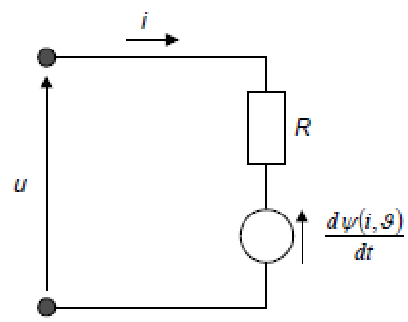

Fig 1 Electrical equivalent of stator phase

The instantaneous torque produced in one phase of SRM is given as below

$$T_m(i,\theta) = \left.\frac{\partial W_{co}(i,\theta)}{\partial \theta}\right|_{i=cst} = \int_0^i \frac{\partial \psi(i,\theta)}{\partial \theta}.di \quad (3)$$

Where

$\left.\frac{\partial W_{co}(i,\theta)}{\partial \theta}\right|_{i=cst}$ the differential change in co-energy with respect to rotor position Which can be evaluated at constant phase current.

The electromagnetic torque, which is sum of all instantaneous torque of SRM can be written as

$$T_{SR}(i,\theta) = \sum_{k=1}^{n_S} T_{mk}(i,\theta) \quad (4)$$

Mechan)e expressed as below:

$$T_e - T_l = j.\frac{d\omega_r}{dt} + B.\omega_r \quad (5)$$

here T_L is the load torque, ω_r is the rotor speed, j and B are respectively the moment of inertia and the coefficient of friction. When equation (5) is re-arranged in order to write the speed expression,

(6)

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B.Fuzzy Logic

Fuzzy logic is technique to embody human like thinking in control system. A fuzzy control can be designed to try equal human thinking Fuzzy control system consists of the four blocks as shown in figure.

A fuzzy control system with n inputs and one output is characterized with a base of knowledge expressed as results. The results are connected by "else", the method of evaluating entries in relation to fuzzy sets (fuzzyfication) and a method of passing blur the real output Y (defuzzyfication) .Inference systems evaluate all the rules and establish a conclusion.

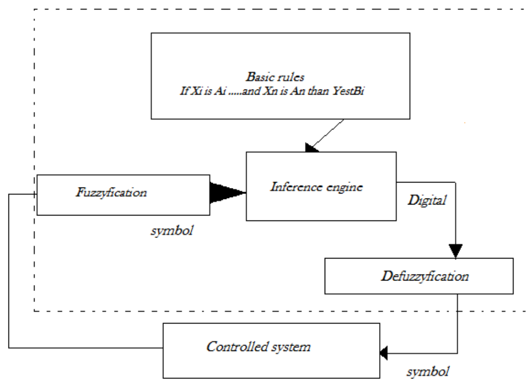

Fig. 2:General scheme of a fuzzy interference system

C.Dynamic model of SRM

When the input voltage and rotor position is known, By using dynamic model to obtain the phase current and phase torque. Secondly dynamic model is obtain by combining electrical equation and mechanical equations.

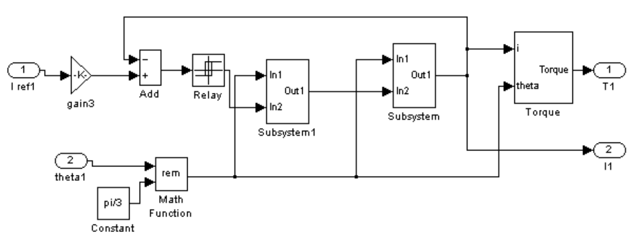

Fig 3 Simulation block diagram of dynamic model of SRM

D.Speed control of SRM

In this paper FLPI, FPI and NSTFPI controller with ANN tuning is used as the speed controller. The system also consists of a hysteresis band controller which does current control, a converter and a trigger circuit which drives the switches in the converter into conduction or cut off.

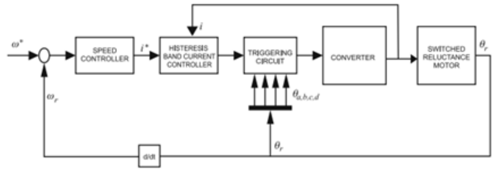

Fig 4 Speed control block diagram of SRM.

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III. APPLICATION OF NSTFPI CONTROLLER

The NSTFPI controller with ANN tuning used as the controller in the speed control of SRM is seen in figure The NSTFPI controller consists of two parts; the FLPI and the self-tuning mechanism. The purpose of self-tuning is to increase the controller performance byimproving $\Delta i*(k)$, the output of the controller. For this aim ANN is used as the self-tuningmechanism. The NSTFPI controller has two input variables and one output variable. The input variables are E(k) and CE(k), while the output variable is $\Delta i*(k)$.

The input and output variables of NSTFPI controller can be defined as $E(k) = e(k) \cdot G$ (7)

$$CE(k) = ce(k) \cdot Gce \qquad (8)$$

$$\Delta i*(k) = \Delta I(k) \cdot G_{\Delta i} \cdot \alpha \qquad (9)$$

where e(k) is the error between reference speed and rotor speed, ce(k) is the change of error in speed, $\Delta I(k)$ is the output of the fuzzy logic controller, and G_e, G_{ce} and $G_{\Delta i}$ are scaling factors.

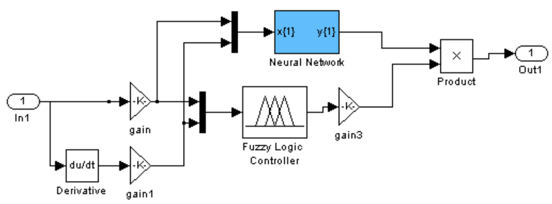

Figure 5. Structure of NSTFPI controller

		E(k)						
		NL	NM	NS	ZE	PS	PM	PL
CE(k)	NL	NL	NL	NL	NM	NM	NS	ZE
	NM	NL	NL	NM	NS	NS	ZE	PS
	NS	NL	NM	NS	NS	ZE	PS	PM
	ZE	NM	NS	NS	ZE	PS	PS	PM
	PS	NM	NS	ZE	PS	PS	PM	PL
	PM	NS	ZE	PS	PS	PM	PL	PL
	PL	ZE	PS	PM	PM	PL	PL	PL

Fig 6 The rules of FLPI controller

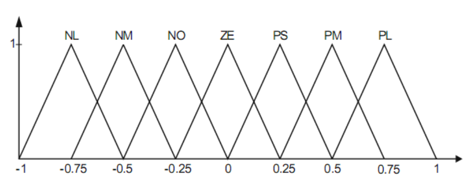

Fig 7 Membership function of FLPI

A.Control

The control system is responsible for giving the required sequential pulses to the power circuitry in order to activate the phases as required. While it is possible to do this using electro-mechanical means such as commutators or simple analog or digital timing circuits, more control is possible with more advanced methods.

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Many controllers in use incorporate programmable logic controllers (PLCs) rather than electromechanical components in their implementation. Here this paper is implemented using PID, FUZZY PID, NEURAL NETWORKS for controlling the Switched Reluctance Motor. This concept is implemented using MATLAB 2009 A and the results are analyzed.

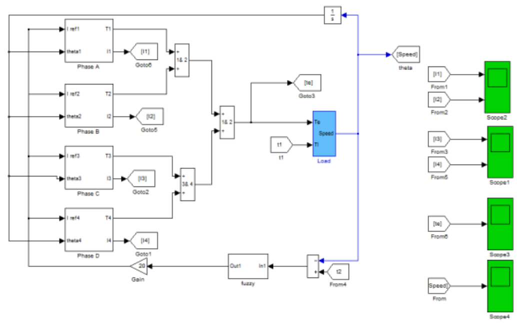


Fig8.Simulation model of speed control of SRM in matlab

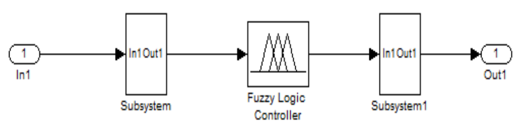
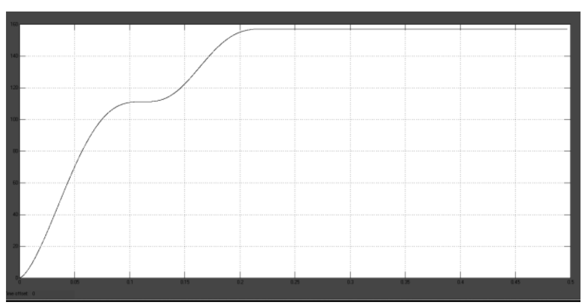
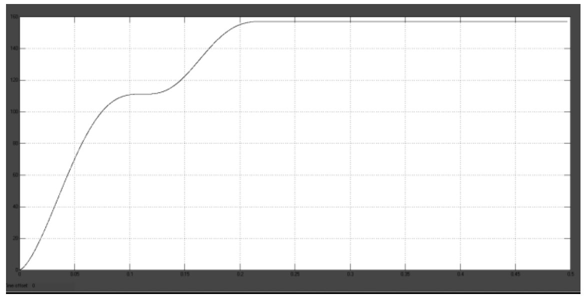


Fig.9 Fuzzy logic controller in Mat lab

IV.CONCLUSION & FUTURE SCOPE

Generally to increase the performance of switched reluctance motor can be done by either designing the magnetic circuit of SRM or design the control circuit of SRM. By analysis the design of different non linear control circuit, concluded that the performance of NSTFPI controller with ANN tuning is superior over other linear and non linear controller with rise time.





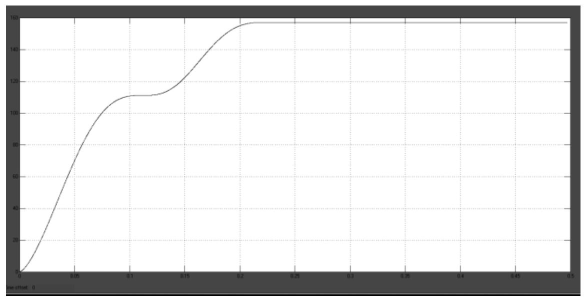


Fig 10 Comparison speed response of fuzzy, FLPI, & NSTFPI controller

Neural technology, particularly neuro-fuzzy techniques has advanced rapidly in recent year and its potential for application in electrical machine seems enormous.

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