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Switched Reluctance Motor for Hybrid Electric Vehicle

[1]Aarim C. Sijini, [2]E. Fantin and [3]L. Prakash Ranjit

[1]PG Scholar, Power Electronics and Drives, Dr. Sivanthi Aditanar College of Engineering, India
[2]Irudaya Raj /Assistant Professor, Department of Electrical and Electronics Engineering,
Dr.Sivanthi Aditanar College of Engineering, India
[3]Assistant Professor, Department of Electronics and Communication Engineering,
P.B. College of Engineering, India

Abstract: TheElectric vehicles are becoming increasingly important as not only do they reduce dependence on oil, but also they can be used to minimize noise and pollution.There are many electric-propulsion system for a Hybrid ElectricVechicle (HEV). The SRMs are gaining much interest and are recognized to have a potential for HEV applications because of its severaladvantage. There are, however, several disadvantages, which for many applications outweigh the advantage. The torque ripple, acoustic noise and speed ripple. The highly non-linear nature of the SRM operating in saturation makes analytical modelling extremely difficult.The main aim of this project is to employ the non linear controller for switched reluctance motor to reduce the torque and speed ripple to make it suitable for HEV. The proposal of the switched reluctance motor for hybrid electric vechicle is simulated by using MATLAB simulink model.

Key words: Hybrid electric vehicle · PI Controller · Fuzzy Logic Controller and Switched Reluctance Motor

INTRODUCTION

In this paper the switched reluctance motor is employed for hybrid electrical vehicle with low torque and speed ripple using non linear controller. The simulink model for the speed control of switched reluctance motor is carried out using different speed controllers. The simulink model is designed with PI and Fuzzy logic controller separately and their performance is compared. The Switched Reluctance Motor is an electric motor which runs by reluctance torque. The speed controllers applied here are based on PI Controller and the other one is AI based Fuzzy Logic Controller. The proportionalintegral controller (PI Controller) is a special case of the PID controllerin which the derivative of the error is not used. Many valued logic which is much like human reasoning is in Fuzzy Logic Controller. In industrial control FLC has various applications, particularly wherethe conventional control design techniques are difficult to apply. A comprehensive review has been done for SRM machine modelling, design, simulation, analysis and control.

Hybrid Electric Vehicle: A Hybrid Electric Vehicle (HEV) is a one that combines a conventional Internal Combustion Engine (ICE) propulsion system with an hybrid vehicle drive train. To reduce fossil energy consumption, the utilization ofgreen energy sources has increasingly gained attention worldwide. In addition, the use of electric vehicles (Evs) [1] is also effective in achieving this goal.The series and parallel are the two type of HEV system. Selection of traction motors for hybrid electric vehicle is a very important step that requires special attention. In an industrial point of view, the major types of electric motors adopted for HEVs as well as for EVs include the dc motor, the Induction Motor (IM), the Permanent Magnet (PM) Synchronous Motor and the switched reluctance motor (SRM). In fact, the automotive industry is still seeking for the best electric-propulsion system for hybrid electric vehicles (HEVs) and even for EVs.

Switched Reluctance Motor: The SRM drives for industrial applications are of recent origin. A brief introduction of SRM and its principle of operation is

Corresponding Author: Aarim C. Sijini, PG scholar, Power Electronics and Drives,
Dr. Sivanthi Aditanar College of Engineering, India.

explained in this chapter. A Switched Reluctance Motor is a singly excited, doubly-salient machine in which develop the electromagnetic torque due to variable reluctance principle [2]. The stator only carries winding but both rotor and stator has salient poles. As in dc motor the SRM has wound field coils for stator windings. When the excitation due to the dc supplyis given to the stator windings, a force is created by rotor's magnetic reluctance that align theadjacent stator polewith the rotor pole. In order to preserve sequence rotation, the stator pole windingsswitches 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.

when the rotor pole is equidistant from the two adjacent stator polethe rotor pole is said to be in"fully unaligned position ". This position is called as maximum magnetic reluctance for the rotor pole. The rotor poles are fully aligned with the stator polesin the aligned position, this position is called as minimum reluctance of rotor pole [3]. Figure 3.1 illustrates the 6:4 SRM drives which consists 6 stator poles and 4 rotor poles.

Block Diagram: The block diagram of SRM is shown in the above.When the Dc supply is given to the motor, the motor starts to rotate.The rotor position sensor is used to sense the current position of the rotorand it provides output to the error detector. Error detector compares reference speed and actual speed. The controller gives control signal to the converter according to the error signal. The speed of the motor is controlled by the converter through proper excitation of their corresponding windings [1]. Thus the switched reluctance motors operate.

Speed Control of Srm Using PI Controller: The forced oscillation and steady state error are eliminated by PI controller. Thus, PI controller will not increase the speed of response. PI controller does not have means to predict what will happen with the error in near future. By introducing the derivative mode this problem have been solved and thus to decrease a reaction time of the controller.

$$\Delta = SP - PV$$

Where Δ is the error or deviation of actual value (PV) from the set point (SP).The Proportional-Integral (PI) algorithm computes and transmits a controller output signal every sample time, to the final control element. The computed

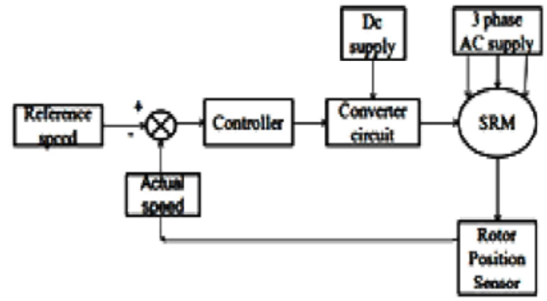


Fig. 4.1: Block diagram of SRM speed control.

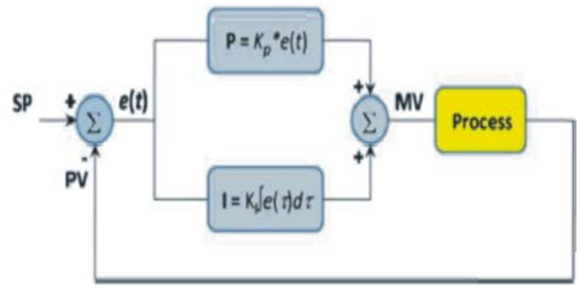


Fig. 5.1: Basic block of a PI controller

output from the PI algorithm is influenced by the controller tuning parameters and the controller error (Δ). Integral action enables PI controllers to eliminate offset, a major weakness of a P-only controller. Its function is to integrate or continually sum the controller error. Based on the control error the PI adds or subtract. The amount added grows or shrinks immediately or proportionatelyas the error grows or shrinks,. Thus the integral action eliminates offset. It continually resets the bias value of controller to eliminate offset as operating level changes. Thus the offset error and the speed of response is increased by PI controller.

Speed Control of Srm Using Fuzzy Logic Controller: LotfiZadeh in 1965 propose the fuzzy logic controller, 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 [4] fuzzy logic system is not based on the mathematical model of process8. The fuzzification, rule base, inference mechanism and defuzzification are the four main stages of fuzzy logic controlleras shown in Figure 6.1. The fuzzification comprises the process of transpose crisp values into grades of membership for linguistic terms of fuzzy sets. The transpose from a fuzzy set to a crisp number is called a defuzzification. The factual knowledge of the operation of the concern experts is stored in knowledge base store.

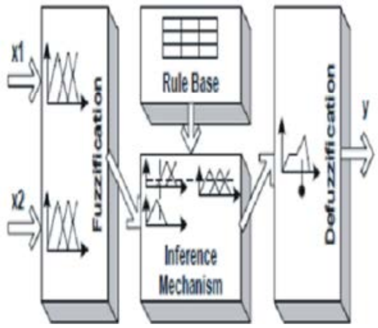


Fig. 6.1: Block diagram of SRM speed control

Fuzzy inference calculate a output from a given input using fuzzy logic. In inference engine, If –Then type fuzzy rules converts fuzzy input to the output [5].

RESULTS AND DISCUSSION

Simulink Model of Open Loop Control of SRM: The following figure shows the motor speed waveform of the open loop control of switched reluctance motor. Speed increases continuously with time as the time proceeds are shown below

The following figure shows the motor flux linkage waveform of the open loop control of switched reluctance motor.

The following figure shows the motor current waveform of the open loop control of switched reluctance motor. The current waveform shows a peak while the phase rotor position is between the turn on and turn off angle.

The following figure shows the Torque waveform of the open loop control of switched reluctance motor. Speed and theta increases continuously with time as time proceeds.

Simulink Model of Closed Loop Control of SRM: The simulink model for closed loop system is designed for the speed control of switched reluctance motor using PI controller and their corresponding output waveform is shown in Figures. From speed waveform it can be notified that the introduction of the controller reduces the steady state error.

Simulink Model of Closed Loop Control of Using Pi Controller: The following figure shows the motor speed waveform of the closed loop control of switched reluctance motor using PI controller. If set speed is 600, the actual speed displayed is 610 is shown below:

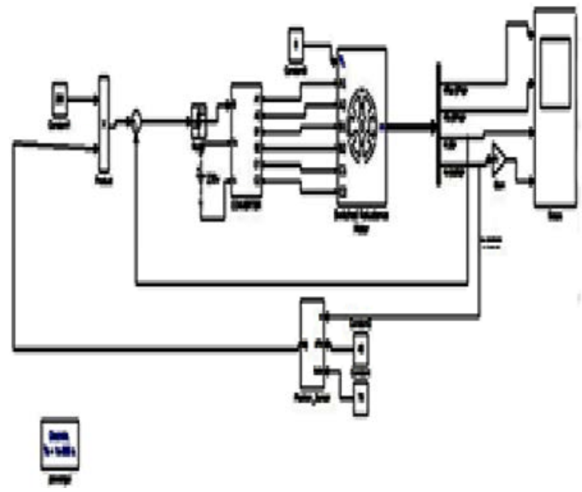


Fig. 7.1: Simulink model of open loop control of SRM

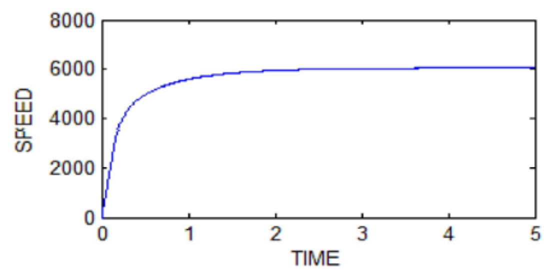


Fig. 7.2: Motor Speed waveforms of open loop control

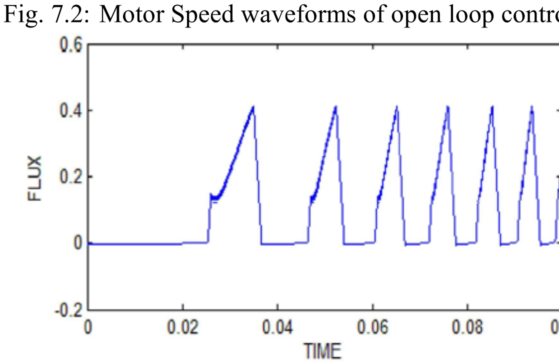


Fig. 7.3: Motor Flux linkage waveforms of open loop control

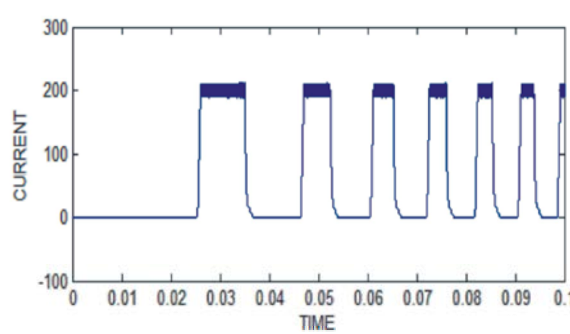


Fig. 7.4: Motor current waveforms of open loop control

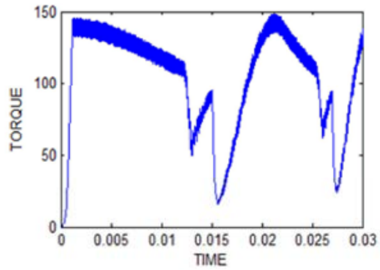


Fig. 7.5: Motor Torque waveforms of open loop control

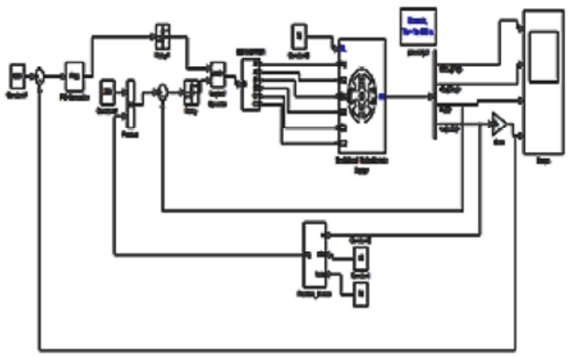


Fig. 7.6: Simulink model of Closed loop control of SRM using PI

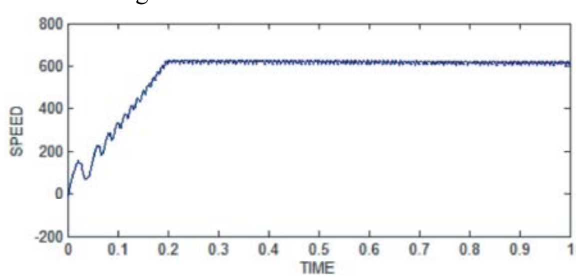
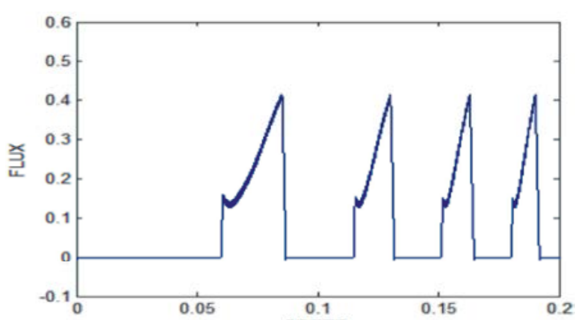


Fig. 7.7: Motor Speed waveforms of Closed loop control using PI controller

The following figure shows the motor flux linkage waveform of the closed loop control of switched reluctance motor using PI controller.



Motor Flux Linkage Waveforms of Closed Loop Control Using PI Controller:

The following figure shows the Torque waveform of the closed loop control of switched reluctance motor using PI controller.

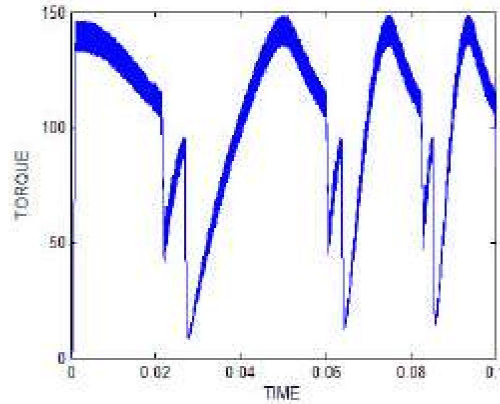


Fig. 7.8: Motor Torque waveforms of closed loop control using PI controller

The following figure shows the motor current waveform of the closed loop control of switched reluctance motor using PI controller. The current waveform shows a peak while the phase rotor position is between the turn on and turn off angle.

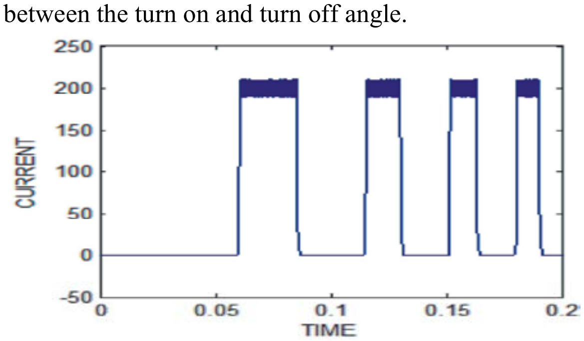


Fig. 7.9: Motor current waveforms of ofClosed loop control using PI controller

Simulink Model of Closed Loop Control of Srm Using Fuzzy Logic Controller: The following figure shows the motor flux linkage waveform of the closed loop control of switched reluctance motor.

The following figure shows the Torque waveform of the closed loop control of switched reluctance motor using FLC controller.

The following figure shows the motor current waveform of the closed loop control of switched reluctance motor using FLC controller. The current waveform shows a peak while the phase rotor position is between the turn on and turn off angle.

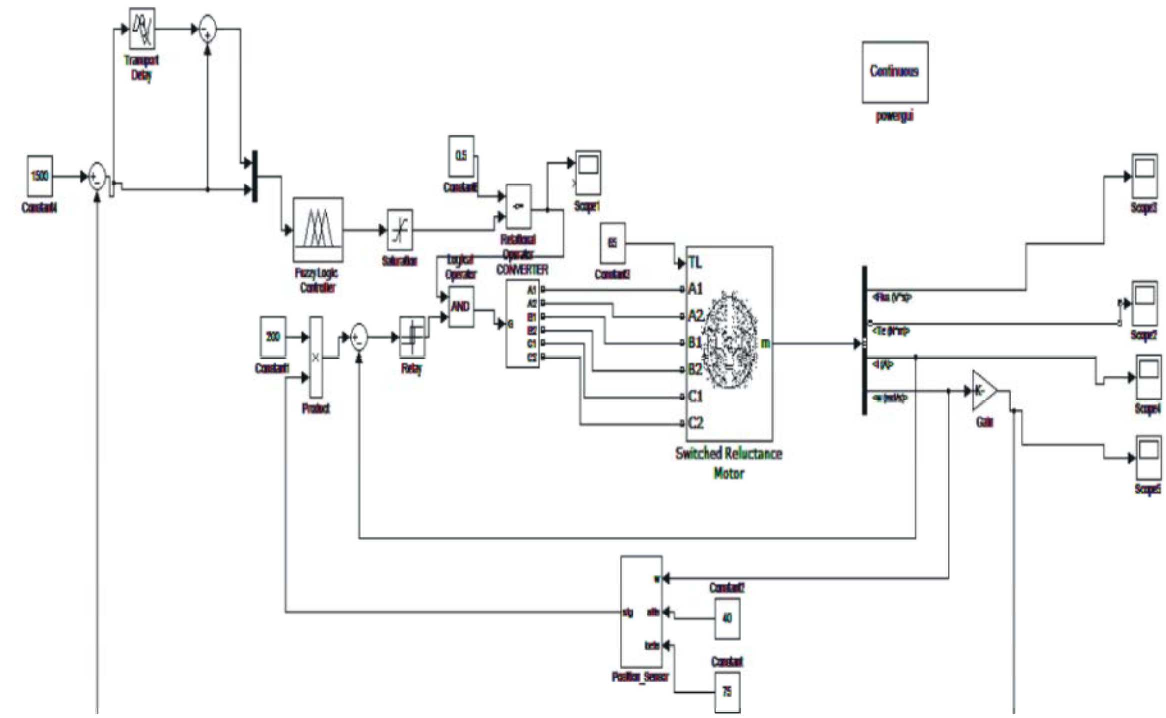


Fig. 7.10: Simulink model of Closed loop control of SRM using FLC

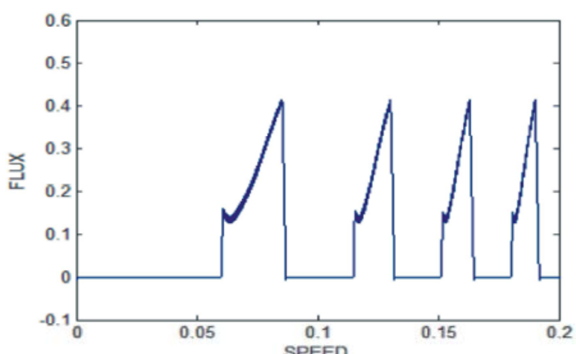


Fig. 7.11: Motor Flux linkage waveforms of closed loop control using FLC controller

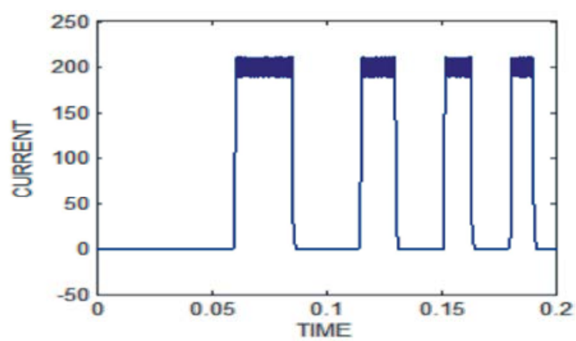


Fig. 7.13: Motor current waveforms of ofClosed loop control using FLC controller

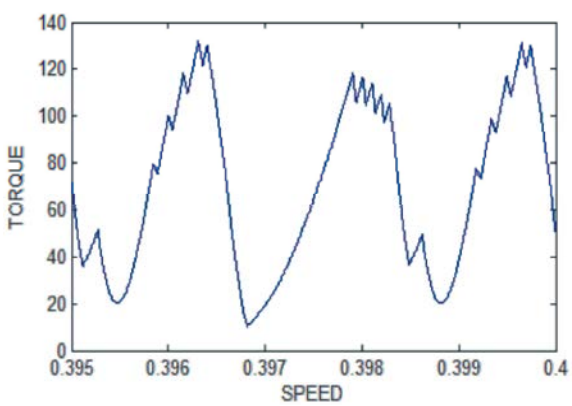


Fig. 7.12: Motor Torque waveforms of closed loop control Using FLC controller

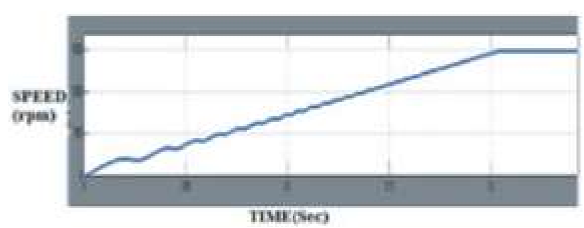


Fig. 7.14: Motor Speed waveforms of Closed loop controlusing FLC controller

The following figure shows the motor speed waveform of the closed loop control of switched reluctance motor using FLC controller. If set speed is 600, the actual speed displayed is 602 is shown below.

Table 1: Comparison of Speed Controllers

Controllers	Torque Ripple Obtained
PI Controller	1.83
FLC Controller	1.70

Comparison of Speed Controllers: The Table 1 shows thespeed comparison of proportional controller and fuzzy logic controller. For reference speed of 1500rpm, the following were obtained.

CONCLUSION

Thus the SRM dynamic performance is forecasted and by using MATLAB/simulink the model is simulated.SRM has been designed and implemented for its speed control by using PI controller and AI based fuzzy logic controller. We can conclude from the simulation results that when compared, the fuzzy Logic Controller FLC is more advantaged than the PI.We can conclude from the simulation results that the Switched reluctance motor with low torque and speed ripple is the good electric-propulsion system for hybrid electric vehicle.

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