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Performance of Permanent Magnet Synchronous Motor by Using Artificial Neural Network Controller

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ABSTRACT: This paper presents a neural network controller for permanent magnet synchronous motor (PMSM). The neural controller is used for current ripple minimization of this type of motors. Two methods of neural controller design are used. The first method is based on two loop controllers (current controller and speed controller). The second method is based on estimation of torque constant and stator resistance in PMSM. The q-axis inductance is modeled off-line according to q-axis stator current. The neural weights are initially chosen small randomly and a model reference control algorithm adjusts those weights to give the optimal values. The neural network parameter estimator has been applied to flux linkage torque ripple minimization of the PMSM. Simulation results using the two methods are compared together. Moreover, the suggested algorithms when compared with other controllers show great success in current ripples reduction.

Keywords: Neural network, PM synchronous motor ripple minimization, current controller

INTRODUCTION

New developments in power semiconductor technology, digital electronics, magnetic materials and control theory have enabled modern ac motor drives to face challenging high efficiency and high performance requirements in the industrial sector. Due to its high efficiency, high power factor and robustness, the permanent magnet synchronous motor (PMSM) has been often used in high performance applications such as robots and machine tools . Usually high performance motor drive systems used in these domains require fast and precise speed response, quick recovery of speed from any disturbance and uncertainties. This makes the control of PMSM difficult at different dynamic operating conditions.

To achieve the best dynamic behavior, the vector control method is often used so that the PMSM can achieve the dynamic performance capabilities of the separately excited DC machine, while retaining the general advantages of AC over DC motors.

The vector control is an efficient method to control a synchronous motor in adjustable speed drive applications in wide range of speeds. Vector control is normally used in ac machines to convert them, performance wise, into equivalent separately excited dc machines. Which have highly desirable control characteristics.

A. Advantage of PMSM over other Motors

(i) The rare earth and neodymium born PM machine has lower inertia when compared with an IM because of absence of rotor cage; this makes for a faster response for a given electric torque. In other words the torque to inertia ratio of this PM machine is higher.

(ii) PM machine has higher efficiency than induction machine. This is primarily because there is negligible rotor losses in permanent magnet machines; the rotor losses in the IM, however, can be considerable, depending on the operating slip. This discussion is applicable to constant flux operation.

(iii) The IM requires of source of magnetizing current for excitation. The PM machine already has the excitation in the form of rotor magnet.

(iv) The need for magnetizing current and the fact that the IM has a lower efficiency necessitate the large rectifier and the inverter for the IM than for a PM machine of the same output capacity.

(v) The PM machine smaller in size than anIM motor of same capacity. Than it is advantageous to use PM machine, especially where space is serious matter.

B. Mathematical Model of PMSM
The following assumptions are made in the derivation.

1) Saturation is neglected although it can be taken into account by parameter changes.
2) The induced EMF is sinusoidal.
3) Eddy currents and hysteresis losses are negligible. Speed control of PMSM motors has emerged as one of the challenging tasks in the control system area.
4) There are no field current dynamics.
5) There is no cage on the rotor.

With these assumptions, the stator d, q equations of the PMSM in the rotor reference frame are as follows:

Vq = Rs iq + Lqp iq + wr φf … (1)
Vd = Rs id + Ldp id- ωr Lq iq …(2)
Also flux linkage equation can be written as,
φd = Ld id + φf …(3)
φq = Lq iq …(4)

Where Vd and Vq are the d, q axis voltages, id , iq are the d, q axis stator currents, Ld, and Lq are the d, q axis inductances, φd and φq are the d, q axis stator flux linkages, Rs is the stator winding resistance per phase and ωr is rotor electrical speed. The electro mechanical torque is given by

Te = (3/2) (P/2) [φf iq – (Ld – Lq) id iq] ….5)
and the equation of motor dynamics is,

Te = TL + Bωm + Jp ωm …(6)

Where
P is the number of poles,
TL is the load torque,
B is the damping co-efficient,
ω_m is the rotor mechanical speed,
J is the moment of inertia
p is the differential operator.
ωr = (P/2) ω_m…(7)

The model equations of PMSM can be rearranged in the form of following first order differential equations
pid = (Vd – Rsid + ωr Lq iq) /Ld …(8)
piq = (Vq –Rsiq– ωr Ld id – ωr φf) / Lq…(9)
pωm = (Te – TL – B ωm) / J …(10)
pθm = ωm …(11)
θm = ∫ωm…(12)
θm is the position angle of rotor.

In order to achieve maximum torque per ampere and maximum efficiency with linear characteristics, direct axis current component id forced to zero [12] and the reluctance torque is zero.

Te = (3/2) (P/2) φf iq …(13)

The d, q variables are obtained from a, b, c variables through the park transform as [13],

Vq = 2/3[Va cosθ + Vb cos(θ-2Π/3) + Vc cos(θ + 2Π/3)] …(14)
Vd = 2/3[Va sinθ + Vb sin(θ-2Π/3) + Vc sin (θ + 2Π/3)] …(15)

The a, b, c variables are obtained from the d, q variables through the inverse of the park transform as,

Va = Vq cosθ + Vd sinθ …(16)
Vb = Vq cos(θ–2Π/3) + Vd sin(θ–2Π/3) …(17)
Vc = Vq cos(θ+2Π/3) + Vd sin(θ+2Π/3) …(18)

II. ANN CONTROLLER

Artificial neural network are nonlinear information (signal) processing devices, which are built from interconnected elementary processing devices called neuronsThe basic building block of the artificial neural network are:

1. Network architecture
2. Setting the weight
3. Activation function

The arrangement of neurons in to layers and the pattern of connection within and in-between layer are generally called as the architecture of the net.here are various type network architectures:

1. Feed forward
2. Feedback
3. Fully interconnected net.
4. Competitive net.

Feed Forward Net
Feed forward network may have a single layers of weights where input are directly connected to the outputs, or multiple layers with intervening sets of hidden units. Neural network use hidden units to create internal representation of the input patterns.

A. Neural Network based Controller for PMSM

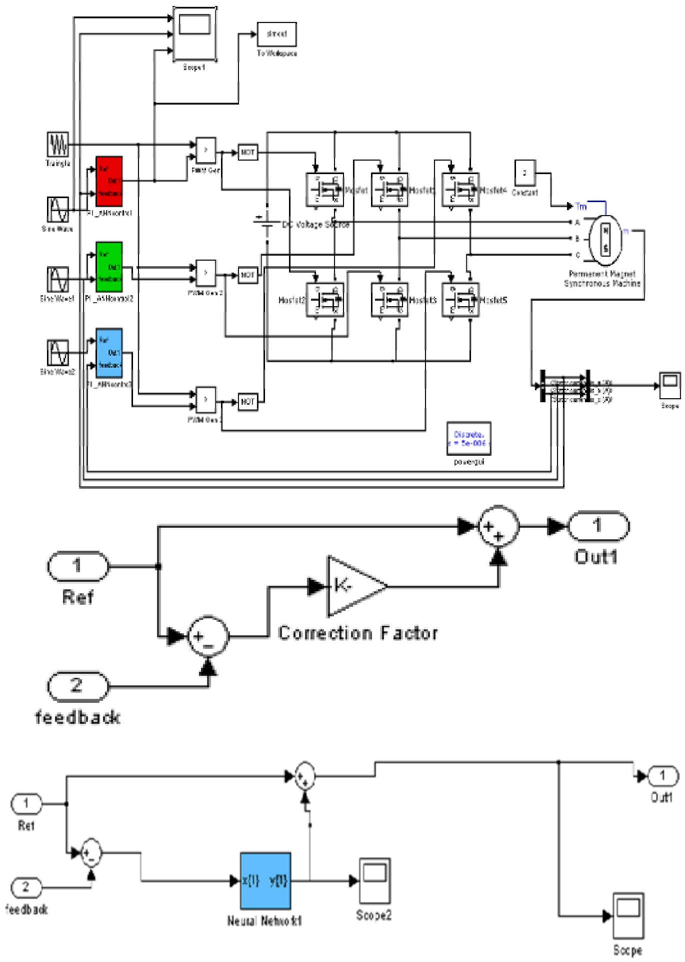

Fig. 1. Simulink Model of PMSM drive with ANN.

III. RESULT

In order to validate the performance of the proposed ANN controllers, the performance of the PMSM drives based on the proposed control scheme is investigated in simulation.. The complete controlled system has been simulated using Matlab/Simulink.

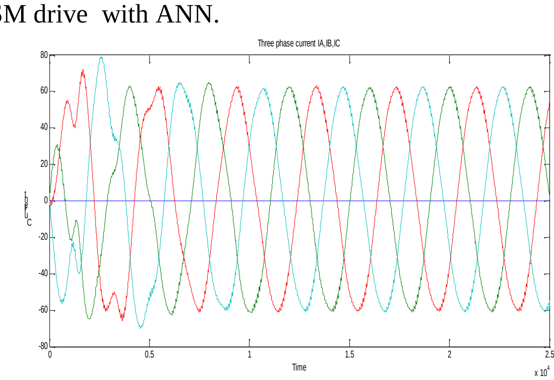

Fig. 2. Current Iabc using ANN controller.

IV. CONCLUSION

In proposed method PMSM is controlled with a neural network in place of PI controller. Neural Network based approach to improve performance of Permanent Magnet synchronous Motors (PMSM). The conventional Proportional-Integral (PI) controller is largely used in industry because of the robustness this regulator procures.

But in some case, when the dynamics of the system vary over time or with operating conditions, the performance of the controller will be spoiled. The Artificial Neural Networks (ANN) used as a current controller seems to be a promising solution in this purpose.

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