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Sensorless model of PMSM based on DTC method with Adaptive System

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Abstract: This paper presents a speed sensorless with direct torque control scheme using Space Vector Modulation (DTC-SVM) for Permanent Magnet Synchronous Motor (PMSM) drive based a Model Reference Adaptive System (MRAS) algorithm. The MRAS is utilized to estimate speed and reduced the torque ripple & improves the accurate output. In other hand the use of SVM method reduces the torque ripple while achieving a good dynamic response. Simulation results are presented and shown the effectiveness of the proposed method.

Keywords: PMSM, DTC-SVM, MRAS, Control technology.

1. INTRODUCTION

In the last years permanent magnet synchronous motor, because of properties such as high efficiency, high torque, high power, small volume and accurate speed control have become more attention and uses in chemical industry, texturing plants, glass industry, transport systems, electrical household appliances, ship engines, robotic automation, and escalators. The control methods used for the permanent magnet synchronous motors are: V/f control, field oriented control and direct torque control [1]. The basic principle of DTC is to directly select stator voltage vectors according to the differences between the reference and actual torque and stator flux linkage. The DTC possesses advantages such as lesser parameter dependence and fast torque response when compared with the torque control via PWM current control [2]. Position sensor with higher quality is a necessary component part of the drive system employed in industrial and automotive applications. But the high cost and strict requirement extremely limit the application in the drive system. So that it is highly desired to develop the position sensor less technology of PMSM. For the mechanical position sensor could be bulky and easy to failure in harsh environments, sensor less technology can increase the reliability of the drive system. Research on sensor less technology has increased in academic and industrial communities over. During recent years, sensor less drives of PMSM have attracted much attention. Many techniques have been proposed in order to estimate the rotor speed and position, such as open-loop estimators using stator voltages and currents, back EMF-based position estimators, MRAS estimators, observe-based position speed and position estimators, high-frequency signal injection and artificial intelligence. This paper adopts the MRAS scheme which uses the PMSM itself as the reference model to estimate the speed of the motor.

2. PERMANENT MAGNET SYNCHRONOUS MOTOR

During the last decade, permanent magnet synchronous motors have been used widely in the industry to replace DC motors and induction machines. The main characteristics of these motors are the low inertia, the high efficiency, power density and reliability. Due these advantages, permanent magnet synchronous motors are ideal for the applications where a quick accurate torque control is required. The Permanent Magnet Synchronous Motor is a rotating electric machine where the stator is a classic three phase coils like that of an induction motor and the permanent magnets are located on the rotor surface. A PMSM provides rotation at a fixed speed in synchronization with the frequency of the power source, regardless of the fluctuation of the load or line voltage. The motor runs at a fixed speed synchronous with mains frequency, at any torque up to the motor's operating limit.

These types of machines are extensively used in servo drives for low power machine tool, e.g. robots, positioning devices etc. They are receiving increased attention by possibility to use in the region of larger power e.g. electricity generation. The following requirements for servo drives must be served:
• high possible power to weight ratio,
• large torque to inertia ratio – high acceleration possible,
• smooth torque in wide speed – small pulsation of speed,
• full torque at zero speed – stand still working,
• high speed operation,
• compact design and small size.

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3. CONTROL OF PERMANENT MAGNET MOTORS

Scalar control is based on relationships which are valid in steady state. Only magnitude, frequency of voltage, current are controlled. This method is employed when several motors are driven in parallel by an inverter.

V/f control is the simplest control schemes. The control is an open loop scheme and does not use any feedback loops. The idea is to keep stator flux constant at rated value so that the rotor develops rated torque/ampere ratio over its entire speed range.

Field Oriented Control: The fundamental weakness of sinusoidal commutation is that it attempts to control motor currents that are time variant in nature. This breaks down as speeds and frequencies go up due to the limited bandwidth of P-I controllers. Field Oriented Control solves this problem by controlling the current space vector directly in the d-q reference frame of the rotor. In the ideal case, the current space vector is fixed in magnitude and direction (quadrature) with respect to the rotor, irrespective of rotation. Because the current space vector in the d-q reference frame is static, the P-I controllers operate on dc, rather than sinusoidal signals. This isolates the controllers from the time variant winding currents and voltages, and therefore eliminates the limitation of controller frequency response and phase shift on motor torque and speed. Using Field Oriented Control, the quality of current control is largely unaffected by speed of rotation of the motor.

Direct Torque Control (DTC) is one method used in variable frequency drives to control the torque (and thus finally the speed) of three-phase AC electric motors. This involves calculating an estimate of the motor's magnetic flux and torque based on measured voltage and current of the motor. The corresponding speed sensorless DTC for PMSM is shown in Fig. 1.

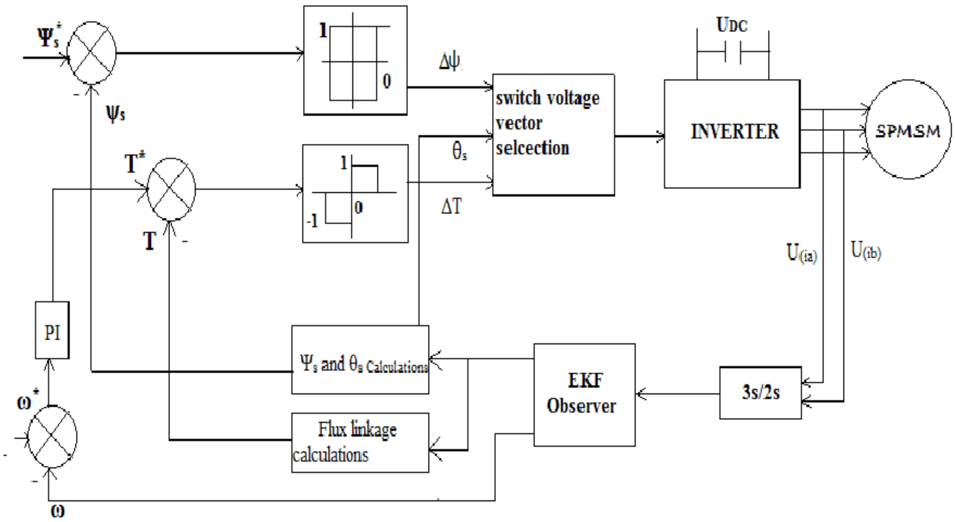

Fig. 1 Speed sensorless DTC for PMSM

4. MODEL REFERENCE ADAPTIVE SYSTEM (MRAS) BASED TECHNIQUES

Theoretically MRAS computes a desired state (called as the functional candidate) using two different models (i.e. reference and adjustable models). The error between the two models is used to estimate an unknown parameter (here speed is the unknown parameter). A condition to form the MRAS is that the adjustable model should only depend on the unknown parameter. Here, the reference model is independent of rotor speed, whereas the adjustable model is dependent on the same. The error signal is fed to the adaptation mechanism. The output of the adaptation mechanism is the estimated quantity (ωr,est), which is used for the tuning in adjustable model and also for feedback. The stability of such closed loop estimator is achieved through Popov’s Hyper stability criterion. The method is simple and requires less computation. Depending on the quantity (i.e. the functional candidate) used to formulate the error signal; various kinds of MRAS are possible. In, an MRAS is developed with d- and q-components of flux. However, the method is heavily dependent on stator resistance variation and suffers from the integrator related problems like drift and saturation. To overcome the problem, an MRAS with on-line stator resistance estimation, Reactive power-based MRAS and Neural Network (NN) based MRAS is used. Among all of these methods, reactive power based MRAS is more popular for speed estimation as it is independent of stator resistance. A block diagram of the proposed MRASbased rotor speed estimator is shown in Fig. 2.The reference model computes instantaneous reactive power (Qref) and the

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adjustable model computes steady-state reactive power (Qest). Both the reactive powers are then compared to form the error signal. The error signal is then passed through an adaptation mechanism to estimate rotor speed. In the successive section it will be proved that a PI controller is sufficient for adaptation mechanism. The estimated rotor speed is used to tune the adjustable model until the two reactive powers (Qref and Qest) become same. It is important to mention that in the proposed MRAS, continuous monitoring of speed error signal (eω) and reactive power error signal (ε) is required; otherwise instead of negative feed-back positive feed-back may take place and the system may become unstable.

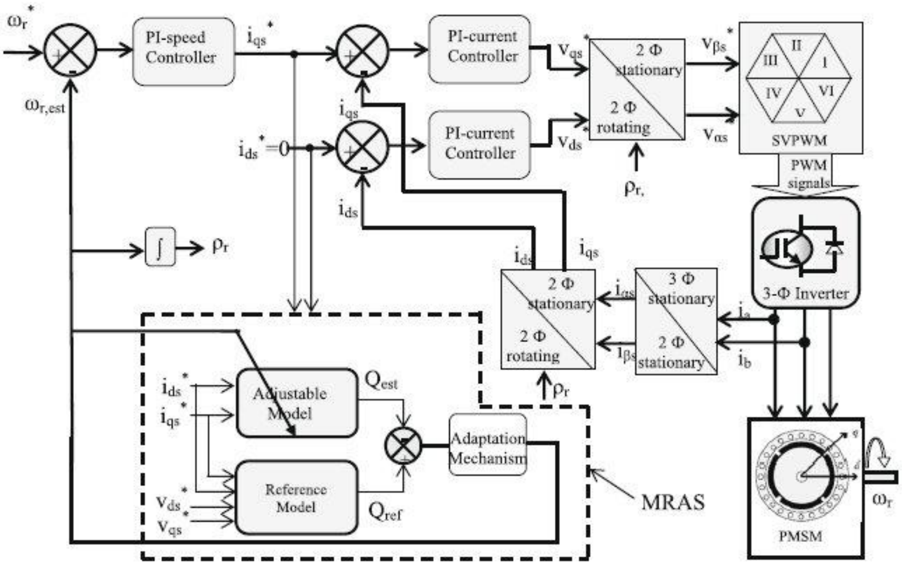

Fig. 2 Block diagram of PMSM with MRA

5. SIMULATION RESULTS

The rotor speed is estimated and simulate with MATLAB software. In Fig. 2, the estimate output speed of MRAS compare with the reference speed of input and uses from this speed as the real speed of machine. And from the simulated results it is observed that the speed of the PMSM is controlled and maintained constant. The simulation results with MATLAB software indicate that speed sensor less control of PMSM based on DTC method with MRAS has preferable good dynamic performance, speed estimation precise and fast torque response. This control technology is available both for SPMSM and IPMSM. The corresponding speed and toque waveforms are shown in Fig. 3 & 4.

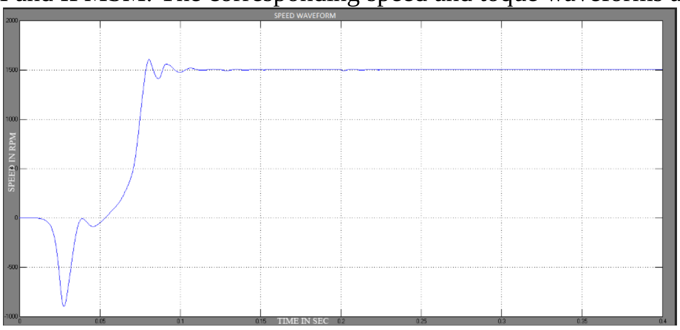

Fig. 3 Speed of PMSM

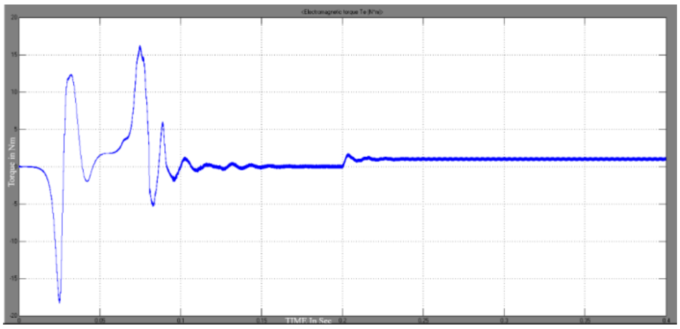

Fig. 4 Torque of PMSM

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6. CONCLUSION

DTC method is designed for an efficient control of the torque and flux without changing the motor parameters and load, with in this method the flux and torque can be directly controlled with the inverter voltage vectors. The DTC is use in a wide speed range. In this MRAS technique is simple and it will reduce the mathematical computation time. The experimental results are obtained both in load torque and several speed conditions. Using the model reference adaptive system for estimate the rotor speed of a PMSM, it will effect of the variation of motor parameters. MRAS method using the adjustable model and the reference model so that estimates the position and speed of the rotor, which in this method uses the motor itself as the reference model. The simulation results with MATLAB software indicate that speed sensor less control of PMSM based on DTC method with MRAS has preferable good dynamic performance, speed estimation precise and fast torque response. This control technology is available both for SPMSM and IPMSM.

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