Mathematical Modelling of and control of PMSM Motor Drive by using Genetic Algorithm

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***Abstract*— Now a days in most of the applications AC electrical machines are used because most of the power available is alternating in nature. In particular permanent magnet synchronous motor (PMSM) drive which operates on ac power is better choice for robotic applications due to its reliability, smooth characteristics and high-speed performance. For accurate speed control, production of required torque and elimination of ripples present in torque efficient control techniques need to be developed. The performance of the controller completely depends upon the mathematical model of the system. Hence in this work a novel approach based on genetic algorithm is proposed to develop the accurate model of PMSM drive to implement direct torque control schemes. present trend in all applications ac electrical machines are using due to all most all the power generation transmission and utilization is ac. Nowadays especially in robotics required machine is ac PMSM drive due to its reliable, smooth torque and Good high-speed performance. This machine requires to control speed and to reduce estimated torque and flux ripples. Due to this reason controlling method is required in PMSM. DTC with genetic Algorithm is implemented in this paper. This paper consists of mathematical modelling equations, a genetic algorithm with pmsm.**

Keywords— PMSM, DTC, Parkes transformation,Genetic Algorithm .

I. INTRODUCTION

The investigators gave a detailed description that the PMSM is being greatly used for high-production utilization, such as robotics and industrial machines, which involve speed controllers that give not only good ability, high-quality, high efficiency, but also flexibility in the construction system and performance. But in industrial applications, there is much unreliability, such as system parameter inaccuracy, external load disturbance, friction force, unmodeled unclearness, always decreases the ability oath machine driving system. In these electrical machines torque and flux error - estimation and control are important. Here two control methods i.e., DTC method and FOC. Field orientation control is difficult due to reference frame transformation and it is dependent on system parameters.

To succeed in dealing with DTC strategies was implemented by the researchers. The early scheme of DTC is to control flux linkage ripples and torque by setting appropriate voltage vectors. That derives on the bond between slip, frequency, and torque. This review paper consists of torque and flux estimator block, Inverter, switching table, PMSM and genetic algorithm instead of PI controller to estimate speed flux and torque errors. PMSM is modelled based on generalized machine modelling analysis. Here common reference frame is chosen with d-q transformation. The way in which a three-phase machine is normally represented by their voltage and current equations. The differential equations that explain the way in which a machine are a time flexible (apart from when the rotor is stationary). The mathematical modeling of that a system lead to be complex since the flux linkages, evolved currents and voltages change progressively as the electric circuit is in relative motion. For such a composite electrical motor analysis, mathematical transformations are often used to twain variables and to solve equations require time differ quantities by recommendation all variables to a normal frame of the source.

The rotor frame of concern is taken because the state of the rotor magnets verify, individually of the stator voltages and currents, the prompt induced EMFs and after the Ia, I*b, and I*c(stator currents) and τ of the machine, the ψr (rotor fluxes) are not individually changes, they are influenced by the stator voltages and currents, it means the q_s and d_s axis stator windings are modified to the reference frames that are rotating at rotor speed. The effect is that there is ω=0 gap in center the rotor and stator magnetic area and the stator q and d axis copper windings have a fixed phase relationship with the rotor magnet axis, that is in the d axis using the machine modeling [1-3].

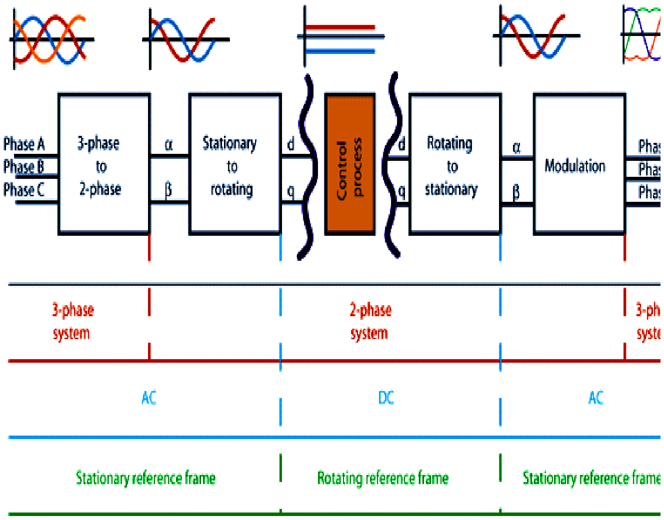

Figure 1: Block diagram of PMSM transformation

Figure 1 gives the brief description of three to two phase and two phases to three phase transformations of PMSM.

This mutation converts vectors in the stabled two-phase orthogonal static system into orthogonal rotating source frame which is shown in figure 2.

Mainly, 3 reference frames considered in this process are:

1. 3ϕ reference frame, in which Ia, Ib, and Ic are co-planar 3ϕ extant at an angle of 120degrees to each other.

2. Orthogonal invariable frame, in which Iα and are vertical to each other, but in the same plane as the 3ϕ reference frame.

3. Orthogonal rotating frame, in that Id is at the angle θ (an angle) to the α axis and Iq is perpendicular to Id along with the q axis.

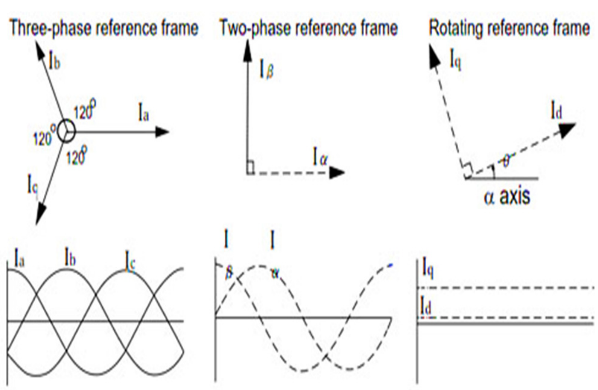

Figure 2: Reference frames of PMSM Motor Phasor diagrams

Figure 2 shows the reference frame of PMSM Motor phasor diagrams. The phasor diagrams represent three-phase reference frame to two phase reference frame and into rotating reference frame. i.e., abd to alpha-beta to dq frame. This figure shows complete conversion of 3∅ to 2∅.

II. MATHEMATICAL MODELLING OF PMSM

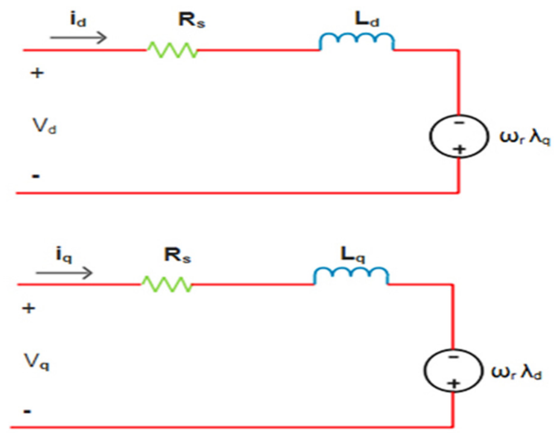

Figure 3: Equivalent circuit of PMSM

The mathematical modelling equations of PMSM with respect to the stator windings (a_s, b_s, c_s) the voltage equations from the above equivalent circuit are:

$$V_{abcs} = r_s I_{abcs} + \frac{d}{dt}\lambda_{abcs} \quad \text{----------- (1)}$$

Where V_{abcs} the stator phase voltage,

r_s the phase winding resistance, I_{abcs} the phase current and λ_{abcs} the flux linkage of phase winding

From the figure 3, the voltage and flux linkage equations are represented as

$$V_q = r_s i_q + \omega_r \lambda_d + \frac{d}{dt}\lambda_q \quad \text{---------- (2)}$$

$$V_d = r_s i_d - \omega_r \lambda_q + \frac{d}{dt}\lambda_d \quad \text{----------- (3)}$$

$$\lambda_d = L_d i_d + \lambda_M \quad \text{------------------------(4)}$$

$$\lambda_q = L_q i_q \quad \text{------------------------------(5)}$$

$$R_s = diag\left[r_s \ r_s \ rs\right] \quad \text{---------------------(6)}$$

The electromagnetic torque and mechanical equation

$$Te = \frac{3}{4} P \lambda_M i_q \quad \text{--------------------(7)}$$

$$J\frac{d\omega_r}{dt} = \frac{P}{2}(T_e - T_L) \quad \text{--------------(8)}$$

$$\varphi_s = \int (V_s - R i_s) dt \quad \text{-------------------(9)}$$

Torque in terms of flux linkages and current is given as

$$Te = \frac{3}{2}\frac{P}{2}\left(\varphi\alpha i\beta - \varphi\beta i\alpha\right) \text{---------------(10)}$$

Stationary reference frame transformed to d-q reference frame by using parks transformation. Park's transformation is well-known 3ϕ to 2ϕ transformation in machine analysis [3-5].

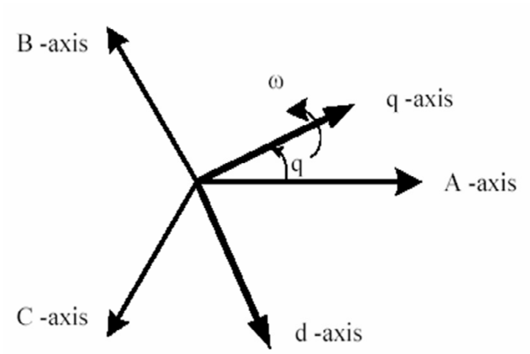

Figure 4: Park's transformation phasor diagram

Figure4represents the phasor representation of parks transformation.

The Park's transformation equation is of the form

$$\left[f_{qdos}\right] = T_{qdos}(\theta)\left[f_{abcs}\right] \text{-------(11)}$$

$$T_{qdos}(\theta) = \frac{2}{3}\begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin(\theta) & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \text{----- (12)}$$

Similarly based on equation (12) below equation is Converted abc to dq transformation.

$$\begin{pmatrix} v_q \\ v_d \\ v_0 \end{pmatrix} = \frac{2}{3}\begin{pmatrix} \cos\theta r & \cos(\theta r - \frac{2\pi}{3}) & \cos(\theta r + \frac{2\pi}{3}) \\ \sin\theta r & \sin(\theta r - \frac{2\pi}{3}) & \sin(\theta r + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{pmatrix}\begin{pmatrix} v_a \\ v_b \\ v_c \end{pmatrix} \text{--(13)}$$

Based on these mathematical modelling equations PMSM is designed.

III. PMSM WITH GENETIC ALGORITHM

During time step, each member of the population is evaluated. For each error (ω_e) (τ_e) (ψ_e) and change in the speed error (ωc_e). The output variable of the controller is changed in the reference current ((k)$i\delta$) [6-10].

The speed flux and torque errors are defined as:

$$e_{\omega}(k) = \omega * - \omega(k)$$

$$e_{\tau}(k) = \tau * - \tau(k)$$

$$e_{\psi}(k) = \psi * - \psi(k)$$

$$c_e(k) = e(k) - e(k+1)$$

Where ω τ and ψ are the reference speed torque and flux.
(k) and *(k + 1)* denote actual and previous values.

In this implementation, evaluation signals are the phase currents are *a, b, c* and the position *theta-r.* The position signal is used to evaluate the speed, torque, and flux. The switching signal generator is used to control turn-on angle *theta-r* on, turn-off angle *theta-r* off, and pulse width modulation duty cycle.

The process of controlling speed, torque, and flux is:

1. Set the speed signal of the PMSM.
2. Estimate the speed torque and flux error and change in speed error.
3. Select the number of integers to presents each controller values Kp and Ki. choose crossover probability (pc) and mutation prospect (pm).
4. Produce an early population of Kp and Ki obtain (we select in the random process) input sample time T and set time t.
5. Produce Δi(k), for every population member Ci, i=1,2,3----n using the regular PI control rules.
6. Assign fitness to each member of the population Ci,i=1,2,3……..n i=1, 2, 3, n, P E (k) 1 ω = 9

   $$p_1 = e_{\omega}(k)$$

   $$p_2 = \delta_i(k)$$

   $$F = \frac{1}{(\alpha_1 . p_1^2 + \alpha_2 . p_2^2)}$$

7. Produce the next generation using GA operators and let *t: = t+T* go to step 5
8. The maximally fit becomes *C** and send the change of control action (*i*(k)*) to control the drive. Similar steps followed by the flux and torque.

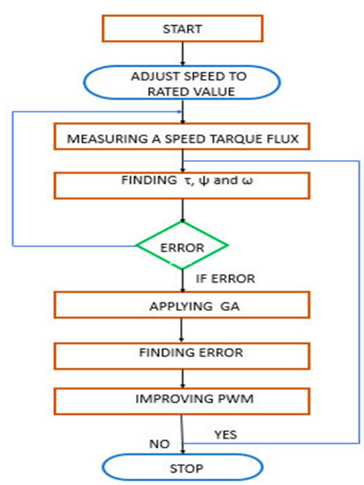

Figure 5: Flow chart for Genetic Algorithm

Figure 5 gives the brief explanation of PMSM with a genetic algorithm. from this flowchart, we can analyse the process of genetic algorithm with PMSM. Based on the steps of genetic algorithm speed can be set to the rated value i.e., the synchronous speed of PMSM. Measuring the values of torque flux and speed. If any change in error occurs then GA is applied to estimate the errors of flux speed and torque i.e, e_ω, e_ψ, e_τ .

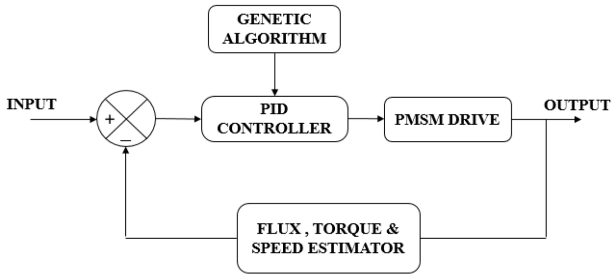

Figure 6: Basic block diagram of PMSM with Genetic Algorithm

Figure 6 shows the basic block diagram of PMSM with a genetic algorithm which is used to estimate the errors of torque, speed and flux. Based on these the torque and flux ripples are minimized by tuning of PID with genetic algorithm.

IV. RESULTS

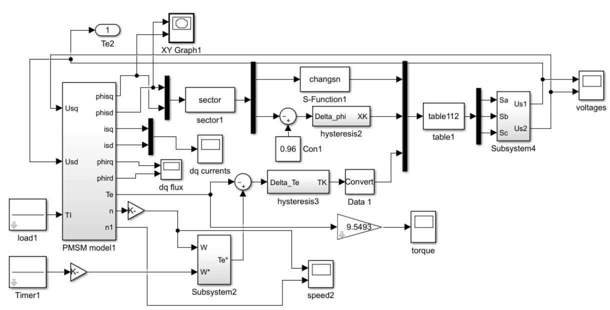

Figure 7: Simulation diagram of PMSM with genetic algorithm

Figure 7 shows the design of pmsm by using Matlab/simulink based on modelling equations and genetic algorithm steps. PID controller is tuned by considering least most occurrence error to optimize this error genetic algorithm tool is used in the design.

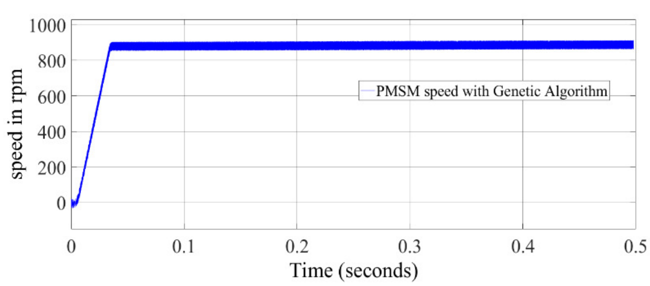

Figure 8 : Simulation results of PMSM speed with genetic algorithm

Figure 8 shows the simulation results of pmsm speed with genetic algorithm. Results with genetic algorithm gives better performance compared with PID controller. In this speed characteristics steady state error and rise time is reduced to minimum value.

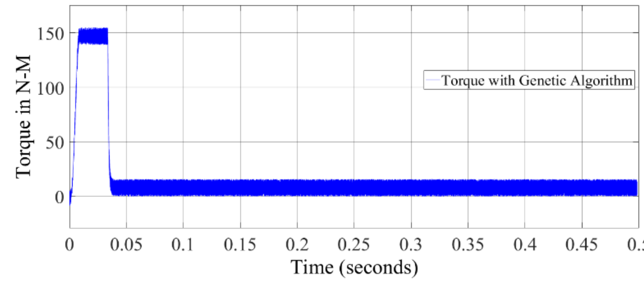

Figure 9 : Simulation results of PMSM Torque with genetic algorithm.

Figure shows the simulation results of pmsm torque with genetic algorithm. By using genetic algorithm improves the performance of torque which reduces the ripples further more compared with PID controller.

Table1:Comparison of PID controller and Genetic Algorithm

S.NO	Rise Time	Overshoot	Settling Time
Speed with PID Controller	22.72 ms	2.688%	19.98ms
Torque with PID Controller	4.41ms	5.28%	20ms
Speed with Genetic Algorithm	21.26ms	1.75%	19ms
Torque with Genetic Algorithm	3.96ms	5.11%	19ms

As mention in the table 1 that the comparison of PID and Genetic Algorithm for PMSM. As seen in the table that speed and torque of genetic algorithm for PMSM gives better performance compared to PID controller.

V. CONCLUSION

This paper analyses the mathematical modelling of PMSM and parks transformation which is used to transform three phases to two phase transformations. Mathematical modelling equations are designed based ion the equivalent circuit of PMSM. A genetic algorithm is used in PMSM which optimizes the errors in the machine to work efficiently. As PMS AC motor is mainly used in industrial applications in servo drives robotics and industry, such applications need speed controllers with, high capacity, flexibility and high implementation. By using a genetic algorithm in PMSM instead of PID controller we can estimate speed torque and flux errors and can reduce the ripples of torque and flux.

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