



STABILITY ANALYSIS OF GOLDEN-SECTION ADAPTIVE CONTROLLERS FOR SWITCHED RELUCTANCE MOTOR CHARACTERISTIC MODEL

Prabhu Manikandan.K.B¹, Dr.P.Suresh Kumar²

Abstract— The SRM is used in various industrial applications due to its profitable advantages. Initially PI controller used for speed control of switched reluctance motor. Then fuzzy logic and H- Infinity control methods are used for speed control of switched reluctance motor. Finally GA based H -Infinity control technique applied for speed control for switched reluctance motor. H infinity control is an external control technique so the weight of the transfer function matrix is improved and the system is controlled perfectly by totaling the input weight noise function matrix value and weight uncertainty. The weight of the transfer function matrix is changed at every different system states. The process of finding an optimal control weight is complex because the H-Infinity control process is a closed loop control. This would be fall of control accuracy and also increases the merging time. To overcome these problems, an optimal GA based H-Infinity control concept is proposed. In the proposed control process, the optimal transfer function matrix weight is obtained by Genetic Algorithm. The proposed GA based optimal H-Infinity control method is simulated in MATLAB and also speed of the SRM is controlled by the proposed optimal GA based H - Infinity control method.

Index Terms— Switched Reluctance Motor, PI control, Fuzzy logic control , H-Infinity control, Robustness and GA based H-Infinity control algorithm.

1. INTRODUCTION

The Switched Reluctance Motor is applied in various industrial applications due to its profitable advantages. But, the robustness speed of SRM is one of the major drawbacks, which greatly affects the performance of motor. Control the speed of SRM using H-infinity control strategy. This H-infinity control technique is stronger against robustness. In the proposed speed controller, the rotor position of the SR motor is applied to the controller. The speed variation of the rotor is determined from the reference speed and applied to the controller as input. Then, the speed difference and the same sensitivity function are determined. The sensitivity function prediction is based on the input side weight of the controller. The weight adjustment process is repeated until a stable speed condition is achieved. Then, the output of the proposed control technique is compared with the existing control technique and the robustness is analyzed.

In normal control technique have the uncertainties have parameters namely model error and variation outer disorder. But, the H-infinity control technique is an external control technique. The weight of the transfer function matrix is improved and the system is controlled perfectly by totaling the input weight noise function matrix value and weight uncertainty. The weight of the transfer function matrix is changed at different system state. Therefore, an optimal control weight is needed to make the system robust. The process of finding optimal control weight is complex because the H-infinity control process is a closed loop controller. This would result in fall of control accuracy and also increases the merging time. To overcome these difficulties, the optimal H-infinity control concept is proposed. In the proposed control procedure, the optimal transfer function matrix weight is obtained by genetic algorithm which is an efficient optimization algorithm. The proposed GA based optimal H-infinity control method is implemented in MATLAB. Also, the speed of the switched reluctance motor is controlled by the proposed optimal H-infinity control technique and the speed controlling concert is tested with the straight H-infinity control technique. The weight noise setting is obtained for every time instant and optimal weight noise is calculated. The optimal weight noise setting can be attained by H-infinity optimal control using GA approach

2. PI CONTROL TECHNIQUE FOR SRM

Proportional-Integral (PI) controllers are widely used in Switched reluctance motor drive for accurate speed control and better speed holding capacity. The combination of proportional and integral increases the speed of the response and reduces the steady state error . The PI controller is widely used in industry as it is a simple and effective controller for applications that do not require a more sophisticated approach. For the speed control of this SRM, the PI controller has been deemed adequate for a variable speed SRM not requiring servo like control. Figure 2 shows the PI controller based switched reluctance motor drive. SRM current controller sees a nonlinear plant with varying plant gain even within normal operating condition. Additionally, the current reference is time-varying. As expected and verified experimentally, integral (I) control is

¹ PG Student /EEE, ²Professor/EEE, Mahendra Engineering College (Autonomous), Namakkal, Tamilnadu, India

² PG Student /EEE, ²Professor/EEE, Mahendra Engineering College (Autonomous), Namakkal, Tamilnadu, India

not effective in case of a finite-time tracking problem. The controller gains had been increased to reduce the tracking error in the rising and falling portions of the current reference. This had resulted in oscillations in current for constant part of current reference. This establishes that constant gain PI current controller is not suitable for high performance current controller in SRM.

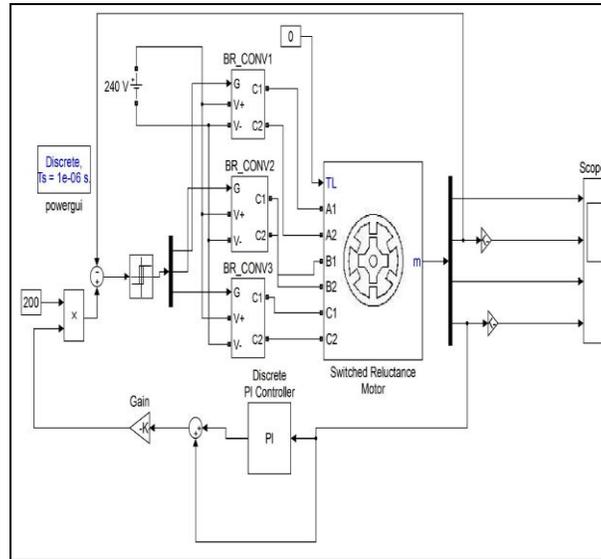


Figure 1. Simulation diagram of PI controller based SRM Drive system

2.1. Simulation Results of PI Controller for SRM

Figure 2 shows the SRM current of PI controller. Initially the starting current nearly 250A and finally settled at 150A.

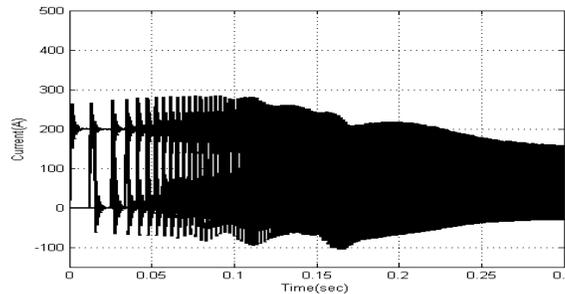


Figure 2 SRM Current of PI controller

Initial Motor starting torque is 165Nm and finally settled the motor torque at the value of 75Nm.

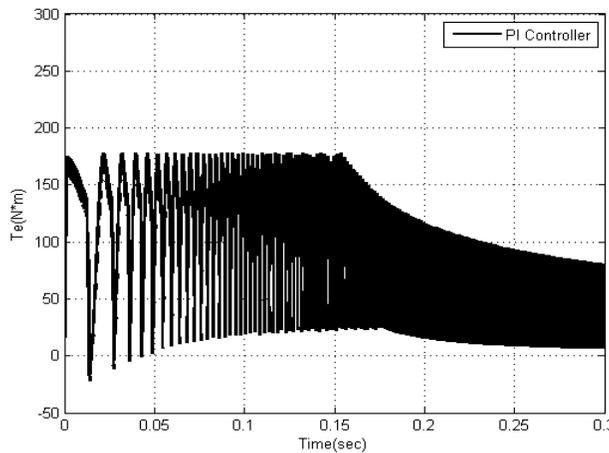


Figure 3 SRM Torque of PI controller

Figure 3 shows the SRM speed of PI controller. Starting speed of SRM rapidly increase to 8200 rpm and after 0.28 sec SRM maintain the speed around 4500rpm.

3. FUZZY LOGIC CONTROLLER FOR SRM

Figure 4 shows the Mamdani fuzzy logic controller based SRM. Fuzzy logic controller block inserted the SRM Simulink mode. The main function of the FLC is to take the output voltage of the converter and compared with the reference voltage to produce the actuating signal which will compensate with the set voltage, thus the SRM will now be supplied with rated voltage. Converter gets activated the windings of the Switched reluctance motor. The torque production in the switched reluctance motor is explained using the elementary principle of electromechanical energy conversion in a solenoid. The fuzzy logic controller is implemented in the SRM drive system. FLC is used in closed loop control and better performance of reduced harmonics and accurate speed regulation as that of the set speed is obtained

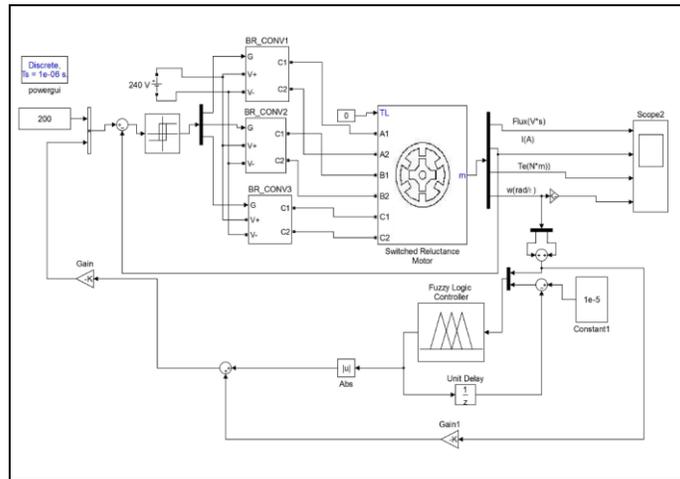


Figure 4 Mamdani fuzzy controller based SRM Control Model

3.1. Fuzzy Rules Description

Fuzzy rules for the FLC to control the error in speed can be given as follows: there are nine rules are used for fuzzy logic controller based SRM drive.

Figure 4 shows the implementation of fuzzy logic controller based on SRM drive system. FLC is robust to load disturbance or sudden change in reference speed. It has got significant steady state error as compared with that for conventional proportional integral controller. Hence an implementation of a hybrid controller is necessary to overcome with the drawbacks existing in the FLC.

Table 1 Fuzzy rule set

ΔE	L	M	H	L	M	H	L	M	H
L	L	L	H	L	L	H	L	L	H
L	L	L	H	L	L	H	L	L	H
L	L	L	H	L	L	H	L	L	H
M	L	M	H	L	M	H	L	M	H
M	L	M	H	L	M	H	L	M	H
M	L	M	H	L	M	H	L	M	H
H	L	M	H	L	M	H	L	M	H
H	L	M	H	L	M	H	L	M	H
H	L	M	H	L	M	H	L	M	H

Figure 5 shows the SRM Torque performance under FLC. Initially starting torque value of 155Nm and torque settled at 75Nm.

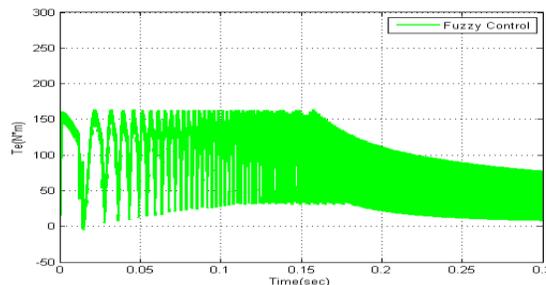


Figure 5 SRM Torque performances under FLC

Figure 6 shows the SRM current of Fuzzy logic controller. Initially starting current nearly 200A and finally settled at 98A.

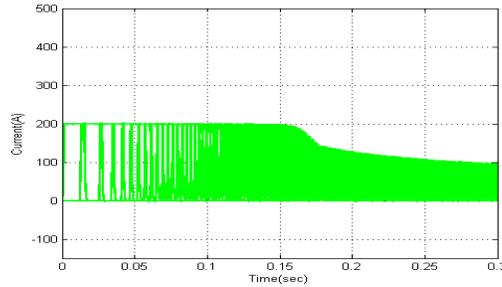


Figure 6 SRM Current under FLC

The PI-controller takes decision during steady state to reduce steady state error of the system and the fuzzy logic controller takes decision during transient state to get fast response and low overshoot when the absolute value of speed error is greater than 7 rpm. This set value depends upon the fuzzy logic controller and the sampling frequency of for the case of steady state, the PI-controller dominates the control output to significantly reduce steady state error of the system and the FLC contributes to the output to provide fast response and low overshoot when the absolute value of speed error is higher than 7 rpm.

4. H-INFINITY CONTROLLER

4.1. Introduction

Robust methods endeavor to achieve robust performance or stability in the occurrence of bounded modeling errors. In difference with an adaptive control policy robust control is static rather than adapting to capacity of variations. The controller is designed to work assuming that positive variable will be unknown H infinity loop shaping is a planned methodology in modern control theory. It combines the fixed insight of classical control methods H- infinity optimization techniques to accomplish controllers whose stability and performance properties hold good in spite of bounded differences between the nominal plant assumed in design and the real plant encountered in practice. The control system designer describes the desired reaction and noise-suppression properties by weighting the plant transfer function in the frequency domain the resulting ‘loop-shape’ is then ‘robustified’ through optimization. The general structure of H-infinity control is illustrated as shown in Figure 10.

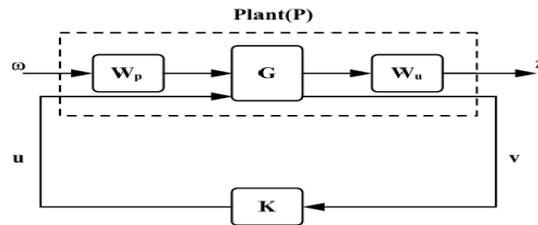


Figure 7 H-infinity Feedback Control Structure Configuration

The general formula for the above system is illustrated below,

(1)

where, and are the error and output of the H infinity feedback control system.

The value of P(s) is the transfer function of SRM, which is given as,

(2)

where, the R_m be the transfer function resistance, the condition for satisfying the closed loop system is,

$T_{z\omega}(s) \parallel_{\infty} \leq \gamma$ (3)

where, $T_{z\omega}(s)$ is the closed-loop transfer function matrix and γ the machine impedance angle. The weight of the matrix is adjusted to control the output of the motor. The weight adjustment process is repeated till the SRM speed reaches a stable condition that is described in equation (5.3). The output of the system is represented in the frequency domain. The input and output weight of the system are W_p and W_u . Usually, the H-infinity control problem is solved using Riccati equations. Here, the control problem is considered as the mixed sensitive problem. The closed loop stable speed condition of SRM is described as,

$$\|T_{z\omega}\|_{\infty} = \left\| \begin{bmatrix} -W_p GS & -W_p S \\ -W_u T & -W_u KS \end{bmatrix} \right\|_{\infty} \leq \gamma \quad (4)$$

where, GS , S , T and KS are the pre-specified templates of all the closed loop transfer function of SRM. The sensitive weight functions W_p and W_u are defined as follows. The inverse of the weighting function $W_p(j\omega)$ is used to impose a performance specification in terms of the sensitivity functions.

(5)

The control output u is weighted according to the SRM limitations.

(6)

Where, M_u , M_s are the mutual inductance of the output and saturation conditions, A_s is the specific electrical loading of the system, ω_b , ω_{bc} are the angular velocity parameters of SRM, ζ is the damping ratio. Then, using the sensitive function equations (5) and (6) the sensitivity of the SRM is maintained. So, the steady state error of the system is reduced and the controller gain is ensured. The speed variation is compensated by reducing the uncertainty of the system by means of adding weight. The weight matrix of the system is defined based on the rated speed of SRM. Once the weight function is defined, then the output speed of the SRM is applied to the H-infinity controller. The H-infinity control strategy is compared with the actual speed of the motor from the reference speed. According to the speed variation, the weight is added and the motor speed is regulated. The updating of weight is performed by the Riccati equation, which is used to analyze the inequalities of the weight matrix for the requirements.

4.1 Simulation And Results

The proposed H-infinity robust controller based SRM rotor position speed control technique is simulated in MATLAB working platform (version 7.12). From the simulated model, the rotor speed control performance of the proposed control technique is analyzed. Then, the speed control characteristics of the H-infinity control technique are compared with the existing speed control technique such as PI controller and fuzzy controller. After that, the torque, flux, and transfer function of the SR motor are described. The simulink model of the proposed control system is illustrated in Figure 8.

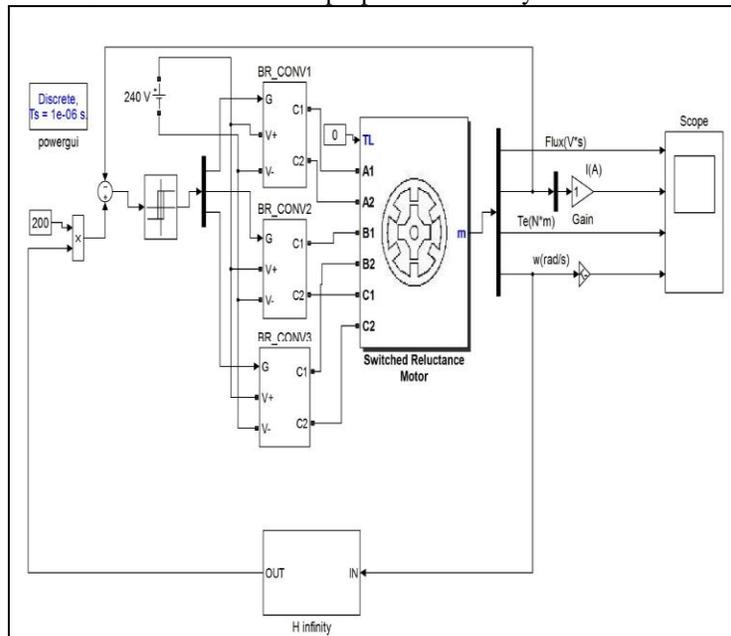


Figure 8 Simulink Model of the H-Infinity Controller

Figure 9 shows the Speed Control of H - Infinity controller for SRM. Initially speed is increased from 0 to 4500rpm at small time interval. After 0.04 sec SRM maintained the constant Speed of 4500 rpm.

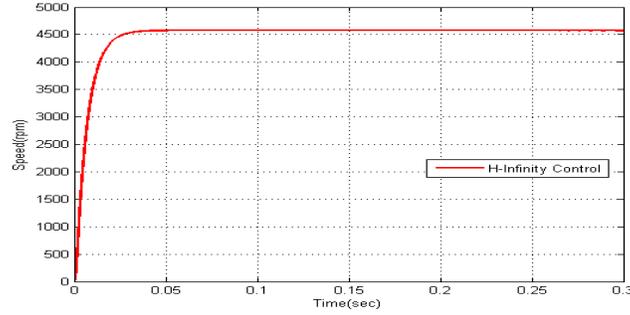


Figure 9 Rotor Speed control of H-infinity control

Figure 10 shows the SRM current of H- Infinity controller. Initially starting flux nearly 0.4Wb and finally settled at 0.25Wb.

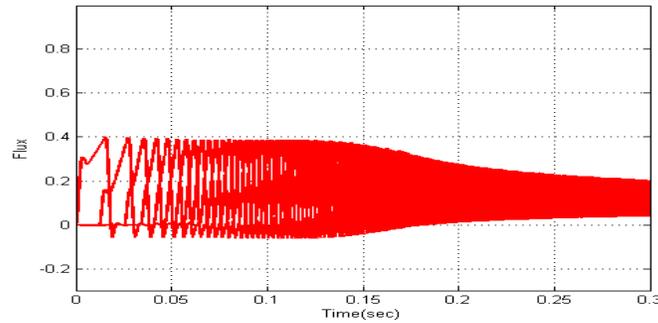


Figure 10 SRM Flux variation of H-infinity control

Figure 11 shows the SRM torque of H-Infinity controller. Initially starting Torque nearly 150Nm and finally settled at 75Nm.

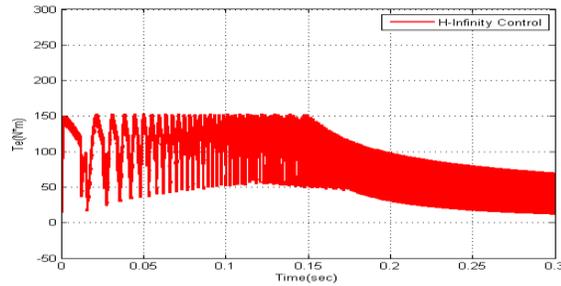


Figure 11 SRM torque of H-Infinity control

Figure 12 shows the SRM current of H-Infinity controller. Initially starting current nearly 250A and finally settled at 75A.

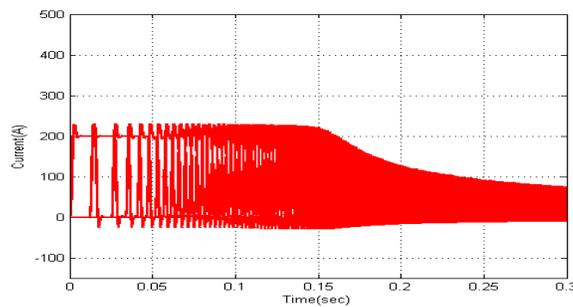


Figure 12 SRM current of H-Infinity control

H - Infinity controller of SRM, the rotor speed control performance accuracy and controlling time are analyzed. In Figure 13, the rotor speed of SRM is smoothly controlled by H-infinity controller.

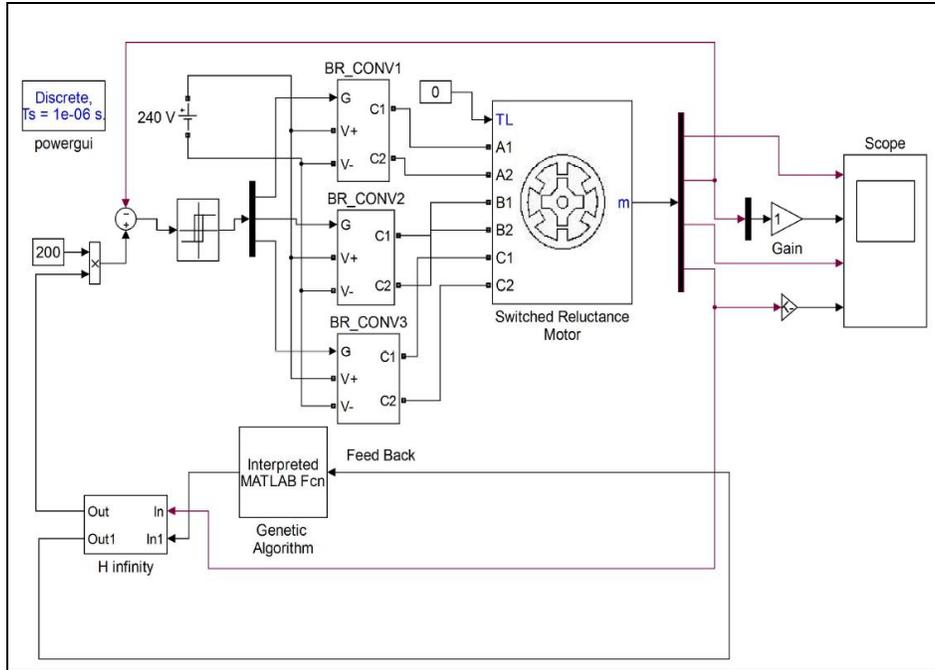


Figure 13 Simulink Model of Proposed Controller for SRM

4.3. Simulink Model Description

Figure 14 shows the SRM Torque of GA based H- Infinity controller. Initially starting torque be the 148 Nm and finally settled at 70Nm.

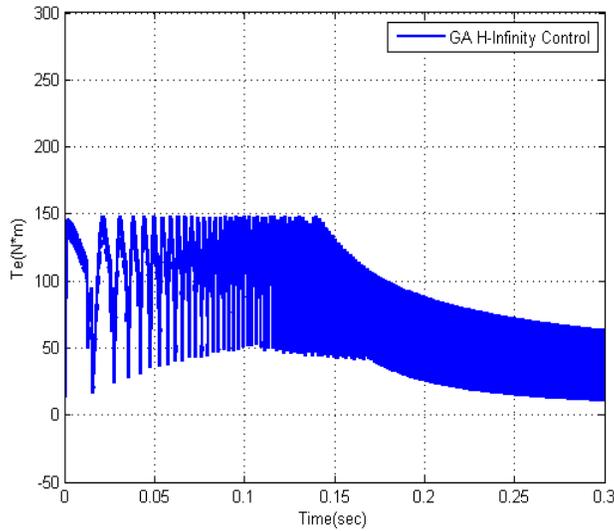


Figure 14 SRM Torque performance of GA based H-Infinity control

Figure 14 shows the SRM Speed of GA based H-Infinity controller. Initially starting speed be the 4500 rpm and finally settled at 4550 Nm.

5. COMPARISON OF RESULTS

Table 2 Comparison of various SRM controller performances

Motor Parameters	PI Controller	Fuzzy Controller	H infinity Controller	GA based H infinity controller
Speed control action in sec	6	32	6	5
Speed in rpm	4500	4500	4550	4550
Torque in Nm	85	85	80	75

Current in Ampere	150	110	80	50
Flux in Weber	0.35	0.4	0.4	0.4

The comparison of Speed performance of Fuzzy Logic control and PI controller for SRM shown in Figure 15. The PI and fuzzy controller technique has taken more time for achieving desired rotor speed.

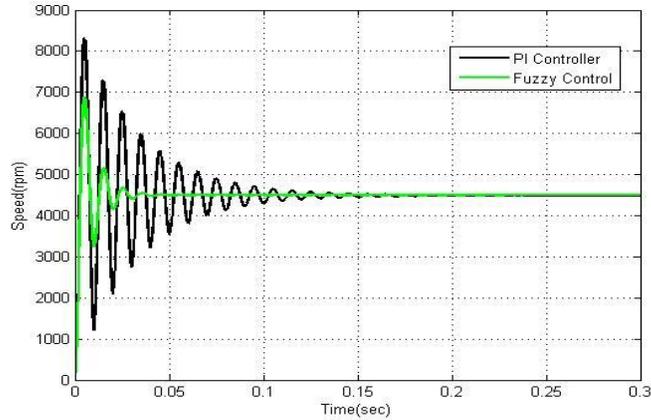


Figure 15 Comparison of Speed performance under Fuzzy and PI controller for SRM

5.1 H-Infinity and GA based H-Infinity controller for SRM

The comparison of Speed performance of Fuzzy Logic controller, PI controller, H-Infinity control and GA H-Infinity controller for SRM shown in Figure 16.

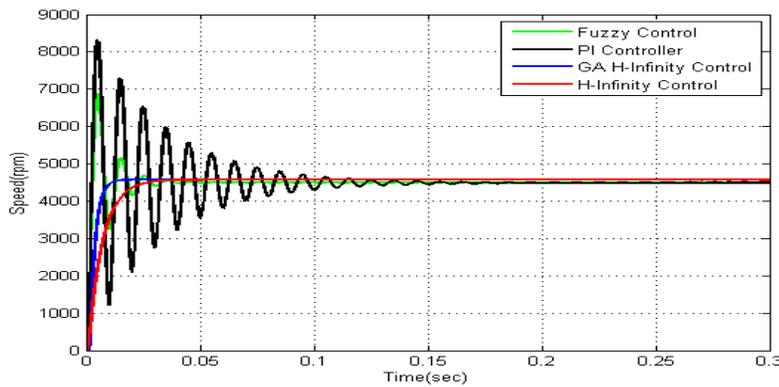


Figure 16 Comparison of Speed performance under various controller for SRM

The comparison of Torque performance of Fuzzy Logic controller, PI controller, H-Infinity control and GA H-Infinity controller for SRM shown in Figure 17.

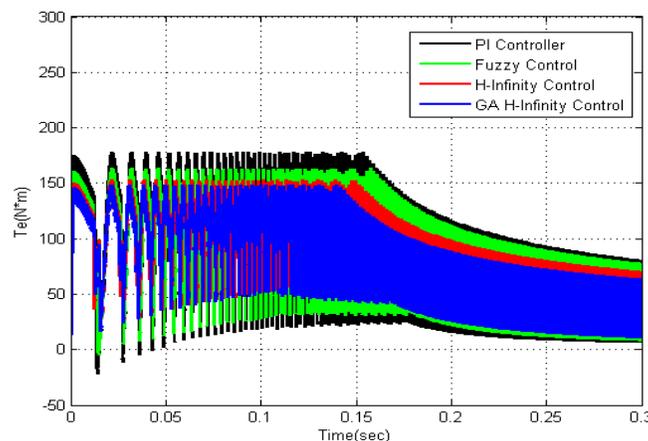


Figure 17 Comparison of Torque performance under various controller for SRM

The comparison of Current performance of Fuzzy Logic controller, PI controller ,H-Infinity control and GA H-Infinity controller for SRM shown in Figure 18.

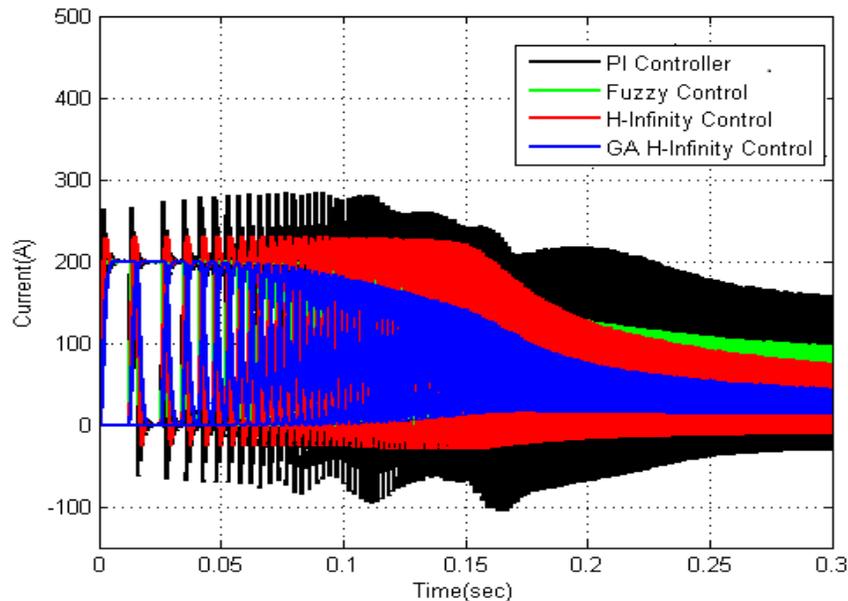


Figure 18 Comparison of Current performance under various controller for SRM

6. CONCLUSION

Overall performance of the Proposed method more suitable for reducing robustness of SRM and improve the Speed control operation of the Switched reluctance motor. Corporately proposed GA Based H –Infinity controller based SRM shown better performance than other controllers. The proposed control technique was simulated and the output drawn was analyzed. The output performance was compared with the other speed control techniques. The control techniques used for comparison were PI controller, H-Infinity Controller and fuzzy controller. From the comparison results, it is found that the proposed control technique is most suitable for controlling the speed of SRM. The response time and steady state error of the H-Infinity controller using GA was less than the H-Infinity, fuzzy logic and PI controllers. GA based H - Infinity controller gives the robust performance compared with others controllers. GA based H infinity controller based SRM consumes less current value compared with other controllers. GA based H- Infinity controlled SRM achieved low starting time, minimum torque ripple, minimum starting current, overshoot free speed and reduced speed oscillation. So efficiency of the GA based H- Infinity controlled SRM is high. Overall, the proposed H-Infinity control technique using GA has achieved a remarkable level in controlling the rotor speed and smooth speed variation of SRM motor.

7. REFERENCES

- [1] Ahmed Tahour, Abdelkader Meroufel, Hamza Abid & Abdel Ghani Aissaoui 2018, 'Sliding Controller of Switched Reluctance Motor', Leonardo Electronic Journal of Practices and Technologies, vol.12, pp.151-162.
- [2] Alcantara, S, Skogestad, S, Grimholt, C, Pedret, C & Vilanova, R 2011, 'Tuning PI controllers based on H-Infinity Weighted Sensitivity', Mediterranean Conference on Control and Automation, pp. 1301-1306.
- [3] Anand kumar, S 2015, Control systems, PHI Learning Pvt Ltd, New Delhi.
- [4] Bae, H K & Krishnan, R 2016, 'A study of current controllers and development of a novel current controller for high performance SRM drives', IAS annual meeting on Industry Applications Conference, vol. 1, pp 68-75.
- [5] Baiming Shao, Lukic & Emadi, A 2015, 'A digital current control for switched reluctance motor drives', International Symposium on Industrial Electronics, pp. 1163-1168.
- [6] Behzad Mirzaeian 2016, 'Genetic Algorithm Based Optimal Design of Switching Circuit Parameters for a Switched Reluctance Motor Drive', International conference on Power Electronics, Drives and Energy systems, pp. 1-6.
- [7] Chowdhuri, S, Biswas SK & Mukherjee, A 2016, 'Performance Studies of Fuzzy Logic Based PI-like Controller Designed for Speed Control of Switched Reluctance Motor', IEEE Conference on Industrial Electronics and Applications, pp.1-5.
- [8] Felix Joseph, X & Pushpa Kumar, S 2017, 'Design and Simulation of a PI Controlled Soft Switched Front End Converter for Switched Reluctance Motor', International Journal of Computer Applications, vol.34, no.10, pp.9-15.
- [9] Gamal M Hashem & Hany M Hasaniien 2017, 'Speed Control of Switched Reluctance Motor Based on Fuzzy Logic Controller', International Power Systems Conference, pp.228-292.
- [10] Guo Wei, Ma Zhiyuan & Qionghua, Zhan 2011, 'An simplified estimation method of PI control parameters for switched SRM drive system', International conference on Electrical Machines and Systems, vol. 2, pp.946-949.
- [11] Guojun Yu, He Cheng, Rui Li, Hao Chen, Jian Wang & Yingjie Huo 2012, 'The design of switched reluctance motor variable-speed system based on digital signal controller', IEEE Conference on Power and Energy, pp 347-351.
- [12] Jie Xiu, Changliang Xia & Hongwei Fang 2016, 'GA-Based Adaptive Fuzzy Logic Controller for Switched Reluctance Motor Drive', International conference on Intelligent Control and Automation, vol.2, pp. 8226-8230.