Adaptive Neuro-Fuzzy Inference System Based Field Oriented Control of PMSM & Speed Estimation

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***Abstract*-- This paper studies the speed sensor-less Field Oriented Control (FOC), of permanent magnet synchronous motor (PMSM) fed by a space vector pulse width modulation (SVPWM). The characteristics for the PMSM is considered by two different algorithms, the first one is a Model Reference Adaptive System (MRAS) and the second algorithm utilized Adaptive Neuro-Fuzzy Inference System (ANFIS). The PMSM mathematical model is evaluated by ANFIS and MRAS algorithms under different speed and load torque in terms of stator voltage and torque equations. The motor speed is controlled via FOC and proportional – integral controller (PI) method. PMSM were considered by using highly non-linear, complex, time dependents (dynamics state), and unapproachability of some of the states and outputs for measurements. MATLAB package is used in this paper to simulate the proposed system and the rotor speed are estimated and controlled when the motor operate at the constant and varying speed at two states of step change in the load torque. Results discovered a good efficiency of the complete drive system at different conditions.**

Keywords— PMSM; ANFIS; MRAS; NEURO FUZZY; FOC; PI.

I. Introduction

The FOC technique, with its independent flux/torque control was essentially the greatest method in the (PMSM) drives. The main aims of FOC are to control the torque variations and the mechanical speed to adjust the phase currents in the stator in order to avoid current spikes during temporary condition. PMSM has been extensively employed in high performance drive treatments for its compensation (e.g. compactness, high efficiency; reliability; suitability to environment; smaller size; high power density). It is widely used in machine tools and robots, [1]-[3]. In this paper the rotor speed was estimated using two methods. First was applied Model Reference Adaptive System (MRAS) model without any speed sensors. Second was used (ANFIS) technique, [4], [5]. Using shaft sensors showed disadvantages as unreliability, machine size, noise interferences and noneconomic. Therefore, employing MRAS and ANFIS scheme eliminating the rotor position sensor placed on the rotor of the machine and reduced this disadvantage. The ANFIS algorithm is used to estimate the speed of the PMSM, by using the several equations and number of membership function [4], [6-7]. The control input of ANFIS and MRAS controller are direct and quadrature current and direct and quadrature voltage that setting the parameters of the membership functions.

II. Modeling of PMSM

The PMSM contains of stator with three phase windings and rotor have the permanent magnets material on its surface to provide the required field flux [4], [8-12]. The dynamic model of PMSM without damper winding was developed on rotor reference frame assuming the following:
1) Saturation is ignored, 2) The produced EMF is sinusoidal, 3) Losses of eddy currents and hysteresis are insignificant, and 4) field current dynamics no exist.

The stator voltage equations in the rotating reference frame are given by:

$$V_q^r = r_s\, i_q^r + \omega_r \lambda_d^r + \frac{d\lambda_q^r}{dt} \quad (1)$$

$$V_d^r = r_s\, i_d^r - \omega_r \lambda_q^r + \frac{d\lambda_d^r}{dt} \quad (2)$$

The flux linkage in rotor reference frame is

$$\lambda_q^r = L_q i_q^r \quad (3)$$

$$\lambda_d^r = L_d i_d^r + \lambda_m \quad (4)$$

The stator voltage equations in the rotating reference frame in equations (1, 2) becomes

$$V_q^r = r_s\, i_q^r + L_q \frac{di_q^r}{dt} + \omega_r L_d i_d^r + \omega_r \lambda_m \quad (5)$$

$$V_d^r = r_s\, i_d^r + L_d \frac{di_d^r}{dt} - \omega_r L_q i_q^r \quad (6)$$

Where, r_s, L_d, and L_q are the resistance of the stator, d-axis inductance, and q-axis inductance respectively, ω_r is the rotor rotational speed, and λ_m is the permanent magnet flux [4], [12]. Equations (5, 6) used to simulate the PMSM model in d-q axis with the equivalent circuit diagram as depicted in Fig. 1.

$$T_{em} = \frac{3P}{2}\left(\lambda_m i_q^r + \left(L_d - L_q\right) i_q^r i_d^r\right) = T_L + B + \omega_m + J\,\frac{d\omega_m}{dt} \quad (7)$$

Where T_{em} is the developed torque [4], [8-12].

III. Model Reference Adaptive System (MRAS)

The PMSM mathematical model and the measured inputs of the actual system were developed to produce the estimated outputs. The associated errors of the computed outputs in

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