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PI Controller for Switched Reluctance Motor

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Abstract: *Switched reluctance motor (SRM) is a machine which produces torque due to the tendency of the rotor to attain minimum reluctance position on excitation of the stator winding. This double salient motor is suitable for high temperature and high speed applications. It has simple construction and is fail safe. The excitation to the stator winding is controlled depending on the feedback from the position of the rotor. Here a PI controller is designed to control the speed of the machine. Based on the position of the rotor, the excitation of the stator phase is controlled through a suitable converter. Close loop control is obtained with MATLAB simulink programme.*

Key words: *Switched reluctance motor, PI controller, converter, close loop control, minimum reluctance*

1. INTRODUCTION

Switched reluctance motor as the name indicates is a reluctance motor. The stator and rotor of the machine are salient pole. Only the stator has concentric windings. Generally the stator poles outnumber the rotor poles. Here a 12/8 i.e stator with 12 poles and rotor with 8 poles is considered. This gives a three phase machine with each phase formed by connecting in series the windings of four diametrically opposite poles. The rotor has no winding. It is made up of steel laminations and does not have magnet. It is simple and has low inertia. The rotor has a tendency to move to minimum reluctance or maximum inductance position once the stator windings are excited. So the excitation of a phase depends on the position of the rotor. A position sensor is hence required. This is fed back to control the firing of the converter and hence the particular phase.

II. DETAILS OF SWITCHED RELUCTANCE MOTOR

As said earlier the SRM rotor has a tendency to move to minimum reluctance position and this gives rise to reluctance torque [1, 2]. The stator and rotor poles are said to be aligned when they are exactly below each other. This is maximum inductance or minimum reluctance position. The torque at this position of the rotor and stator poles is also zero. In this aligned position if the same phase is excited, the rotor fails to move. A position sensor is required to locate the position of the rotor poles which are not aligned with the stator poles so that, that particular stator phase can be excited.

2.1 Voltage equation of SRM

The voltage applied across each phase of the stator winding is as per Faradays law given by the following expression

$$V = IR + \frac{d\varphi}{dt} \tag{1}$$

Where V=terminal voltage, I=phase current, R= winding resistance and φ = flux linkage.
The flux linked with the winding is a function of current I and the position θ of the rotor and hence varies with I and θ. Considering this equation (1) can be written as:

$$V = IR + \frac{d\varphi}{d\theta} * \frac{d\theta}{dt} + \frac{d\varphi}{dI} * \frac{dI}{dt} \tag{2}$$

Where $\frac{d\varphi}{d\theta} * \frac{d\theta}{dt}$ = instantaneous back emf, and $\frac{d\varphi}{dI}$ =instantaneous inductance L(θ, I).

2.2 Torque Equation
It is well known that

$$\emptyset = i * L(\emptyset, \theta) \tag{3}$$

For magnetic saturation neglected

$$\emptyset = L(\theta) * i \quad (4)$$

The magnetic co-energy is given by

$$W_c = \int_0^i \emptyset(\theta, i) di \quad (5)$$

Substituting equation (5) in equation (4) we get

$$W_c = \int_0^i L(\theta) i di \quad (6)$$

$$= \frac{i^2}{2} L(\theta)$$

We know that

$$T = \frac{dW_c}{d\theta} = \frac{d}{d\theta}\left[\frac{i^2}{2} * \frac{L(\theta)}{d\theta}\right] \quad (7)$$

$$\therefore T = \frac{i^2}{2}\frac{dL}{d\theta} \quad (8)$$

The equation indicates that the torque is independent of the direction of the current.[3]

The average torque is defined as

$$T_{ave} = J\frac{dw}{dt} + Bw + T_L \quad (9)$$

Where J= rotary inertia, B= damping coefficient and T_L= load torque
The Equation (9) is implemented in MATLAB Simulink to obtain Theta value is as shown in figure (1)

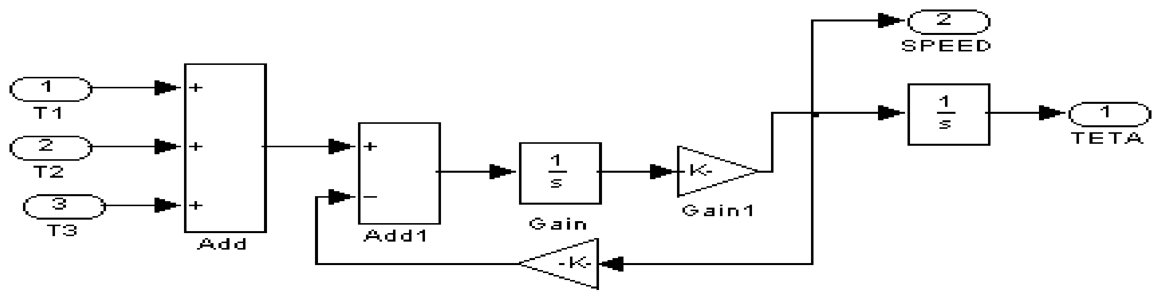

Figure 1 Model to obtain theta

2.3 Inductance Profile

For a particular phase when the stator and rotor teeth are at the start of overlapping, that particular phase is excited. The inductance starts increasing from its minimum position to towards the maximum and the torque also increases [3, 4, 5]. The inductance is minimum under unaligned position and maximum under aligned position of the stator and rotor teeth. The torque is zero when the poles are unaligned. The inductance profile of SRM is shown in figure (2).

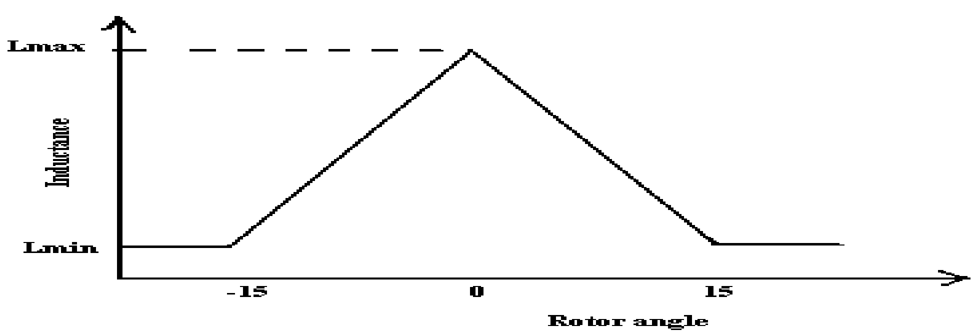

Fig 2 Inductance profile

III. POWER ELECTRONICS AND PI CONTROLLER

The power converter and controller plays important role in smooth running of the SRM. The asymmetric converter is commonly used for SRM . The PWM current controller implemented in this work controls the converter. The converter has two switches in each phase. The ON and OFF of these switches is controlled by the output signal of the current controller. The signals from the commutation control the current controller [6]. The actual and desired values of On and OFF theta are compared by the commutation circuit and accordingly current is fed to the current controller and converter. The actual speed is obtained and compared with the desired speed. The error is fed to the PI controller. The output of the PI controller which is current is fed to the current controller which ultimately modifies the torque to reach the desired speed. Thus the required speed is obtained by changing the torque.

3.1 PI Controller

In a Proportional Integral (PI) control, the error obtained by comparing the desired speed (50 rpm) and actual value acts as an input to the controller. The controller acts upon the error in order to reduce it by varying the process control inputs. P depends on the present error and gives an output proportional to the current error. The response can be modified by including proportional gain K_p. The gain should be properly chosen else a large gain makes the system unstable and small gain affects the sensitivity of the controller.

The integral control depends on the past errors[7]. It accounts the magnitude as well the duration of the error. The accumulated error is multiplied by integral time constant K_i. The integral control brings the control variable back to the exact set point even after disturbance. But its response to the error is slow which in some cases may make the system unstable.

3.2 PI controller for SRM speed control

A PI controller is used here to control the speed of the SRM. Depending on the actual torque developed by the motor and the rotor position, the speed of the machine is obtained. The speed is compared with the desired speed and the error is fed to the PI controller to obtain the relevant current. This current modifies the output of the power electronics circuitry and hence the excitation to the SRM which ultimately develops the required torque. The block diagram of controller implemented in MATLAB Simulink is shown in figure (3).

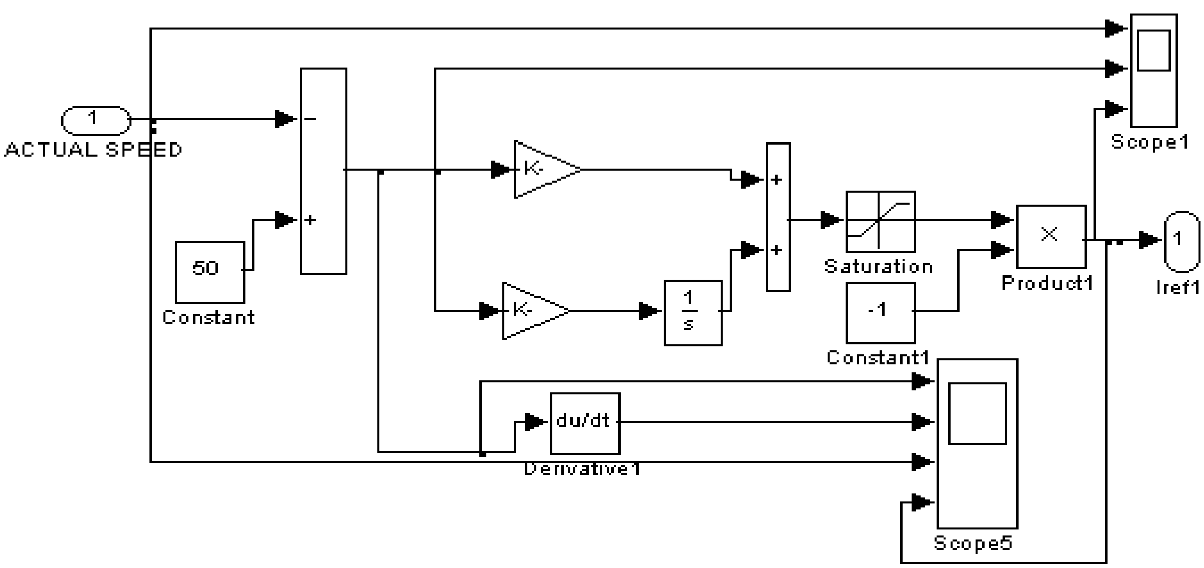

Figure 3. Block diagram of PI controller

IV. SIMULATION RESULTS

The mathematical model, asymmetric bridge converter, machine dynamics and a PI controller block diagram were developed in MATLAB Simulink programme. The ON and OFF values of theta were set and a PWM technique was developed to control the current. The corresponding current waveforms, inductance profile and torque developed are obtained as shown in figure 4,5,6 respectively by using MATLAB SIMULINK programme. The actual and desired speed is compared and a PI controller is implemented to achieve the desired speed. The resulting speed waveform is shown in figure 7.

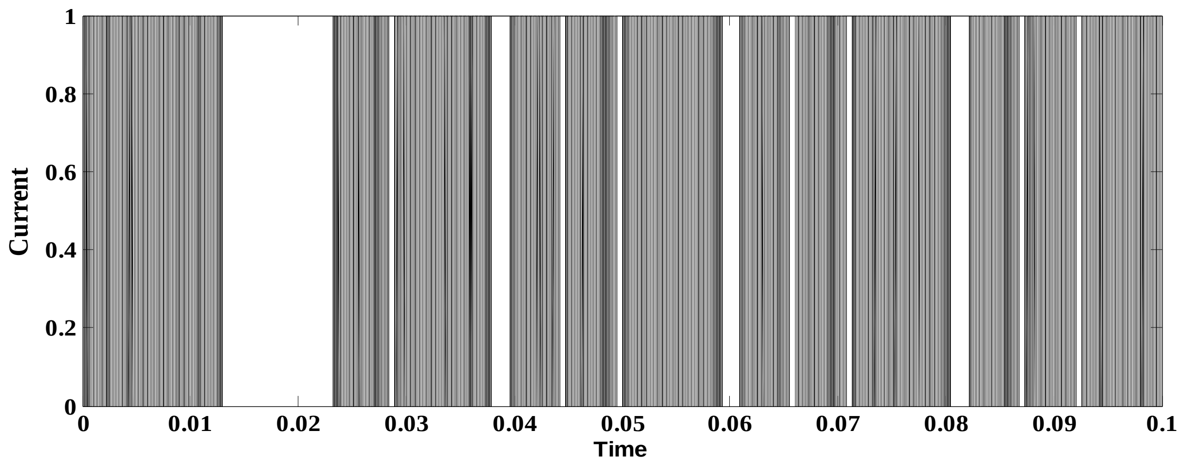

Figure 4 Current vs Time

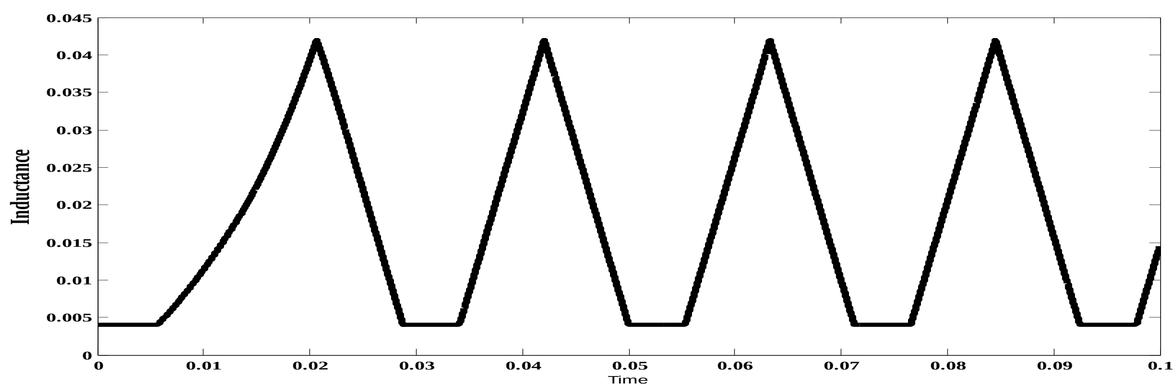

Figure 5 Inductance of one phase

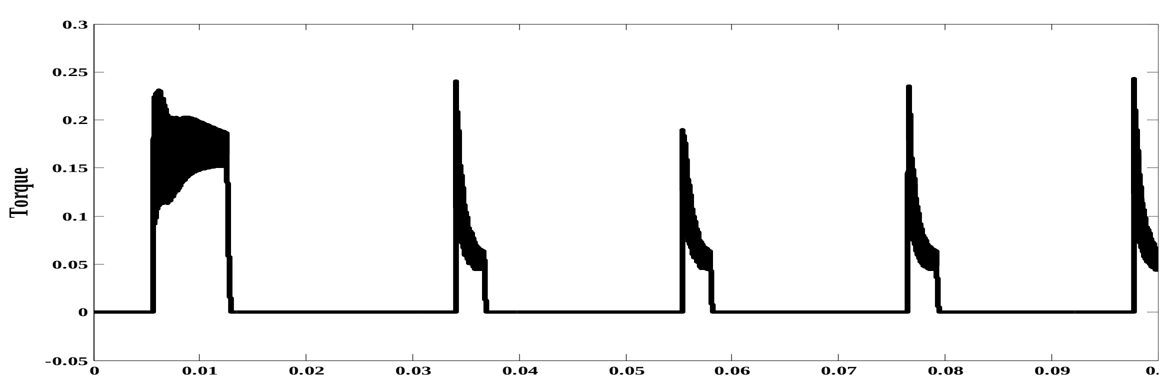

Figure 4 Torque of the motor

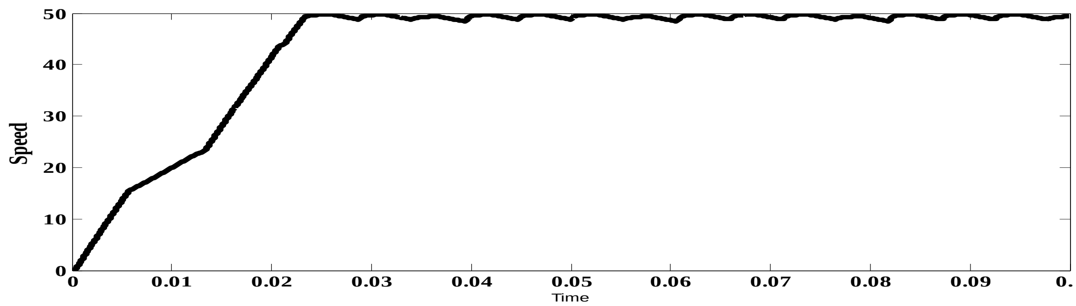

Figure 7 Speed obtained by the PI controller

V. CONCLUSION

The torque developed by the 12/8 switched reluctance motor depends on the rotor position and the inductance profile of the machine. To achieve the desired speed for the machine the power converters and excitation of the machine must be proper. In this paper a PI controller is developed using Simulink model to act upon the speed error and take proper action to bring the actual speed to the desired value. The speed waveform shows that the steady state error is reduced.

REFERENCES

1. R. Krishnan, "Switched Reluctance Motor Drives: Modelling, Simulation, Analysis, Design and Applications", CRC Press,
2. T. J. E. Miller, "Switched Reluctance Motors and their Control", Magna Physics Publishing and Clarendon Press-Oxford, 1993.
3. S. Vijayan, S. Paramasivam, R. Arumugam, S. S. Dash, K. J. Poornaselvan, "A Practical approach to the Design and Implementation of Speed Controller for Switched Reluctance Motor Drive using Fuzzy Logic Controller", Journal of Electrical Engineering, vol.58, No.1, 2007, pp. 39- 46.
4. Vikas S. Wadnerkar, Dr.G.TulasiRam Das, Dr.A.D.Rajkumar, "Performance Analysis Of Switched Reluctance Motor; Design,Modeling And Simulation Of 8/6 Switched Reluctance Motor" Journal of Therotical And Applied Information Technology, 2005-2008.
5. M. G. Rodrigues, W. I. Suemitsu, P. Branco, J. A. Dente, L. G. B. Rolim, "Fuzzy Logic Control of a Switched Reluctance Motor", Proceedings of the IEEE International Symposium, vol.2, 1997, pp.527-531
6. De Doncker, R., et al. 2011. Advanced Electrical Drives, Power Systems. In: *Switched Reluctance Drive Systems*. : Springer Science+Business Media B.V., pp. 361-437.
7. X.Felix Joseph, Dr.S.Pushpa Kumar, "Design and Simulation of a PI Controlled Soft Switched Front End Converter for Switched Reluctance Motor", International Journal of Computer Applications (0975 – 8887) Volume 34– No.10, November 2011

