ISSN (Online) 2394-6849

International Journal of Engineering Research in Electronics and Communication Engineering (IJERECE)
Vol 4, Issue 11, November 2017

Speed Control of Permanent Magnet Synchronous Motor by Using Non-Linear SMC with Fuzzy-Logic Control

[1] Dr.K.Sri Kumar
UCEK,Kakinada

Abstract:- **In functional Permanent magnet synchronous motor (PMSM) many uncertainties and disturbances exists which are both external or internal such as un predicted dynamics, changes of parameters and interruptions in loads.The linear PI Controller technique is very tedious for restricting these disturbances. In turn, Sliding mode control (SMC) which is non-linear control method is adopted for improving the control performances and disturbance benefiting technique. A system which dynamically adjusts to the disturbances is being employed by SMC method based on one unique sliding-mode reaching law(SMRL),this will control chattering reduction input while maintaining high tracking performance of controller. Then, for employing higher disturbances and obtaining servo precision, an extended sliding mode disturbance observer (ESMDO) is being proposed for assessing lumped uncertainties directly. A fuzzy sliding mode controller is used for reducing the disturbances during loading. Simulation and experimental results both show the validity of the proposed control approach.**

Keywords: **PMSM-Permanent magnet synchronous motor SMC-Sliding-mode control SMRL-Sliding mode reaching law ESMDO-Extended sliding mode disturbance observer.**

I. INTRODUCTION

These days many industries are employed with AC motors, Squirrel cage inductions are more popular among them due to their compact structure, economical and physical maintenance and other aspects, even these also have some limitations, when the working speed which is lower than the speed of rotating magnetic field and the changing slip which depends on load torque. That is an increase in load torque results decreasing in working. So, these motors are not apt for applications which require precise control of speed and position such as servo systems. Whereas by fluctuating the frequency of rotating magnetic field the synchronous speed of the synchronous motor can be precisely controlled, but the production, and maintenance costs are very high. Many of the industrial applications, where acutely performing drive systems, like CNC machines, submarine propulsion, robotics and automatic production systems in industries etc. are being employed with Permanent magnet synchronous motors (PMSM) these also have high efficiency and while constructing and designing both stator and rotor are considered for obtaining high performing motors . As PMSM's are very compact, have very high torque density. The slip rings for excitation of the field are less used in PMSM which reduces the losses and maintenance of the rotor.

In PMSM the traditional PI control system is being used because of easiness while applying it, but it is tedious to obstruct the interruptions which are produced internally or externally like un-modelled dynamics, parameter variations, friction force, load disturbances etc. while adopting linear control methods in practical PI control algorithm [13].There are many control systems which overcome these interruptions. From those methods SMC method is quite famous due to its undisturbed properties due to internal and external uncertainties which give perfect tracking performance which was successfully applied in many fields. The preciseness of the SMC system can be achieved by selecting large control gains which results in excitation of high frequency dynamics known as chattering phenomenon. To defeat this problem a unique reaching law was proposed for designing the speed and current integration control and a system variable was used in this law. A sliding-mode speed control for PMSM was developed relaying on this reaching law, for disturbance rejection in SMC, extended sliding-mode disturbance observer (ESMDO) is proposed, for compensating the sliding mode speed control the estimated system disturbance is considered as the feed forward compensation. Thus, a mixed control method combining an SMC part and a feed forward compensation part based on

ESMDO, called SMC+ESMDO, which is a composite control method is developed in which the chattering problem is unavoidable and due to this the performance of the system will be degraded if it meets serious uncertainties, in order to enhance the system performance a feed-forward compensation part is introduced into controller rather traditional feed-forward part. Finally, the capabilities of the proposed control approach were verified by simulation results. In real time PMSM applications it is not possible to evaluate the uncertainties. So, evaluation techniques are to be developed, There are many DOB-Disturbance observer based control methods which are applied in many industrial applications like robotic systems, manipulator systems, power converters, and general control systems etc.

II. PERMANENT MAGNET SYNCHRONOUS MOTOR (PMSM).

The PMSM motor which concentrates 0n fundamental frequency component, in which linear magnetic circuits and equal magnetic fields along the rotor axes are assumed with stator windings sinusoidally distributed are considered, due to which no end fringing effects are considered. The PMSM consists of Y-Connected Windings which are 120O apart from each other.

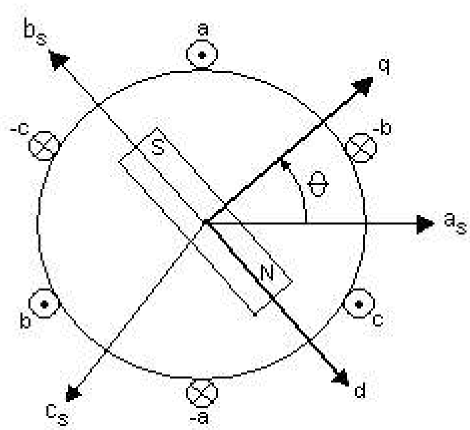

Figure 2.1 PM Motor showing stator windings, Rotor magnet and their magnetic axes.

For reducing the space harmonics and also for approximating the sinusoidal distribution, stator windings are placed with individual coils connected and wound in different slots. The magnetic fields are concentrated at air gaps between the rotor and stator which are made from the materials with lower reluctances when compared with air gaps. So that the magnetic reluctances in stator and rotor may not be selected while all the energy is stored in the air gaps, when air gaps and the radius of the rotors are compared then the fields throughout the gaps are assumed as constants. As the fields choose the low reluctance path they are supposed to be directed radically.

Mechanical Equations:

The placement of rotor depends upon the inductance matrices and the permanent flux linkage of the magnets. For designing the motor completely one needs to include the rotor's mechanical equations.

By utilizing Newton's law

$$J\frac{d\omega_m}{dt} = T_e - T_L$$

Where, J is inertia of rotor and load,
Te is motor torque,
TL is load torque and
ωm = dθm/dt.
Torque is change in energy per angle.
These mechanical equations can be transformed into the rotor reference equations as below:

$$V_q{}^r = (r_s + PL_q)i_q{}^r + \omega_r L_d i_d{}^r + \omega_r \lambda_m$$

$$V_d{}^r = (r_s + PL_d)i_d{}^r - \omega_r L_q i_q{}^r$$

$$V_0{}^r = (r_s + PL_{ls})i_0{}^r$$

$$T_e = \frac{3P}{4}((L_q - L_d)i_q{}^r i_d{}^r + \lambda_m i_q{}^r)$$

$$J\frac{d\omega_r}{dt} = \frac{P}{2}(T_e - T_L)$$

III. SCALAR AND VECTOR CONTROL TO PMSM:

Two different ways can be employed for controlling the PMSM based on the steady states which have valid relationships; they are Scalar and Vector controls. The Scalar Control system consists of Amplitude and Frequency of controlled systems. The vector system consists of control amplitude and position of a controlled space vector. The scalar components are valid in steady states while the vector components are valid in transient conditions also.

Speed controller design for PMSM:

ESO-BASED CONTROLLER FOR PMSM:

There are many disturbances both internally and externally which will spoil the performance of closed loop systems, when they are not designed with corresponding feed-forward compensation control for limiting them, so the estimate of disturbances should be gathered. The ESO which has the ability of disturbance estimation will be taken as state observer, which observes the state of the system and also estimates the lumped disturbances.

The Speed-loop controller which is relayed on ESO is being designed which is shown in fig.3.1.is a generalized PMSM which represents two current loops.

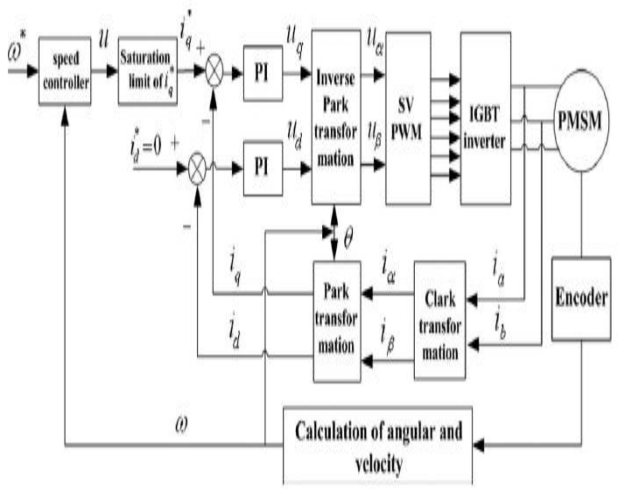

Figure 3.1 Representation of Speed control system of PMSM on vector control.

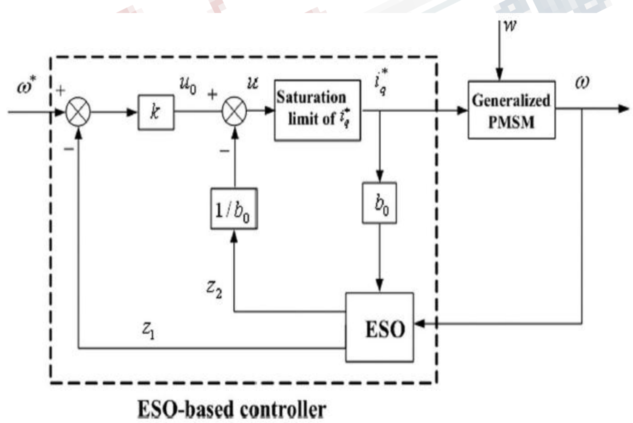

Figure 3.2 Representation of ESO based control system

IV. FUZZY CONTROLLER DESIGN

The Fuzzy control is more effective control system, based on the empirical rules which are easily improved by addition of removal of the existing rules. The conventional methods which are present in the current scenario can be improved by adding new layers of intelligence to the control system. The FLC Consists of FIS (Fuzzy Interface System) Editor which is used to develop simulation of soft switching circuit, where the inputs are VCr and ICr and the output is a crisp value.

Fuzzy inference diagram:

The fuzzy inference diagram shows all the components of fuzzy inference process which is used to formulate mapping from the input to output Membership functions, fuzzy logic operators, and if-then rules describe the process of fuzzy inference. From all the available methods of fuzzy inference, in this paper Mamdani-type (Singleton method) inference method, which is most used method is utilized.

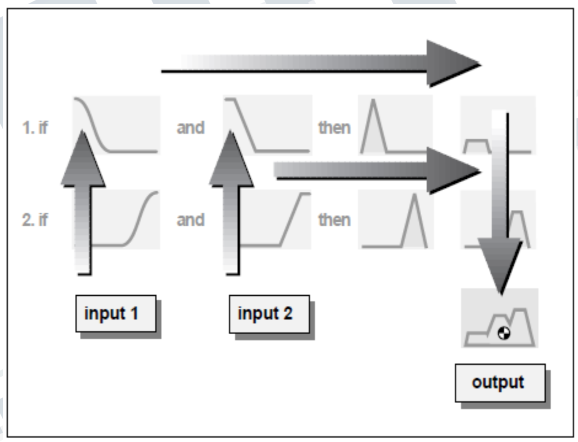

Figure 4.3 Fuzzy Inference Diagram

Fig. 4.1 shows the fuzzy inference diagram which is the base for all fuzzy applications.

V. PROPOSED SMC+ESMDO APPROACH

In this section the simulations of PI and SMC+ESMDO methods made for one PMSM system.

The PI Simulation parameters of current and speed loops is given respectively as proportional gain KPC =10, Kps = 0.5, and for internal gain Kic =2.61, Kis = 20. The parameters of the SMC+ESMDO speed loop are: k = 20, δ = 10, ε = 0.1 and x1 = e.

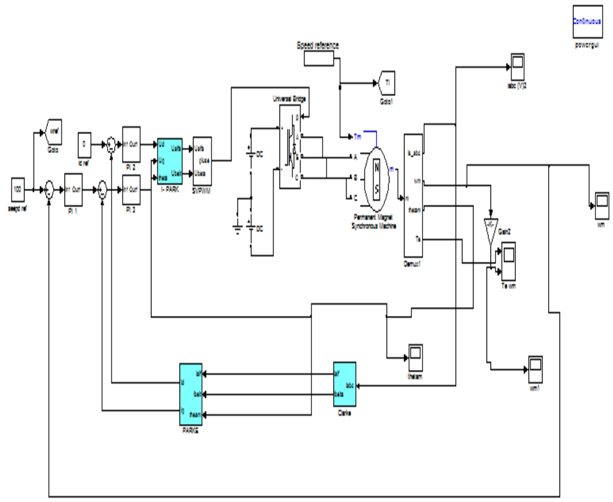

Fig: 5.1. Simulation block of PMSM with PI controller.

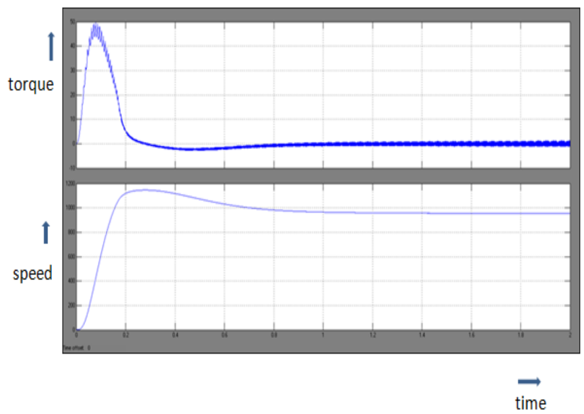

Fig: 5.2. Simulation result with PI controller.

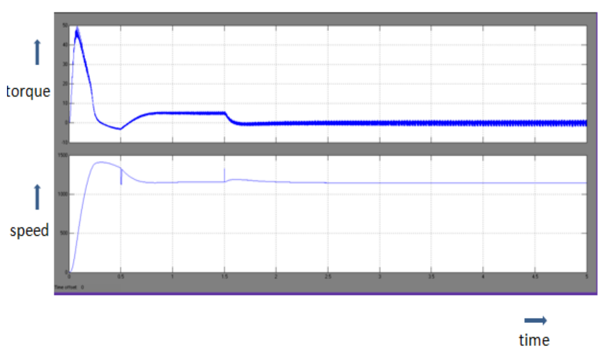

Fig: 5.3. Simulation result with pi controller with change in load.

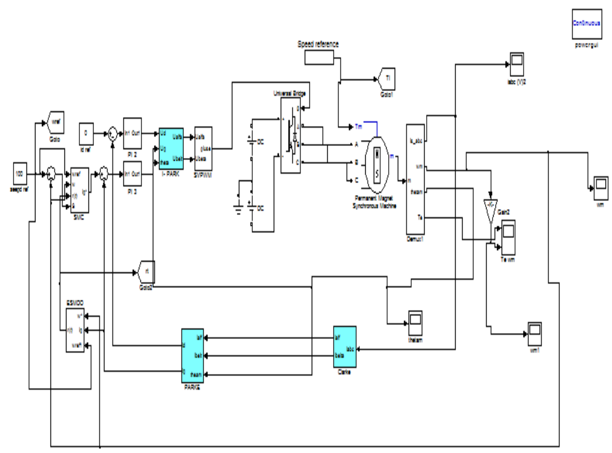

Fig: 5.4. Simulation block of PMSM with SMC controller.

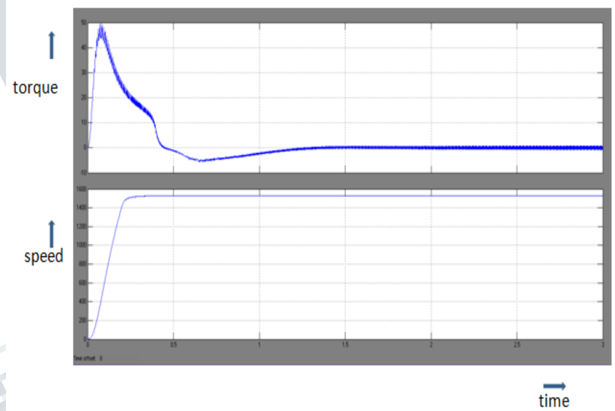

Fig: 5.5. Simulation result with SMC controller.

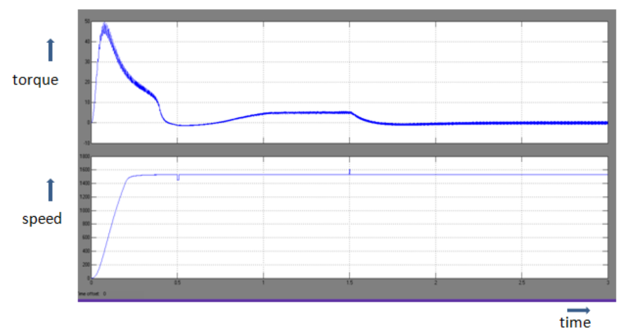

Fig: 5.6. Simulation result with SMC controller with change in load

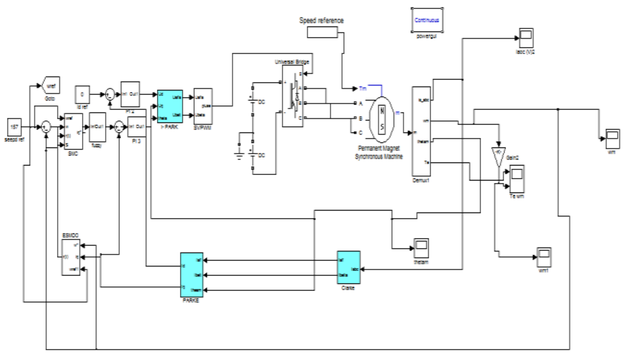

Fig: 5.7. Simulation block of pmsm with SMC FUZZY controller.

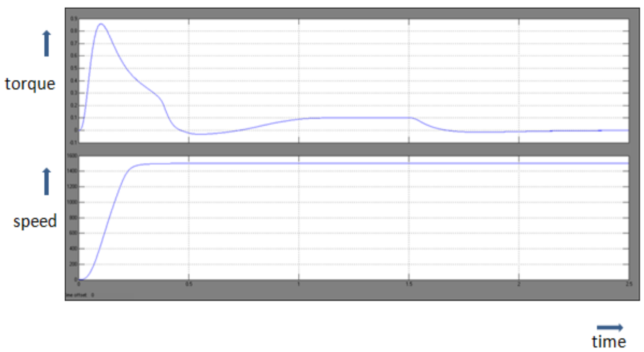

Fig: 5.8. Simulation result with SMC FUZZY controller with change in load.

From the given simulations we can observe that for 1000 r/min reference speed the SMC+ESMDO controller results have shoter setteling times and smaller overshoot when PI is compared with this,the fluctuations of electrical magnetic torque and speed is less for SMC+ESMDO when torque of TL=4N-m is added at t= 0.1s and removed at t=0.2s.

VI. CONCLUSION

This paper proposes a new nonlinear sliding mode control method which has been applied on a permanent magnet synchronous motor, for avoiding the chattering occurrence and also for avoiding the system distiurbances.The system disturbances can be estimated by using the extended sliding mode disturbance observer (ESMDO). A Combined control method is dveloped and implemented using Fuzzy logic, for improving the disturbance rejection ability of the SMC which is termed as SMC+ESMDO.

REFERENCES

[1] Y. X. Su, C. H. Zheng, and B. Y. Duan, “Automatic disturbances rejection controller for precise motion control of permanent-magnet synchronous motors,” IEEE Trans. Ind. Electron., vol. 52, no. 3, pp. 814–823.

[2] X. G. Zhang, K. Zhao, and L. Sun, “A PMSM sliding mode control system based on a novel reaching law,” in Proc. Int. Conf. Electr. Mach. Syst., 2011, pp. 1–5.

[3] W. Gao and J. C. Hung, “Variable structure control of nonlinear systems: A new approach,” IEEE Trans. Ind. Electron., vol. 40, no. 1, pp. 45–55.

[4] G. Feng, Y. F. Liu, and L. P. Huang, “A new robust algorithm to improve the dynamic performance on the speed control of induction motor drive,” IEEE Trans. Power Electron., vol. 19, no. 6, pp. 1614–1627.

[5] Y. A.-R. I. Mohamed, “Design and implementation of a robust current control scheme for a pmsm vector drive with a simple adaptive disturbance observer,” IEEE Trans. Ind. Electron., vol. 54, no. 4, pp.