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OPTIMIZATION ALGORITHM BASED H-∞ CONTROL METHOD FOR CONTROLLING SWITCHED RELUCTANCE MOTOR (SRM)

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ABSTRACT

In classical H- Infinity control technique, 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, in this paper, an optimal H-infinity control concept is proposed. In the proposed control procedure, the optimal transfer function matrix weight is obtained by genetic algorithm (GA) 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 (SRM) 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.

Keywords: *SRM, Speed Control Technique, Optimal H-infinity Control, Robustness and genetic algorithm.*

1. INTRODUCTION

The SRM have been the center of attention of more than a few researches over the past decades [5] [7] [17]. The SRM is a doubly salient tool, in which a torque is produced by the affinity of the rotor to travel to a position where the inductance of the enthused windings is amplified [1]. The even manufacture of electromagnetic torque is a desirable feature of any motor [18]. The advantage of SRM are low manufacturing cost, excellent reliability, fault tolerance, wide range of operational speeds and torque, and fast dynamic responses [6] [8]. As of its ease and low-priced, the SRM is suitable to several applications [2]. During high speed function, the top torque ripple, vibration, and acoustic noise are the foremost disadvantages that heavily upsetting the concert of SRM [3]. As a result, for attaining an improved presentation of the SRM drive, a precise knowledge of the rotor position is needed [9]. SRM drives have been found to be forceful with conventional ac and dc drives due to the uncomplicated motor structure and power converter necessities [19] [20]. A tremendous electromagnetic operation of an SRM can be accomplished merely by the suitable excitation control, although this is fairly difficult to achieve simply from conducting tests [10].

In addition, the SRM has come across some difficulties due to its nonlinear features during speed control. For instance, the role of flux correlation based on phase current and rotor position signifies the key feature of the SRM, however it is delicate to describe such a correlation due to the consequences of magnetic saturation and double saliency of the erection [4]. The SRM is a dominant, dependable and more or less maintenance free tool for variable speed application [11]. For SRM control, the non-linear techniques namely, sliding mode, artificial neural network (ANN), fuzzy logic and gain tuning PI (Proportional Integral) controllers are frequently employed [12]. The long-established control methods are ineffectual in presenting better

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damping presentation [16]. Robust H-infinity control can offer a faultless control to linear systems and high forcefulness to become constant in unfavorable operating states such as parameter change, high disturbance environment actuator saturation and model uncertainty [13] [14]. The H-infinity control theory composes it feasible to pertain multivariable control with frequency domain design method and to attain competent steady control systems [15].

The SRM controlling problem is one of the mixed sensitivity control problems. In this paper, an H-infinity control technique is proposed for controlling the rotor speed of SR motor. The function of the proposed control technique is to identify the position of the rotor and based on the rotor position, the controller weight is adjusted. By satisfying the control strategy condition, the rotor speed of the motor is maintained as stable. From the controlled output, the torque, speed, and current characteristics are analyzed. The details of the problem statement and the proposed H-infinity controller based speed control technique are described in Section 3. Before that, a summarized review about the recently available related researches is given in the Section 2. Section 4 discusses and analyzes the results of the proposed H-infinity control technique and Section 5 concludes the paper.

2. RELATED RESEARCH WORKS: A BRIEF REVIEW

Many related works already existed in the literature are based on rotator control of SRM. Some of them are reviewed here.

Taking into report the consequences of mutual inductances, M. Alrifai *et al.* [21] have suggested for changeable speed switched reluctance motor (SRM) drives. The control system implements two-phase excitation; exciting two neighboring phases could conquer the setbacks related with single-phase excitation such as large torque ripple, increased acoustic noise, and rotor shaft fatigues. In the plan of the suggested control system for the motor, the consequences of mutual coupling among two neighboring phases and their involvement to the generated electromagnetic torque were measured. The suggested controller promises the convergence of the currents and the rotor speed of the motor to their needed values.

Based on the comparison between the FLC and the sliding mode control (SMC), Ahmed Tahour *et al.* [22] have planned a fuzzy logic controller (FLC) for a class of nonlinear system to deal with the nonlinear control problems with modeling uncertainties, plant parameters deviations and exterior commotions. The suggested system presents quick vibrant response with no overshoot and zero steady-state faults. Simulations were carried out for the speed control of a switched reluctance motor to illustrate the legality and the efficiency of the control method. In improving the robustness of control systems with high precision, the simulation effects demonstrate that the controller designed was more efficient than the conventional sliding mode controller.

In addition, based on the redevelopment of control rule base, Shun-Chung Wang *et al.* [23] have offered an adapted type PI-like fuzzy logic controller with output scaling factor (SF) self-tuning method was suggested and experimentally gave evidence in this document for application in the switched reluctance motor (SRM) drive scheme. By decreasing the number of fuzzy sets in the membership function (MF), this document intends to make simpler the structure hierarchy and computational complexity of the controller however yet without losing the system presentation and constancy. The output scaling aspect could be adjusted incessantly for the suggested controller by a gain updating factor, whose value was obtained from the fuzzy logic reasoning with the fault and alter of fault of the plant as the input variables. Based on the practical understanding and knowledge of the SRM's basic vibrant performance, the rule base was built operating mode and experimental practice. Different features of the design concerns about the membership function, rule base, and gain tuning strategy are explained in detail. Conducting tests and results comparison executed on a four Phase 8/6 pole SRM based on the platform of d SPACE DS1104 control desk were specified to demonstrate the possibility and efficiency of the developed techniques with sustain the theoretical considerations.

The setback of (TRM) control in has been explored by X. D. Xue *et al.* [24]. They have applied two enhanced torque-sharing functions for executing torque ripple minimization (TRM) control was offered. The suggested torque-sharing functions were reliant on the turn-on angle, overlap angle, and the anticipated torque. This revise illustrates that for a specified torque the turn-on angle and the overlap angle had considerable consequences upon speed range, maximum speed, copper loss, and competence. Consequently, genetic algorithm was applied to optimize the turn-

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on angle and the overlap angle at different anticipated torque insists operating under the suggested TRM control so as to maximize the speed range and minimize the copper loss. In addition, to obtain the optimized results, four torque-sharing functions were applied. Simultaneously, a quick and precise online strategy to calculate the optimal turn-on and overlap angles was suggested. As a result, to develop the presentations of switched reluctance motor drives operating under TRM control, this document offers an important technique.

G. Sakthivel *et al.* [25] have offered The (BLDC). The brushless DC motor (BLDCM) was getting ample concentration for industrial applications because of their high torque density high competence and tiny size. The benefits of BLDC motor had directed to their extensive spread applied in variable speed drives. The purpose of the document was to improve an intelligent speed control algorithm for BLDC motor in Vissim software which was an atmosphere for model based development of implanted controller for Texas instruments DSPs. In this document TMSC320F2812 DSP was employed as the controller necessary signal conditioning components was applied to make certain high processing speed and accuracy in the overall control system. Compared to conventional PI Controller, the executed system had a quick reaction with small overshoot and zero stable state faults.

Rafik Lasri *et al.* [26] have learned the science in all their fields attempts to touch the boundaries of performance, the control policy was one of the main scientific fields who need very high level of precision and constancy, hence, scientists were for all time attempting to bring novel methodologies to develop the controllers criteria's. The analysis existing in this documents wraps and describes the great involvement that conveys the apply of FLCs in awfully large/several fields of human everyday life, such as : medicine, industrial process, chemical process, aircraft Fuzzy Logic Controllers, Hybrid Control Policy, Industrial Controllers, Application of FLC.

A Switched reluctance motors (SRM) has been suggested by Susmitha. Javvadi *et al.* [27] had benefits of low manufacturing cost, rugged and easy erection and lesser switches in drive circuit. But, a number of its drawbacks are noise, torque ripple and low torque per unit volume. In the fragmented switched reluctance machine (SSRM), some of these restrictions, such as noise and low torque to volume have been alleviated which employs a full-pitched winding. A new segmented switched reluctance machine was suggested in this document. The plan process for segmented switched reluctance motor was termed and different equations were demonstrated. At last Matlab/Simulink based model was improved and simulation results are offered.

Using PI and Fuzzy Logic Controller, A.Ramya *et al.* [28] have revised the speed control of 8/6 Switched Reluctance Motor. Currently the Switched Reluctance Motor has achieved progressively attraction in industries. The speed of the Switched Reluctance Motor was controlled by both PI and Fuzzy Logic speed Controller in MATLAB/Stimulant environment. The simulation result demonstrates that Fuzzy Logic Controller is advanced to PI controller.

3. MODEL OF 6/4 POLE SRM

Switch Reluctance Motor has a fundamental simplicity and low cost that makes them well suited to many applications. Furthermore, the motors have a high robustness due to the ability to activate with the loss of one or more motor phases and are thus well suited to operate in ruthless developed environments. A SRM is a rotating electric motor, where both stator and rotor have salient poles. The stator winding include a set of coils, each of which is wound on one pole. The rotor is made from lamination in order to minimize the eddy current losses. The rotor tries to get to a position of minimum reluctance by align itself with the stator magnetic field when the stator winding are excited. Due to its attractive features of high power density, high efficiency and low maintenance cost, SRM is widely used in high performance servo applications, such as aerospace, industrial and robotics SRM cannot be sprint directly from the supply. It can be run only when the motor is integrated with power convertor, controller and rotor situation feeler. As indicated by its name, phase-to-phase switching in the SRM drive must be precisely timed with rotor position to obtain smooth rotation and the optimal torque output. There are two options for producing the series including a microcontroller to produce the signal or a timer circuit which could also produce the desired signal the use of a timer circuit would be very effective in producing the necessary signal with which to control the circuit. As the required signal is very simple it could easily be implemented by a digital timer.

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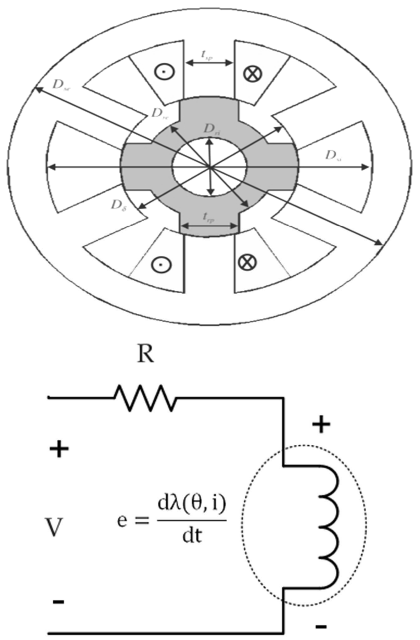

Figure 1: (A) Switch Reluctance Motor And (B) Equivalent Circuit Diagram.

The linear modal of the SRM can be described by their differential equation which can be classified as the voltage equation the motional equation and the electromagnetic torque equation.

$$V = \frac{Ri + d\lambda(\theta, i)}{dt} \quad (1)$$

$d\lambda(\theta,i)$,

Where, V is applied phase voltage to phase R is the phase resistance and e is the back EMF. Ordinarily, e is the function of phase current and rotor position, and λ can be expressed as the product of inductance and winding current:

$$\lambda(\theta,i) = L(\theta,i), i$$

$$V = R.i + d\lambda(\theta,i)\frac{d\lambda(\theta,i)}{di}.\frac{di}{dt} + \frac{d\lambda(\theta,i)}{d\theta}.\frac{d\theta}{dt} \quad (2)$$

T_L, T_e, J, ω And D load the electromagnetic torque, the rotor speed, the rotor inertia and the friction coefficient respectively.

3.1. H-infinity Control Based SRM

H-infinity controller is a robust control technique which is a division of control theory that openly deals with improbability in its approach to controller design. Robust control methods are designed to function correctly so long as tentative parameter or turbulence are within some typically limits. 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 follow.

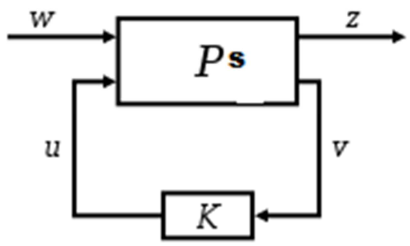

Figure 2: Control Structure Of H-Infinity Controller.

3.2. Problem Formulated in H-infinity Control Strategy

Optimal H-infinity Control Strategy: H- infinity optimal control theories have been developed very quickly and widely applied to treat control system design problems such as mini max model matching. The H-infinity control technique is the external control technique by adding the transfer function weight matrix value. The purpose of adding transfer function weight matrix is to define the systems and to characterize their properties. Using this transfer function matrix but the control model of the system at different input conditions. The weight of the transfer function when matrix is optimized and then, the system should be controlled perfectly. This paper presents a tutorial exposition of the subject. The emphasis is on explaining the relevance of Optimal H-infinity for control engineering. The paper presents new results using optimal H-infinity controller and optimized by (GA) Genetic Algorithm, to the extensive theoretical and mathematical literature on the

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subject. The presentation is limited to single-input-single-output (SISO) control systems. The optimal H-infinity based on tunings process is a closed loop controlling process. Control system deals with the mini max the peak value of certain closed loop frequency response function. Single input and Single output using H-infinity optimal Function. Techniques can be used to minimize the closed loop impact of a perturbation: depending on the problem formulation, the impact will either be measured in terms of stabilization or performance.

3.3. GA Based optimal H-infinity control Strategy

GA based performance in optimization over the conclusion by system parameter and acceleration stability achieves in a minimum time period. The H-infinity control weights are optimized by GA and the optimal control strategy is developed. The control structure of proposed optimal H-infinity control is given as follows.

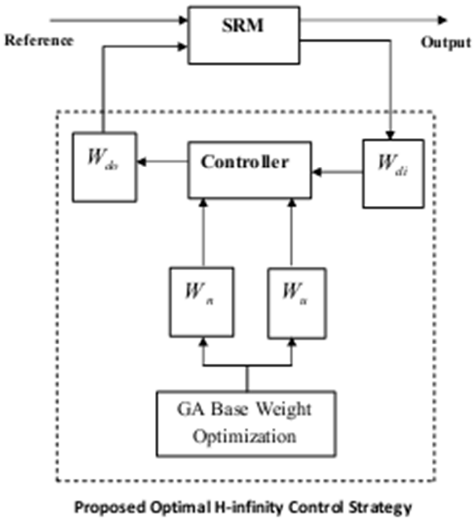

Figure 3: Structure Of GA Based H-Infinity Control.

In figure 4, the weight function are weight uncertainty, weight noise, input weight and output weight are denoted as Wu, W_n, W_{di} and W_{do} respectively. These four parameters are optimized by using GA, improving H- infinity control performance and reducing speed control complexity of SRM. The proposed GA performed by initialization, fitness evaluation, crossover, mutation and termination.

Control parameter using GA: The control parameters are every incremental change (W_n) weight noise error process is initialed at (Wu), W_n $= \leq 0$ the step by step procedure solution the control parameters using GA are:

Step 1: Initialize the population pool of (N_w) number of weight and fill the chromosomes W_k = $(X_1^1, X_2^2, X_3^3 --------- X_n^n)$. Here, $(X_1^1, X_2^2, X_3^3 --------- X_n^n)$ are the chromosomes which are selected by the number of weights considered in H-infinity control. The ranges of chromosomes are randomly selected that is given as following them.

$(W_{u(1)}{}^{\min}, W_{u(1)}{}^{\max})$, $(W_{n(2)}{}^{\min}, W_{n(2)}{}^{\max})$, $(W_{di(3)}{}^{\min}, W_{di(3)}^{\max})$, $(W_{do(4)}^{\min}, W_{do(4)}^{\max})$

Step 2: In this step, the fitness function is evaluated. Here, the fitness function is based on the optimal speed of the SRM. The fitness function is evaluated by the following formula.

$$Fitness\ Function = \omega_{set} - (W_k + \omega_{actual})$$

where, W_k is the combination of W_u, W_n, W_{di} and W_{do} and ω_{set}, ω_{actual} are the set and actual speed of SRM.

Step 3: The crossover genetic operation is performed in the step. In the crossover operation, the genes are exchanged between two parent's chromosomes. The crossover operation is performed based on the crossover points. Then, the crossover rate is determined by following them.

Formula for calculating crossover rate is described as follow.

$$CrossoverRate = \frac{Numberof\ GeneCrossovered}{ChromosomeLength}$$

Step 4: Mutation perform over the W_k^{NEW} at a mutation rate of M_r and obtain a new chromosomes then the selected genes are replaced by new genes value by arbitrarily generating then in the corresponding limited genes values . Neglect the population pool chromosomes and fill it up with the mating pool chromosomes and the new chromosomes W_k^{NEW}.

Step 5: Iteratively repeat the process from step 2 until a maximum number of iterations gets reached, say W_k^{MAX}.

Step 6: Once the iteration process get completed a best chromosome for the population from the selected chromosomes and its fitness value and the power flow is determined from the control

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parameters. Then using the step 1 once again every incremental change are weight function. $0 \le W_k \le N_w$. So that step process start again from $N_w = W_k + \Delta W_k$. The determined the weight noises setting for every time instant that are called as optimal weights. The weight noise setting can be achieved by H-infinity optimal control using GA Approach. Then, using achieved optimal H-infinity control, the SRM speed is maintained in different speed varied conditions.

4. RESULTS AND DISCUSSION

The proposed H-infinity robust controller based SRM rotor position speed control technique was simulated in MATLAB working platform. 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 Speed Controlled by Genetic Algorithm Based on Optimal H-infinity Control. After that, the torque, flux, and transfer function of the SR motor are described. The Simulink model of the proposed control system figure 4.

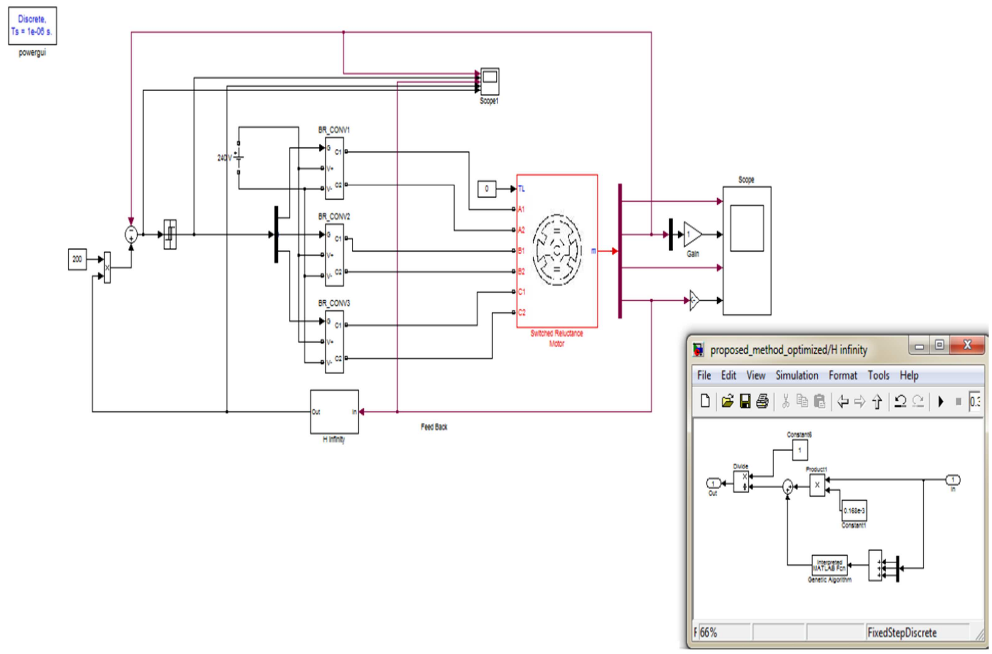

Figure 4: Simulink Model Offered Of Proposed Control System.

4.1. Simulink Model Description:

The proposed control system contains a current-controlled 60-kW 6/4 SRM drive. The SRM is fed by a three-phase asymmetrical power converter having three legs, each of which consists of two IGBTs and two free-wheeling diodes. Here, DC supply voltage of 240 V is used. The converter turn-on and turn-off angles are kept constant at 45 deg and 75 deg, respectively, over the speed ranges. The reference current is 200 A and the hysteresis band is chosen as 10 A. The desired speed of the SRM is settled as above 3000 rpm. Then, the SRM transfer function model is derived in terms of resistance and inductance.

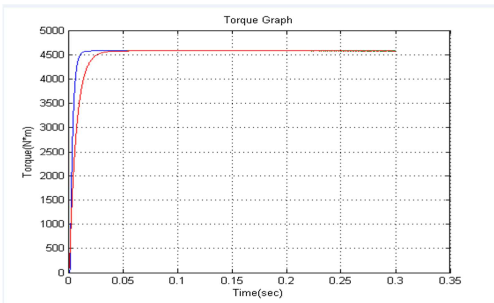

Figure 5: Performance Of SRM Torque

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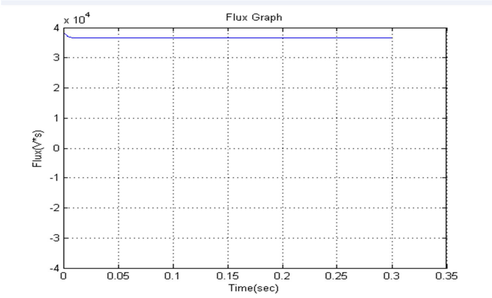

Figure 6: Performance Of Rotor Flux.

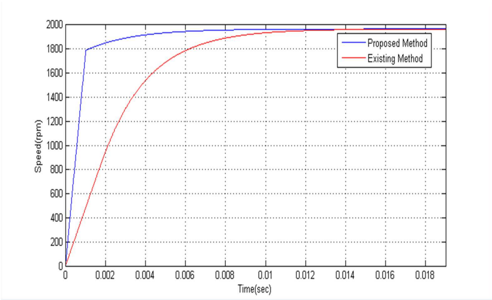

Figure 7: Performance Of SRM Transfer Function Model.

From the above derived model torque and Flux characteristics are obtained. The obtained characteristics are illustrated below. The rotor angular speed of SRM, torque, flux, and transfer function model are described in Fig.5, 6, and 7 respectively. Then, the rotor speed characteristics of the proposed controller are compared with the PI controller and fuzzy controller. The speed of SRM without using the speed controller is illustrated. Then, the performance of the proposed H-infinity controller is described. The comparison performance of proposed controller and without speed controller is illustrated in Fig.8. The comparison performance of Proposed Controller and PI controller is illustrated in Fig.9. The comparison performance of fuzzy logic control and proposed controller is shown in Fig.10. Then, the comparison performance of H-infinity controller and fuzzy controller is shown Fig.11.

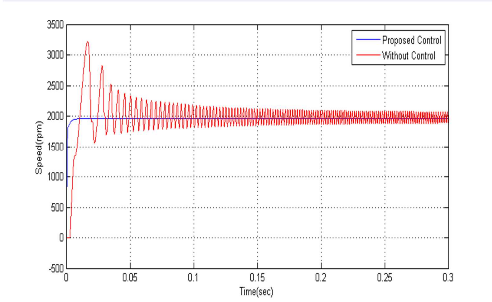

Figure 8: Performance Of Proposed Control Without Speed Controller.

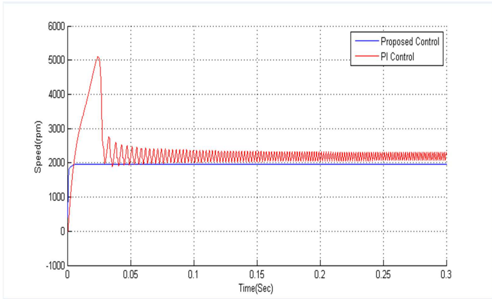

Figure 9: Rotor Speed Comparison Of Proposed Control And PI Control.

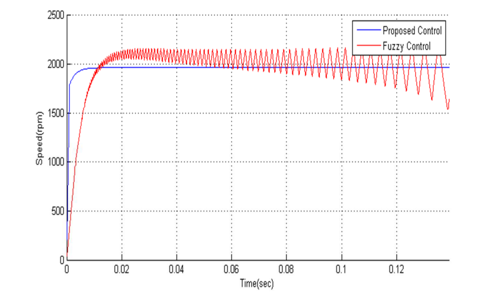

Figure 10: Rotor Speed Of Fuzzy Control And Proposed Control.

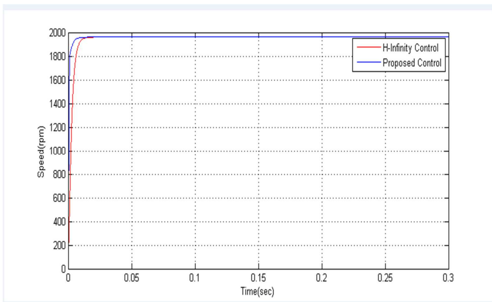

Figure 11: Rotor Speed Comparison Of H-Infinity Control And Proposed Control.

Then, from the speed comparison performance, the rotor speed control performance accuracy and controlling time are analyzed. In Fig.8, the rotor speed of SRM is smoothly controlled by H-infinity

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controller. But, the rotor speed of SRM is oscillated when the speed is controlled without using any control technique. In Fig.9, the proposed controller has smoothly controlled the rotor speed, but it is inefficient in achieving the desired rotor speed. So, the performance of the SRM would be affected. In Fig.10, the PI and fuzzy controller technique has taken more time for achieving desired rotor speed. Among the control techniques, the proposed H-infinity control technique has controlled the rotor speed robustly and the control action response is quick. The speed control action time performance of the H-infinity control and proposed controller.

5. CONCLUSION

In this paper, the rotor speed of SRM motor was controlled by a robust H-infinity control technique. The proposed control technique was simulated and the output drawn was studied. Then, the output performance was compared with the conservative speed control technique. From the comparison results, it was found that the proposed control technique was added functional and accurate for controlling the speed of SRM motor. The existing control techniques used for comparison were H-infinity Controller fuzzy controller, and without using any control technique. Controlling the speed of rotor without using any controller was more difficult and more time consuming for achieving the stable speed. However, the speed of SRM controlled by H-infinity Controller in Genetic Algorithm was better than H-infinity using fuzzy logic controller, but here the stability and accuracy were affected. Moreover, the speed controlled efficiency of the H-infinity controller using genetic algorithm was high and steady than the H-infinity with fuzzy logic, PI and fuzzy based controller. Overall, the proposed H-infinity control technique using GA has achieved a remarkable level in controlling the rotor speed and smoothness of SRM motor.

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