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A Review on Fuzzy Rule Based Control on PMSM Drive

Asif Ali Bhat[1], **Parveen Saini**[2]
Student, M. Tech - EE, EMGOI, Ambala[1]
Assistant Professor, Dept of EE, EMGOI, Ambala[2]

Abstract: This paper describes review on fuzzy rule based control on permanent magnet synchronous motor. It consists of Fuzzy controller that will provide robustness for motor control. This study aims to select the most robust controller against the stator faults, load torque variation and reversing rotation speed. The effectiveness and validity of the proposed control approach will be verified by simulation results. The test and validation of system with fuzzy controller will be compared by PI controller performance. Simulations will be done in MATLAB/Simulink.

Keywords: PMSM, Load Control, PI controller, Fuzzy Controller etc.

I. INTRODUCTION

From the last three decades AC machine drives are becoming more and more popular, especially Induction Motor Drives (IMD) and Permanent Magnet Synchronous Motor (PMSM), but with some special features, the PMSM drives are ready to meet sophisticated requirements such as fast dynamic response, high power factor, and wide operating speed range like high performance applications, as a result, a gradual gain in the use of PMSM drives will surely be witness in the future market in low and mid power applications.

Permanent magnet synchronous motors (PMSM) have attracted increasing interest in recent years for industrial drive applications. The high efficiency, high steady state torque density and simple controller of the PM motor drives compared to the induction motor drives make them a good alternative in certain applications. Other advantages of the PMSM are low inertia, high efficiency, reliability and low cost of the power electronic converters required for controlling the machine [1] . All these facts make the PMSM an excellent candidate for being used in many applications.
Now in a permanent magnet synchronous machine, the dc field winding of the rotor is replaced by a permanent magnet to produce the air-gap magnetic field. Having the magnets on the rotor, some electrical losses due to field winding of the machine get reduced and the absence of the field losses improves the thermal characteristics of the PM machines hence its efficiency. Also lack of mechanical components such as brushes and slip rings makes the motor lighter, high power to weight ratio which assure a higher efficiency and reliability. With the advantages described above, permanent magnet synchronous generator is an attractive solution for wind turbine applications also. Like always, PM machines also have some disadvantages: at high temperature, the magnet gets demagnetized, difficulties to manufacture and high cost of PM material.

Permanent Magnet (PM) synchronous motors are widely used in low and mid power applications such as computer peripheral equipments, robotics, adjustable speed drives and electric vehicles. The Direct Torque Control (DTC) has become an accepted vector control method beside the current vector control. The DTC was first applied to asynchronous machines, and has later been applied also to synchronous machines. In order to take the full advantage of the DTC, the Permanent Magnet Synchronous Motor PMSM has to be properly dimensioned. Therefore, the effect of the motor parameters is analyzed taking the control principle into account.

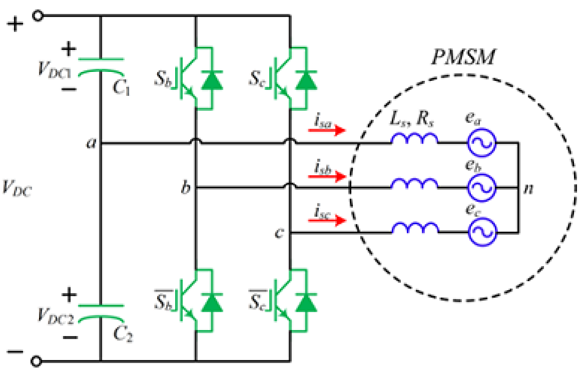

Figure 1: Topology of PMSM Drive

Vector control (or Field Oriented Control) principle makes the analysis and control of Permanent Magnet Synchronous Motor (PMSM) drives system simpler and provides better dynamic response. It is also widely applied in many areas where servo- like high performance plays a secondary role to reliability and energy savings. To achieve the field-oriented control of PMSM, knowledge of the rotor position is required. Usually the rotor position is measured by a shaft encoder, resolver, or hall sensors. In the PMSM, excitation flux is set-up by magnets;

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subsequently no magnetizing current is needed from the supply. This easily enables the application of the flux orientation mechanism by forcing the d-axis component of the stator current vector (id) to be zero.
As a result, the electromagnetic torque will be directly proportional to the q-axis component of the stator current vector (iq), hence better dynamic performance is obtained by controlling the electro-magnetic torque separately. This thesis presents the field oriented vector control scheme for permanent magnet synchronous motor (PMSM) drives, that regulates the speed of the PMSM, is provided by a quadrature axis current command developed by the speed controller. PI controller cab be preferably used for outer speed control loop but because of its fixed proportional gain constant and integral time constant, the behaviour of the PI controllers are affected by parameter variations, load disturbances and speed fluctuation.
The paper is ordered as follows. In section II, it represents related work with proposed system in fuzzy based PMSM System. In Section III, It describes the PMSM system. The problem is defined in section IV. Finally, conclusion is explained in Section V.

II. RELATED WORK

A.Bechkaouiet. al. [1] presented a fault diagnosis method in order to detection the inter-turn short circuit fault in permanent magnet synchronous motor (PMSM) based on the comparative analysis of two types of controllers. This study consists in the sliding mode control (SMC) of the (PMSM) and the two controllers (fuzzy logic controller (FLC) and Adaptive fuzzy logic controller (AFLC) by taking account of the presence of inter-turn short circuit fault. This study aims to select the most robust controller against the stator faults, load torque variation and reversing rotation speed.

Mohamed Kadjoudjet. al. [2] presented that the objective of the model reference adaptive fuzzy control (MRAFC) is to change the rules definition in the direct fuzzy logic controller (FLC) and rule base table according to the comparison between the reference model output signal and system output. The MRAFC is composed by the fuzzy inverse model and a knowledge base modifier. Because of its improved algorithm, the MRAFC has fast learning features and good tracking characteristics even under severe variations of system parameters. The learning mechanism observes the plant outputs and adjusts the rules in a direct fuzzy controller, so that the overall system behaves like a reference model, which characterizes the desired behaviour. In the proposed scheme, the error and error change measured between the motor speed and output of the reference model are applied to the MRAFC.

Suneel K. Kommuriet. al. [3] investigated the problem of automatic speed tracking control of an electric vehicle (EV) which is powered by a permanent magnet synchronous motor (PMSM). A reconfiguration scheme, based on higher order sliding mode (HOSM) observer, is proposed in the event of sensor faults/failures to maintain a good control performance. The corresponding controlled motor output torque drives EV to track the desired vehicle reference speed for providing uninterrupted vehicle safe operation. The effectiveness of the overall sensor fault-tolerant speed tracking control is highlighted when EV is subjected to disturbances like aerodynamic load force and road roughness using high-fidelity software package CarSim.

P. L. Xuet. al. [4] proposed a novel square-wave type carrier signal injection method using zero sequence voltage for sensor-less control of permanent magnet synchronous machine (PMSM) drives. Different from the conventional square-wave type injection methods employed in the stationary reference frame and estimated synchronous reference frame, the proposed square-wave injection is performed on the estimated reference frame, which rotates anticlockwise at twice estimated rotor electrical angular speed. Compared to the conventional square-wave methods with carrier current sensing, theproposed strategy using zero sequence voltage has two main advantages, (a) the amplitude of the resultant carrier response is not related to the injection frequency, and (b) the carrier response does not require differentiation calculation for rotor position estimation.

Zhiyong Zenget. al. [5] presented a three-phase four-switch (TPFS) inverters are generally applied as cost-reduction topologies for permanent magnetic synchronous motor (PMSM) drives because of their reduced number of switching devices. However, undesirable torque ripples are produced by the inverter-fed PMSMs due to the application of non-sinusoidal voltages. Because the torque ripples are strongly influenced by the employed PWM strategy, two commonly used switching sequences in TPFS inverter-fed PMSM drives are fully investigated based on the root mean square (RMS) value of the torque ripples, in which the effects of the different equivalent zero vectors on the torque ripples are presented.

Adeeb Ahmedet. al. [6] presented a Maximum torque per ampere (MTPA) control scheme for buried magnet permanent magnet synchronous motor (PMSM) or internal permanent magnet (IPM) machine. Proposed control scheme was developed based on measurement of only DC link quantities eliminating the necessity of 3-phase current feedback. The scheme employs an online search algorithm with initial condition computed from the a-priory system information. Hybridization of search based algorithm with pre-computed control coefficients ensures robustness against parameter variations while maintaining good dynamic performance.

Ying-Shieh Kunget. al. [7] presented a sensorless speed control IP (Intellectual Property) for PMSM (Permanent Magnet Synchronous Motor) drive. Firstly, the mathematical model of PMSM is derived, and the vector control is built up. Secondly, the rotor flux angle (FA) and rotor speed, which are estimated by using EKF estimator,

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is described. These estimated values are feed-backed to the current loop for vector control and to the speed loop for speed control. In additional, to cope with the uncertainty of system parameter variation, AFC is applied. The parameters of fuzzy rule will be adjusted according to the minimum performance index requirement which is based on the steepest descend method. Thirdly, the Very-High-Speed IC Hardware Description Language (VHDL) is adopted to describe the behaviour of the sensor less speed control IP which includes the current vector controller, EKF, AFC, etc.

III. PERMANENT MAGNETSYNCHRONOUS MOTOR DRIVE SYSTEM

The motor drive consists of four main components, the PM motor, inverter, control unit and the position sensor. The components are connected as shown.

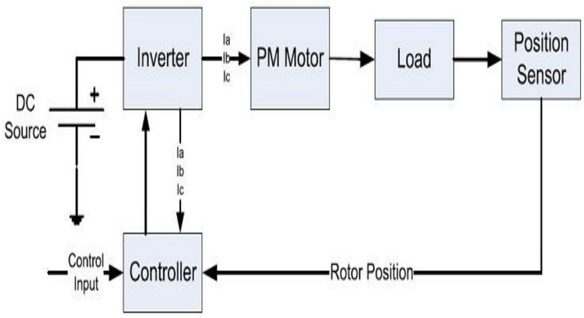

Figure 2: Schematic Block diagram for Drive System

The mathematical model for the vector control of the PMSM can be derived from its dynamic d-q model which can be obtained from well-known model of the induction machine with the equation of damper winding and field current dynamics removed. The synchronously rotating rotor reference frame is chosen so the stator winding quantities are transformed to the synchronously rotating reference frame that is revolving at rotor speed.

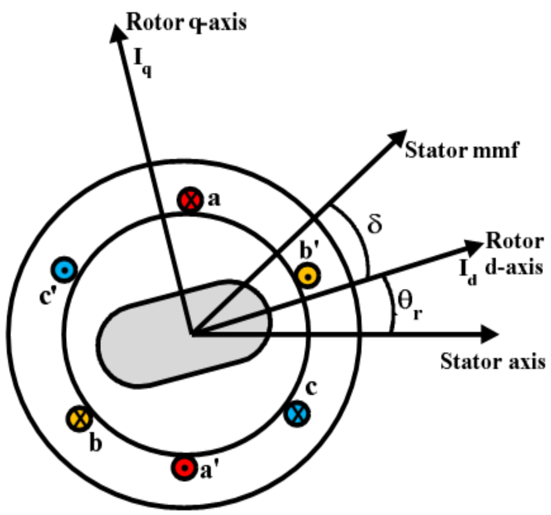

Figure 3: Machine Synchronously Rotating D-Q Reference Frame

The rotor reference frame is chosen because the position of the rotor magnets determine independently of the stator voltages and currents, the instantaneous induced emf and subsequently the stator currents and torque of the machine. When rotor references frame are considered, it means the equivalent q and d axis stator windings are transformed to the reference frames that are revolving at rotor speed. The consequences is that there is zero speed differential between the rotor and stator magnetic fields and the stator q and d axis windings have a fixed phase relationship with the rotor magnet axis which is the d axis in the modelling.

The dynamic d-q modelling is used for the study of motor during transient and steady state. It is done by converting the three phase voltages and currents to dqo variables by using Parks transformation. For analysis purpose equivalent circuits of the motors are used for study and simulation of motors. From the d –q modelling of the motor using the stator voltage equations the equivalent circuit of the motor can be derived.

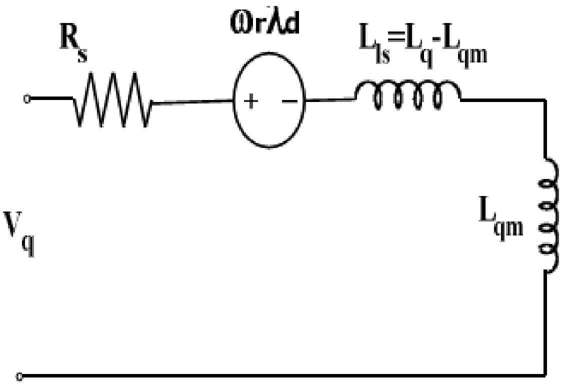

Figure 4: Stator q-axis Equivalent Circuit

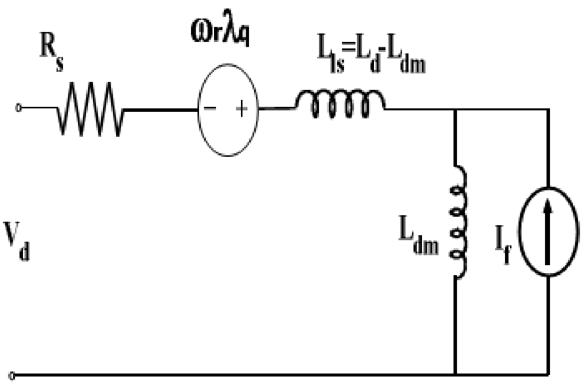

Figure 5: Stator d-axis Equivalent Circuit

The vector control strategy was developed prominently in the1980s to meet the challenges of transient condition analysis and oscillating flux with torque responses in inverter fedinduction and synchronous motor drives during transient as well as steady state condition. The inexplicable dynamic behaviour of large current transients and the resulting failure of inverters was a curse and barrier to the entry of inverter fed ac drives into the market.

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IV. PROBLEM DEFINITION

PMSM drive is largely maintenance free, which ensures the most efficient operation and it can be operated at improved power factor which can help in improving the overall system power factor and eliminating or reducing utility power factor penalties. From the research over PMSM until now it shows that, in future market PMSM drive could become an emerging competitor for the Induction motor drive in servo application and many industrial applications. So now there is a great challenge to improve the performance with accurate speed tracking and smooth torque output minimizing its ripple during transient as well as steady state condition such that it can meet the expectation of future market demand. Modelling and simulation is usually used in designing PM drives compared to building system prototypes because of the cost. Having selected all components, the simulation process can start to calculate steady state and dynamic performance and losses would have been obtained if the drive were actually constructed.

V. CONCLUSION

In this work, it provides a review on fuzzy based PMSM drive for providing smooth response. This paper is mainly emphasized on the study of performance of PMSM drive system using different controllers. The controllers used are mainly Fuzzy controller and PI controller. This study aims to select the most robust controller against the stator faults, load torque variation and reversing rotation speed. The effectiveness and validity of the proposed control approach will be verified by simulation results. The test and validation of system with fuzzy controller will be compared by PI controller performance.

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