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Sensor less Control of 8/6 SRM Drive Via Hybrid Observer Using Fuzzy Logic

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ABSTRACT

This paper present the modeling, analysis of 8/6 SRM using Fuzzy logic with Hybrid observer algorithm. In this algorithm the estimation of rotor position speed and error of speed is measured respectively. This algorithm has been simulated with MATLAB / Simulink for non-linear model of 8/6 SRM and has been designed with Hybrid observer using Current Sliding Mode Observer and Flux Linkage Mode Observer. The result has been compared with difference range of speed is discussed. The Hybrid Observer has the advantages of robustness, high precision and high accuracy, drive performance has been improved. Switched Reluctance Motor are used in applications such as electric vehicles, washers, dryers and aerospace applications as the machines is brushless, maintenance free and has rugged and simple construction.

Keywords: Switched Reluctance Motor (SRM), Current, flux linkages, Hybrid Observer(HO), Fuzzy logic, PID.

1. INTRODUCTION

The electrical drives are very important part of an industry. The requirement of drives depends upon the available mains and load characteristics. Because of its simple and robust structure, high torque to inertia ratio, high thermal capability and high speed potential, reliability, brushless variable speed drive using SRM has become popular relative to other drives and represents an economical alternative to PM brushless motors in many applications [1]. However, the SRM suffers from noticeable torque ripple and acoustic noises that prevent its use in high performance drives. Its main drawback is torque ripple. Brushless variable speed drive using SRM have become popular relative to other drives and represents an economical alternative to PM brushless motors in many applications. In last few years the SRM have gain increasing attention since they offer the possibility of electric drives which are mechanically and electrically more rugged than those build up around the conventional AC and DC motors. In case of SRM drive, the technical superiority of the AC drive is obtained or even superior at a very low cost. This is possible due to the simple motor construction and the requirement of a simple uni-polar power modulator for controlling the speed. In order to get performance oriented Drive, The accurate modelling of a Motor is to be done. The performance of machine can be checked with the help of MATLAB / Simulink [2].

2. SRM OVERVIEW

In Switched Reluctance Motor the torque is developed because of the tendency of the magnetic circuit to adopt the conFigureuration of minimum reluctance i.e. the rotor moves in line with the stator pole thus maximizing the inductance of the excited coil.

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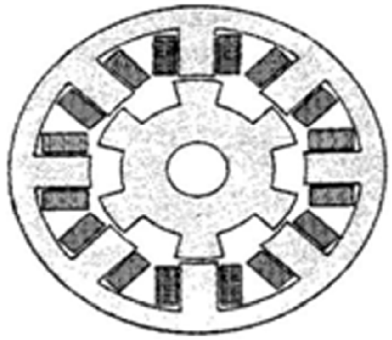


Figure 1: Typical 8/6 Switched reluctance motor (SRM)

The magnetic behavior of SRM is highly nonlinear. But by assuming an idealistic linear magnetic model, the behavior pattern of the SRM can be adjusted with ease of without serious loss of veracity from the actual behavior pattern. The construction of 8/6 (8 Stator poles, 6 Rotor poles) poles SRM is shown in Figure.1. Usually the number of stator and rotor poles is even. The windings of Switched Reluctance Motor are simpler than those of other types of motor. There is winding only on stator poles, simply wound on it and no winding on rotor poles.

The winding of opposite poles is connected in series or in parallel forming no of phases exactly half of the number of stator poles. Therefore, excitation of single phase excites two stator poles. The rotor has simple laminated salient pole structure without winding. This is the advantage of this motor as it reduces copper loss in rotor winding. The stampings are made preferably of silicon steel, especially in higher efficiency applications.

3. PROPOSED BLOCK DIAGRAM OF 8/6 SRM USING HO

3.1. Current Sliding Mode Observer (CSMO)

A Nonlinear model of motor is simulated with the same the measured voltage as inputs, the phase currents are estimated the difference between the actual phase currents and the estimate currents are used by the CSMO to estimate rotor speed and position as shown in Figure.2. It is clear from that the rate of change of the current to the time or the position basically depends on the dc link voltage and the motor speed. These indicate the current can be more easily controlled in order to achieve the torque ripple minimization.

3.2. Flux Linkage Sliding Mode Observer (FSMO)

The FSMO system is driven by the discrepancy between the actual flux linkage and flux linkage estimator outputs. This provides a continuous information of position and speed will be derived [3], based on the two measured quantities (voltage and current) as mentioned as the given Figure.3.

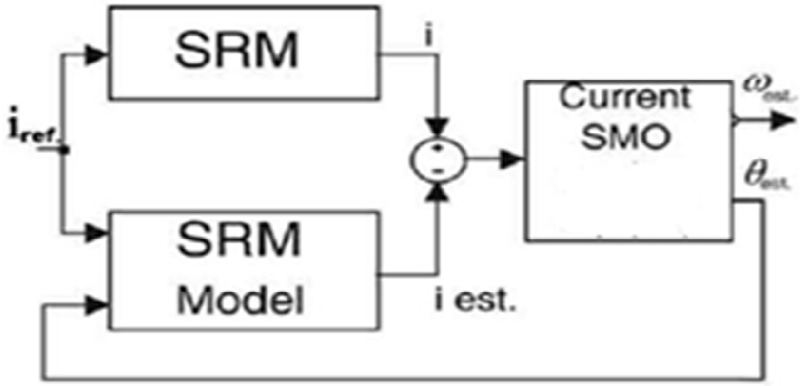


Figure 2: Block diagram of CSMO

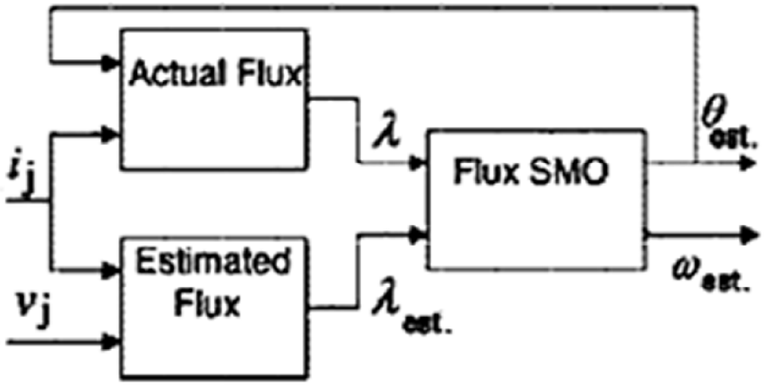


Figure 3: Block diagram of FSMO

3.3. Hybrid Observer (HO)

In CSMO and the FSMO observers need current and voltage sensors for estimate of rotor position and speed. This similarity is important reason to combine of CSMO and FSMO. In this HO, estimate the rotor position and speed of SRM with CSMO and FSMO for wide speed range. The block diagram shows the derived value of position and speed with proposed hybrid observer shown in Figure 4.

Each of the CSMO and the FSMO observers need current and voltage sensors for estimate of rotor position and speed. The block diagram of the HO is shown in Figure 5.

4. FUZZY LOGIC CONTROLLER

A FLC consists of the fuzzification process, the knowledge base and the defuzzification process [3]. The speed error (*E*) and the change of the speed error (*e*) are the input variables and is the output variable (*u*) of FLC. Figure 6 shows the membership functions of *E*, *e* and *u*.

Each membership function has seven fuzzy sets that are Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM) and Positive Big (PB). The rule bases for the proposed FLC are formed by experience gained during simulation on SRMs in open loop operation [4]. Table 1 shows the linguistic rule bases for the proposed FLC.

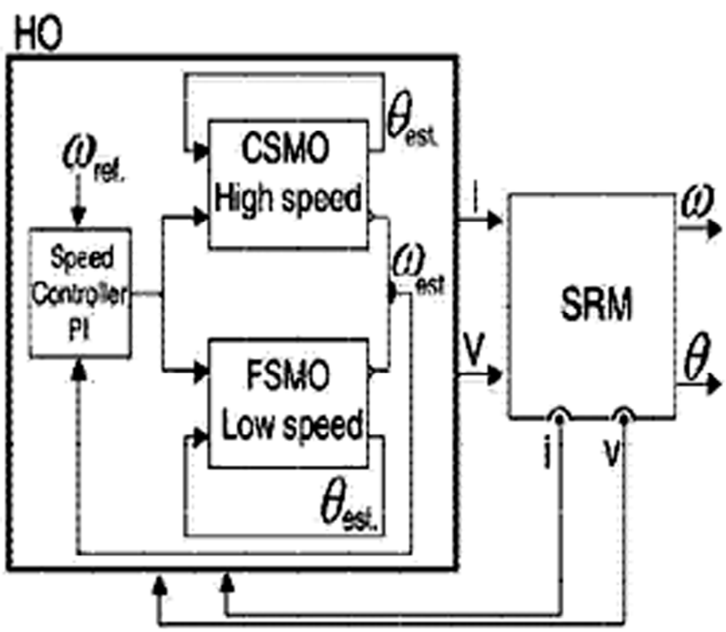


Figure 4: Block diagram of Hybrid observer (HO)

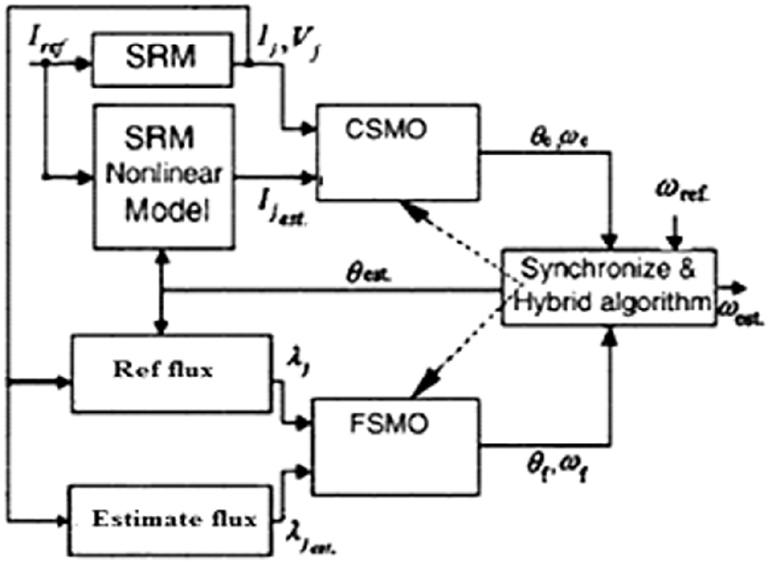
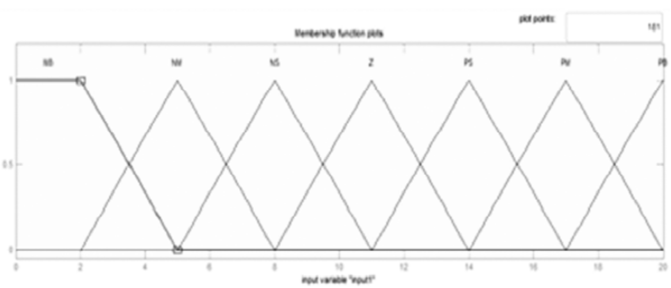
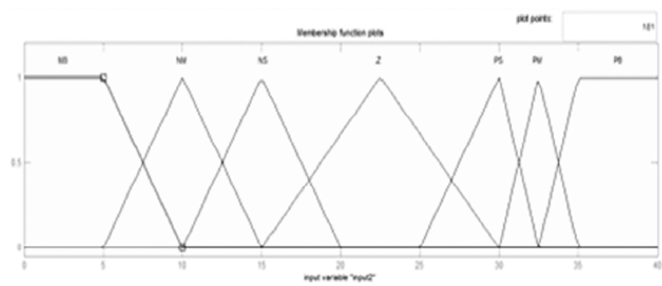


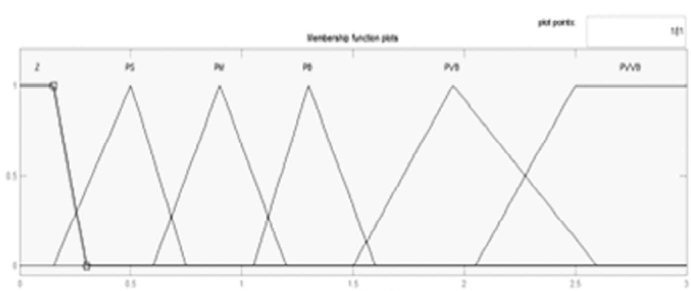
Figure 5: Block diagram for estimate the speed and position of HO



(a) Input variable "E"



(b) Input variable "e"



(c) Output variable "u"

Figure 6: Member functions variables

Table 1
Rules bases for FLC

e\E	NB	NM	NS	Z	PS	PM	PB
NB	PVVB	PVVB	PVVB	PVVB	PVB	PB	PM
NM	PVVB	PVVB	PVVB	PB	PB	PS	PS
NS	PVB	PVB	PB	PM	PM	PS	PS
Z	PM	PS	PS	Z	Z	Z	Z
PS	PB	PB	PM	PM	PM	PS	PS
PM	PVB	PVB	PB	PB	PB	PM	PM
PB	PVVB	PVVB	PVVB	PVVB	PVB	PB	PB

Figure 6 & 7 show member ship function variables and surface viewer of SRM with proposed model of FLC for 1000 rpm.

From this Figures, the proposed controller has small speed error and speed estimation error. Significant reduction in speed ripple decreases noise of SRM.

5. MODELING OF 8/6 SRM USING CSMO, FSMO AND HO

5.1. SRM Converter

The simulation model for SRM drive system and the subsystem of the hybrid observer algorithm as shown in Figure 8.

5.2. Current Sliding Mode Observer (CSMO)

According to the system differential equation the nonlinear model of SRM is derived using CSMO and show the modeled in Figure 9 and subsystem of CSMO as shown in Figure 10. The equation of CSMO for rotor position [5] and speed can be defined as follows [6],

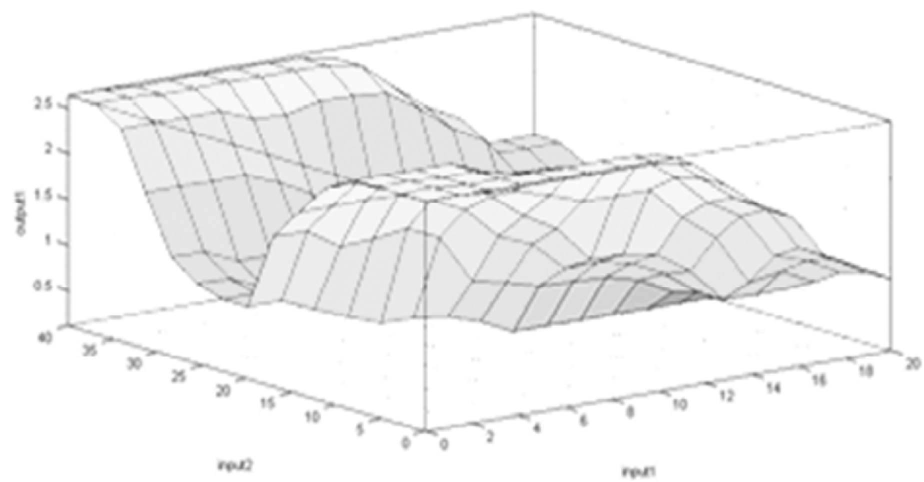


Figure 7: Surface viewer

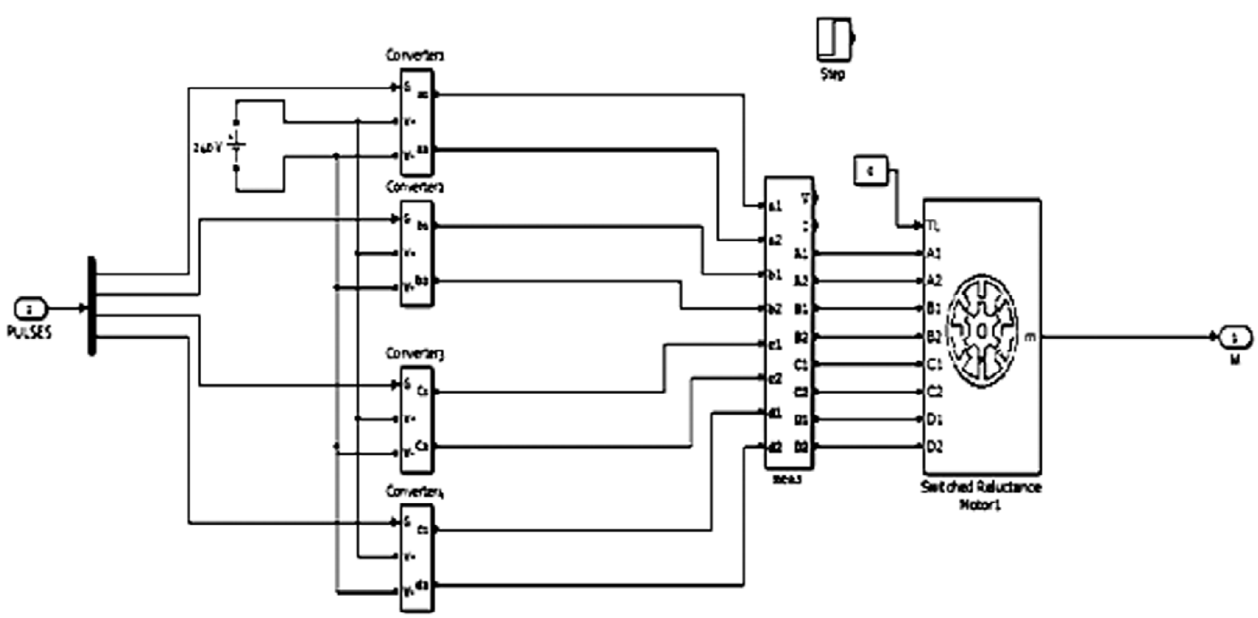


Figure 8: Simulation model of 8/6 SRM converter

$$S(t) = i_j - i_{jest.} \tag{1}$$

Differential equations of CSMO are:

$$\theta_{est\,.=}\,\omega_{est.} + \alpha_{\theta C\,.}\,S_{cont.} \tag{2}$$

$$\omega_{est.} = T_{est.} + \alpha_{\omega C}.S_{cont.} \tag{3}$$

The estimation error is defined as follows,

$$e_\theta = \theta_{est.} - \theta,\ {}_{e\omega} = \omega_{est.} - \omega \tag{4}$$

The corrected gains of CSMO $\theta_{est.C}(k)$ as follows,

$$e_{\omega c}(k) = \omega_{est.}(k) - \omega_{est.C}(k-1) \tag{5}$$

By appropriately choosing the two CSMO gains $\alpha_{\theta C}, \alpha_{\ \omega C}$ can make,

$$\alpha_{\theta c} = \alpha\theta c - \varepsilon_{\theta c} \tag{6}$$

$$\alpha_{\omega c} = \alpha_{\omega c} - \varepsilon_{\theta c} \tag{7}$$

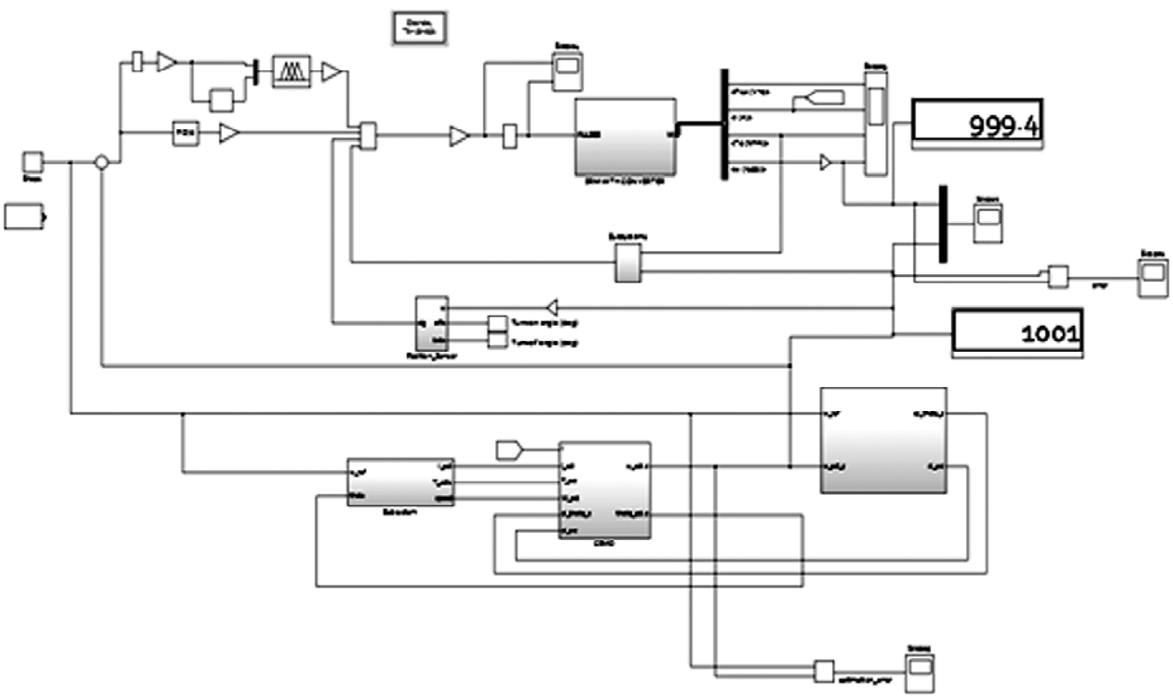


Figure 9: Modeling of CSMO

5.3. Flux Linkage Sliding Mode Observer (FSMO)

For the flux-linkage estimator, the estimated feedback value of the flux-linkage controller can be obtained by integrating using the directly measured phase voltage and current. The zero initial value of phase current guarantees that the integral operation is reset every cycle, thus preventing the accumulation of errors [6].

$$\lambda_{jest.}(t) = ({}^{V}{}_{j}(\tau) - i_j(\tau).r_j)d\tau \tag{8}$$

where v_j, i_j and r_j are the voltage, current and resistance of j^{th} phase. A reasonably accurate but simplified flux linkage model is used to obtain the phase flux linkage and is given as follows,

The differential equations of FSMO are

$$\theta_{est.} = \omega_{est.\,+}\,\alpha_{\theta F}\,\mathrm{sgn}(e_\lambda) \tag{9}$$

$$v\omega_{est.\,=}\,\alpha_{\theta F}\,\mathrm{sgn}(e_\lambda) \tag{10}$$

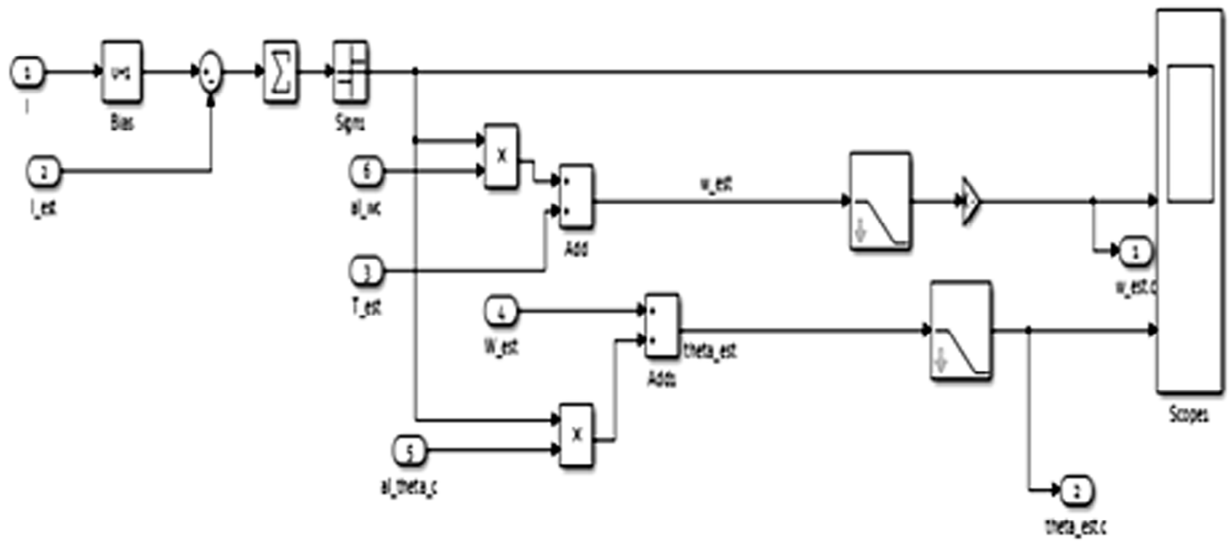


Figure 10: Subsystem for CSMO

The corrected gains of FSMO $\theta_{est.F}(k)$ as follows,

$$e_{\omega c}(k) = \omega_{est.}(k) - \omega_{est.}F(k-1) \tag{11}$$

By appropriately choosing the two FSMO gains $\alpha_{\theta F}, \alpha_{\omega F}$ can make,

$$\alpha_{\theta F} = \alpha_{\theta F} - \varepsilon_{\theta F} \tag{12}$$

$$\alpha_{\omega F} = \alpha_{\omega F} - \varepsilon_{\theta F} \tag{13}$$

For the flux-linkage estimator, the estimated feedback value of the flux-linkage controller can be obtained by integrating using the directly measured phase voltage and current. The zero initial value of phase current guarantees that the integral operation is reset every cycle, thus preventing the accumulation of errors. The following simulation model and subsystem of FSMO is shown in Figure 11 & 12 respectively.

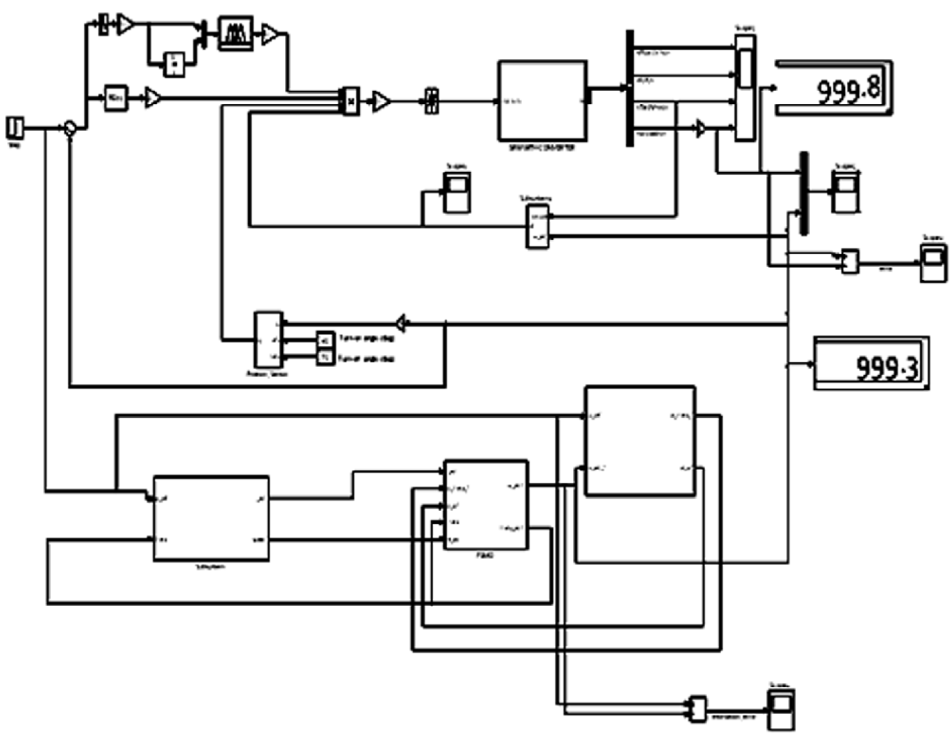


Figure 11: Modeling of FSMO

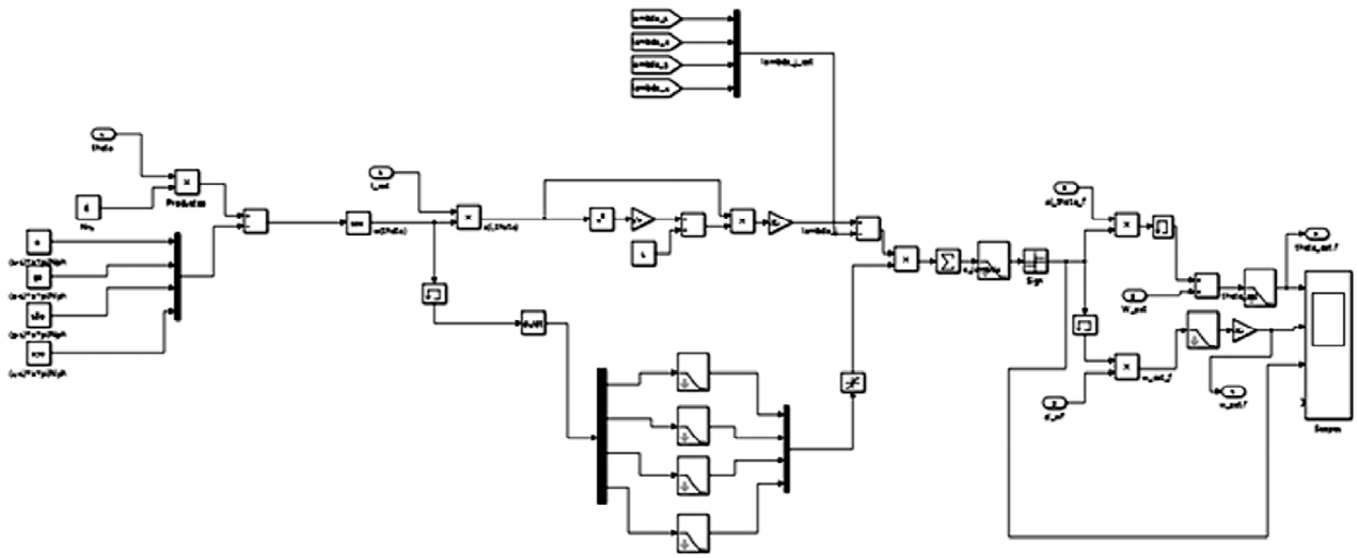


Figure 12: Subsystem for FSMO

5.4. Hybrid Observer (HO)

It has the advantage of automatically switching from CSMO to FSMO only after real time synchronizing position and speed data between CSMO and FSMO. This algorithm has the advantage of automatically switching from CSMO and FSMO only after the real time synchronizing of position and speed data between CSMO and FSMO. The following model of HO as shown in Figure 13 and subsystem also shown in Figure 13.

The hybrid observer selection and synchronous unit of HO as the combination of Current Sliding Mode Observer and Flux Linkage Sliding Mode Observer as follows,

$$e_{\text{est.}}(k) = e_{\omega C}(k) - e_{\omega F}(k) \tag{14}$$

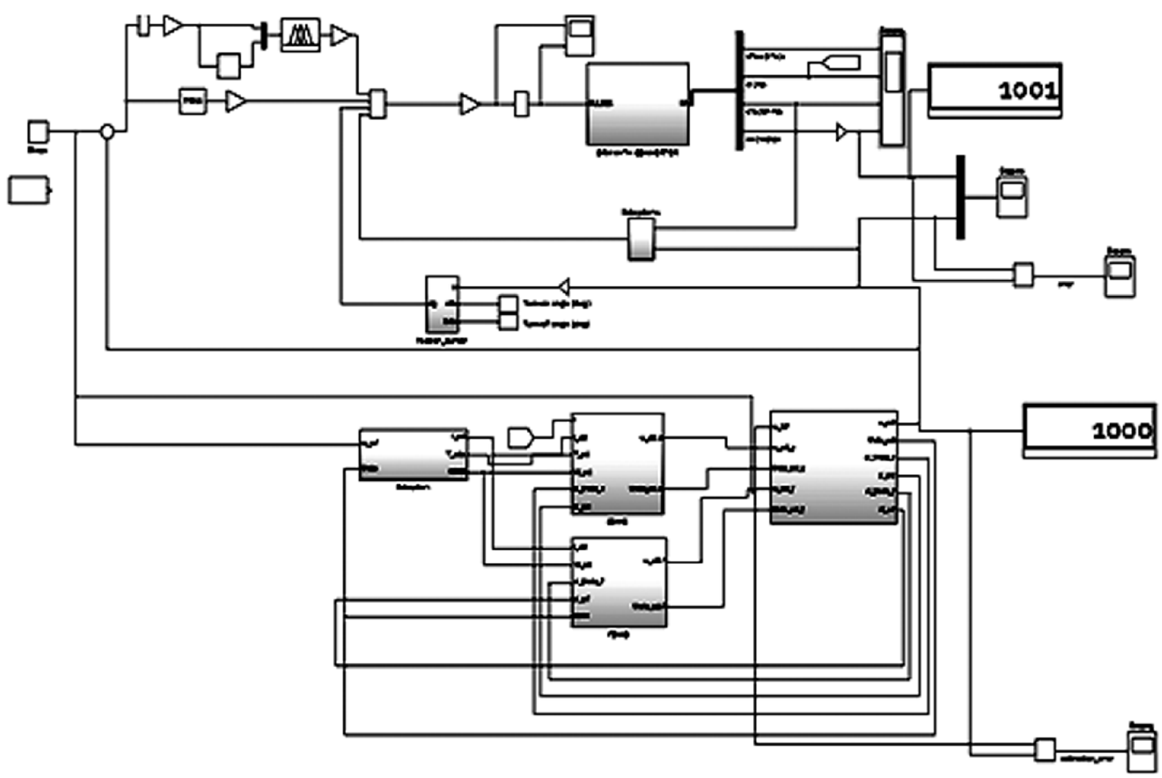


Figure 13: Modelling of HO

6. SIMULATION RESULTS

The above observer are simulated by MATLAB/SIMULINK, where the parameters of SRM are $\omega = 1000rpm$, the number of rotor teeth $N_r = 6$, the number of stator teeth $N_s = 8$, the number of phases $N_{ph} = 3$. In this simulation, turn-o/turn-off angles have been selected for minimizing the torque ripple and optimizing the speed estimation.

6.1. Current Sliding Mode Observer

Figure 14 illustrate the CSMO simulation results for ω = 1000rpm. These results showed the flux, current, Torque, Speed, speed estimation error and position estimation error [7].

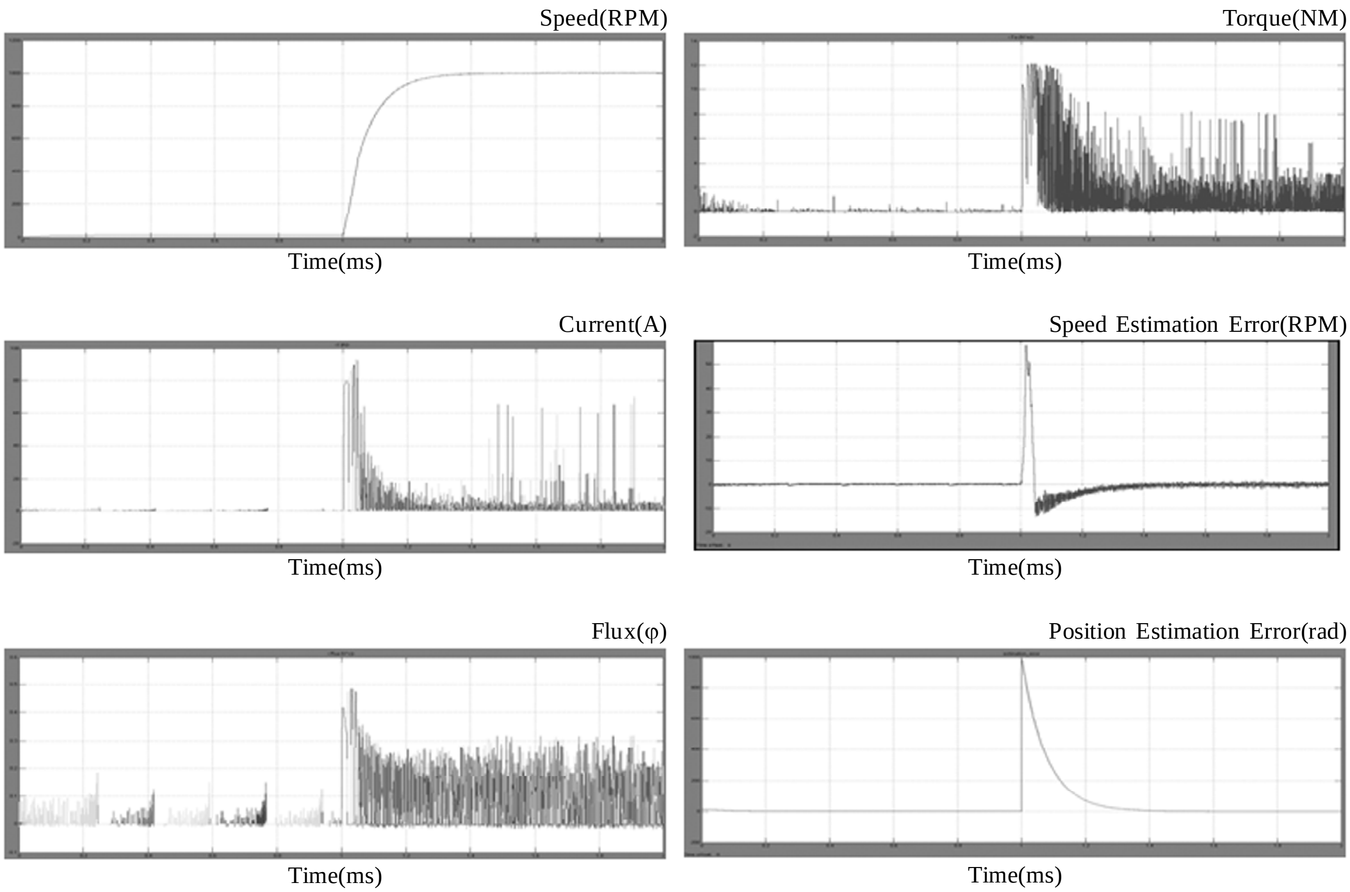
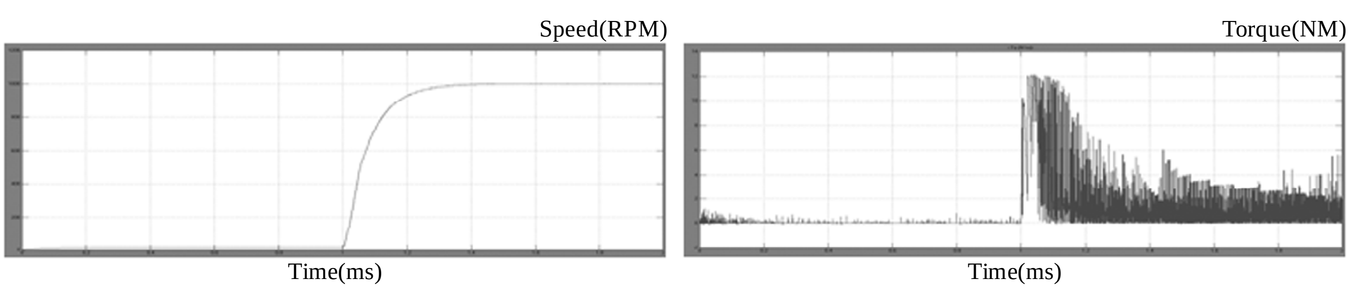


Figure 14: Simulation results at 1000 RPM

6.2. Flux Linkage Sliding Mode Observer (FSMO)

Also, Figure.15 show the FSMO simulation results ω = 1000 rpm. These results demonstrate that the FSMO for the flux, current, torque, speed, speed estimate error and position estimation error[7].



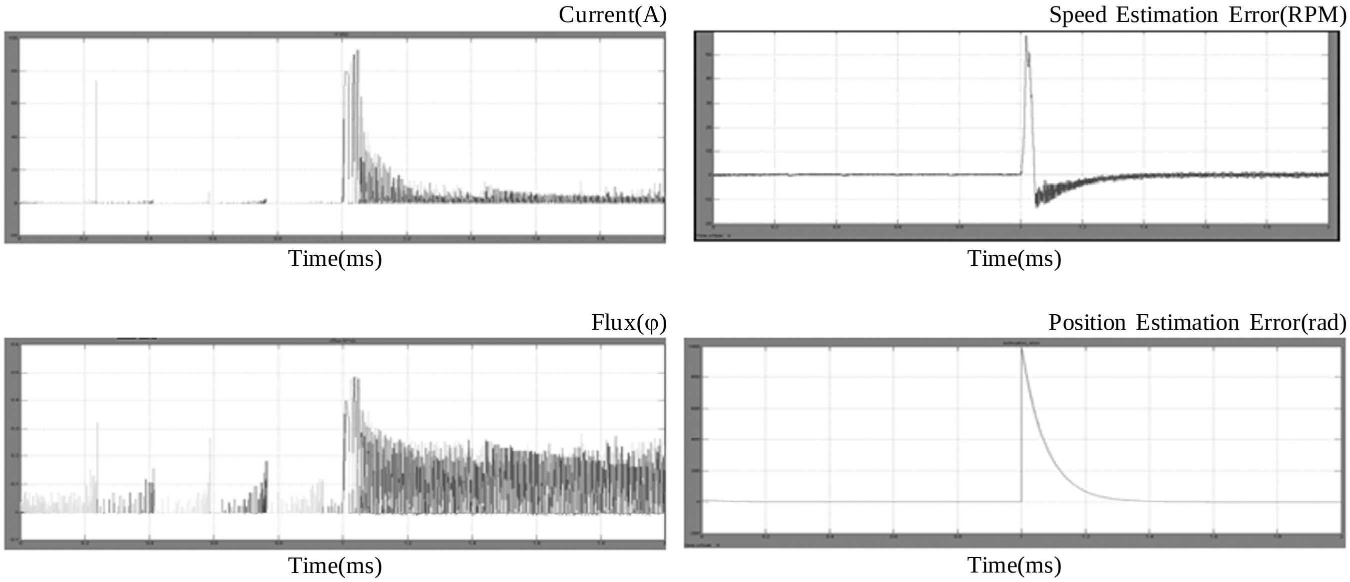


Figure 15: Simulation results of FSMO at 1000rpm

6.3. Hybrid Observer (HO)

Finally, It is mentioned as the modeling of HO to the combination of CSMO and FSMO. This observer, the flux, current, torque, speed, estimates the rotor position and speed for all high and low speeds by CSMO and FSMO[1], and synchronize the outputs. Figure.16 illustrates the HO simulation results for $\omega = 1000$rpm. It is clear that the HO estimation errors are smaller CSMO and FSMO errors and has good performance for wide speed range and load changes [3].

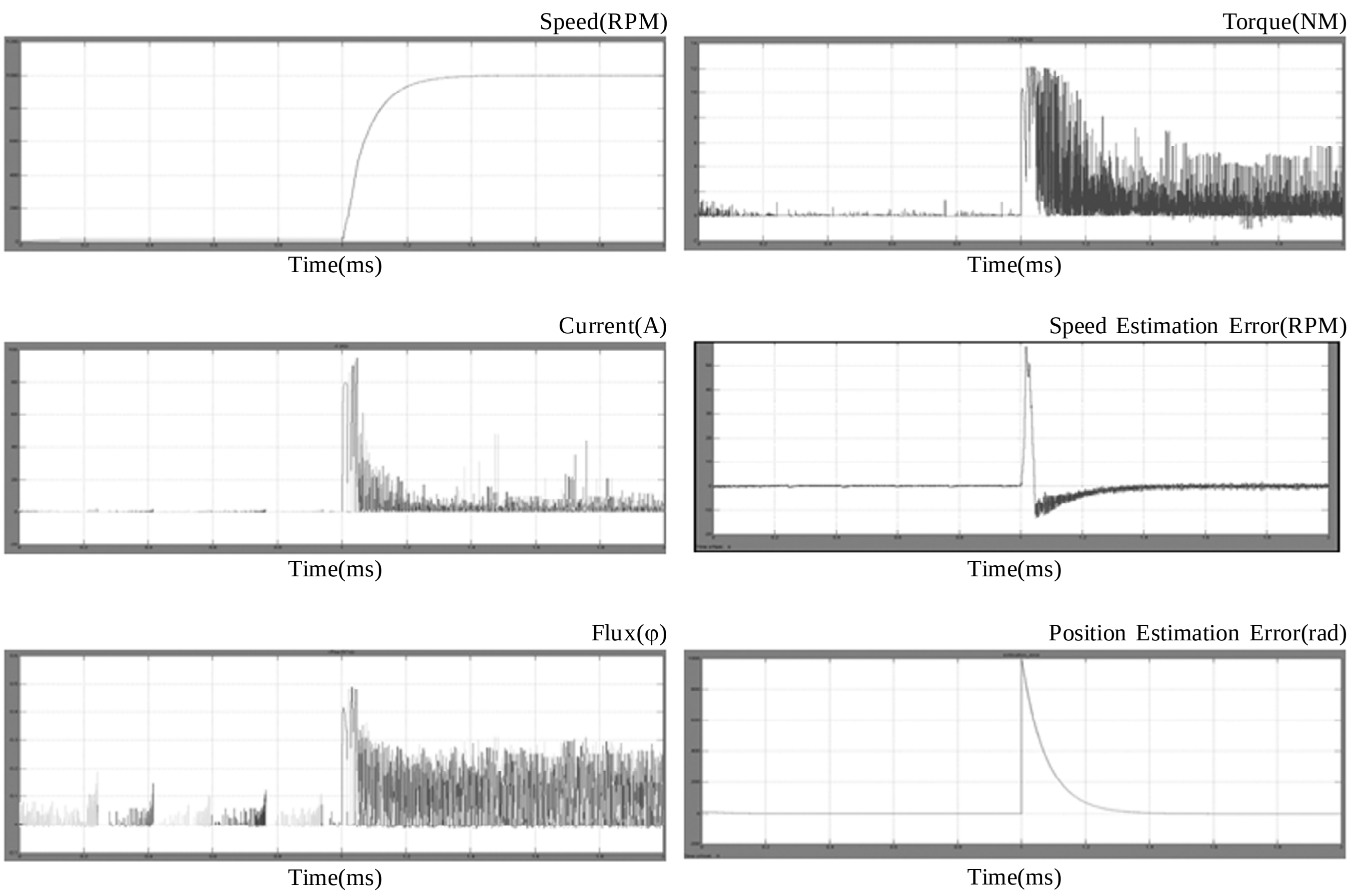


Figure 16: simulation results of HO at 1000 RPM

7. CONCLUSION

In this paper, Hybrid Observer algorithm using fuzzy PID is proposed. It is used only phase currents and voltages that can be easily measured from motor terminals to estimate the rotor position, estimate speed error which makes it reliable operations. For reducing the torque ripple, Fuzzy PID algorithm of turn-on/turn-off angles for power switches has been regulated to get optimum value of rotor position is found out. Simulation results show that Hybrid Observer has good performance for wide range of speed applications.

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