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A Sensorless Closed Loop Speed Control of PMSM Using Artifical Neural Networks

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Abstract:-This paper presents modeling, speed control of a PMSM drive in a sensorless closed loop. The hysteresis current controller is used for inner loop current control and PI controller for outer loop speed control. In this paper the design of a Artifical Neural Network based approach is used to improve efficiency control of Permanent Magnet synchronous Motors (PMSM). The conventional Proportional Integral (PI) controller is mainly used in industry because of the robustness this regulator acquires. But in some case, when the dynamics of the system changes over time or with operating conditions, the performance of the controller will be spoiled. it is necessary to know the initial position. The starting procedure is a problem under sensorless drives, because no information is available before starting. In this work, we shall establish a new convenient technique for detecting the rotor initial position, based on signal tests applied to the stopped machine. The validity of the proposed sensorless control strategy, according to the different initial rotor position conditions are discussed and simulation results are presented.

Keywords:-Neural Network, Permanent Synchronous Motor, Vector Control, PI Controller, Hysteresis Current Controller. Permanent Magnets Synchronous Machine (PMSM), Filter (EKF), sensorless drive, initial position estimation.

1.Introduction

In recent years many models have been made in the study of synchronous staticmachine converter. A typical approach has been based on the PMSM vector control.The PMSM vector command needs a precise knowledge of the rotor position which ensures the machine self driving. This knowledge can be directly obtained by a position sensor or indirectly by a speed sensor. The drawbacks of the mechanical sensor use, placed on the machine shaft are numerous [8-10]. First, the mechanical sensor presence increases the volume and the global system cost. Then it requires an available shaft end which can constitute a drawback for smallsized machines. function with mechanical sensor,various studies have been made to suppress that mechanical sensor while preserving the best performances of the machine [11-18]. These studies have investigated different methods of the vector control without sensor. They are all based on the use of some electrical variable currents and voltages, to estimate the rotor position according to a representative model of the machine. Moreover, the installation of this sensor requires a chock relating to the stator, operation which proves to be delicate and decreases the reliability of the system.In view of these limitations that introduce the machine

The angular self driving rule of the permanent magnets synchronous machine consists in getting the polar wheel axis rigidly locked with the rotating field, otherwise an inductor flux component would appear on the transversal axis and the dynamic model must be taken back. The information on the rotor position constitutes the self driving loop, is used to tie down the stator flux to the inductor one. From that point, it is possible, through an appropriate command, to make evolve in time, the stator flux vector with the rotor real position and the one we wish. The motor is said to be "self driven". Figure 1 shows the diagram of the synchronous servo-motor with magnets and jutting out poles, with a sinusoidal e.m.f.

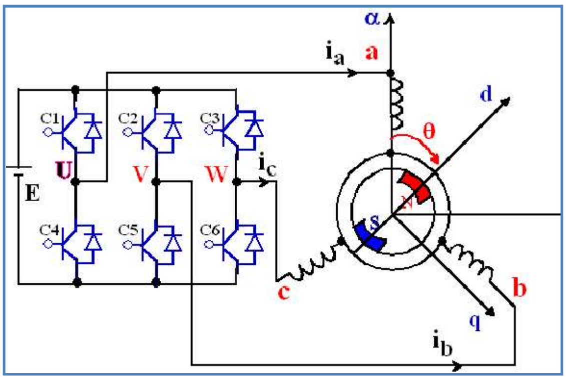

Figure 1 : diagram of the servo-motor analytical model

The vector control needs that the current iq be either in quadrature as far as the rotor flux is concerned. In consequence the current id must be co-linear to the rotor flux. By specifying a particular value of the current id, say id=0, the electromagnetic torque becomes proportional to the stator current iq and as a consequence it becomes the main parameter of adjustment.The synchronous motor model becomes similar to a DC motor.

Maintaining the same value of the current (id =0), allows to obtain for a certain amplitude of stator currents, the maximum of the relation torque/current. To control the speed and/or the position we act on the current iq, that is to say on the torque developed by the motor.There are essentially two methods for that control strategy. The first consists on controlling the alternative current circulation in the machine stator winding (according to the a, b, c reference), the second in regulating the Park components of these currents (according to the d,q reference). The PI corrector choice contributes to find uncoupling qualities between the two axis. This type of correctors are effectively useful to maintain the strength when the useful for parametrical estimation is uncertain or in case of characteristic variations of the machine. When the reference idref is imposed zero, the compensation of the current effects of axis d is useless. These constatations contribute in the sense of a simplification of the global control algorithm, and so of the necessary architecture to its implantation.

2.Rotor Position Detection

In salient-pole motors the rotor asymmetry leads directly to differences in the magnetic reluctance values in the rotor direct axis (*d*-axis), which is the axis of permanent magnet flux, compared to the values found in the quadrature axis (*q*-axis), which is the axis perpendicular to *d*-axis. So measuring both values of the initial rotor position can be derived from the two measurements [2]. However the majority of permanent magnet drives are of non-salient nature, e.g. bread loaf or radial magnet design, where the values of *Ld* and *Lq* are nearly equal. The rotor position detection technique proposed in this article uses a similar effect. It is caused by magnetic saturation in the stator laminations and can be found in almost every permanent magnet motor . The reason for this is that almost every electric motor design targets its cost minimum. This leads to high magnetic loading inside the motor, i.e. magnetic flux densities from 1.5T up to 1.8T in the stator tooth areas are common in order to achieve high drive efficiency and good

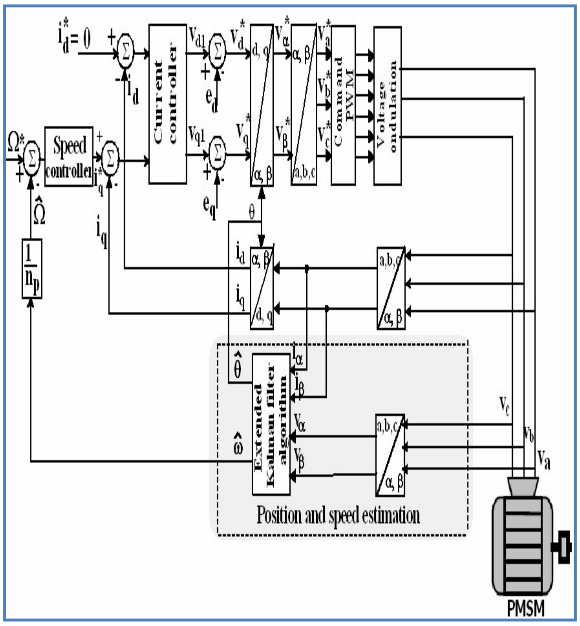

Figure 2 : PMSM sensorless vector control

utilisation of the motor materials. Flux densities of that level cause light up to middle saturation in the electromagnetic paths of the stator windings. Since the motor windings are equally distributed within the stator bore, the teeth belonging to one phase have different locations within in the stator bore relative to the teeth of the next phase. The amount of the saturation depends on the position of the rotor magnets relatively to the stator teeth looked at. Hence the degree of saturation of the teeth, which belongs to a phase, depends on the rotor position. If we apply a current in a phase winding, this current

produces a magnetic flux which adds to the flux of the permanent magnet. If the direction of the current generated flux

points in the same direction as the rotor *d*-axis, the total flux increases which leads to a higher saturation level of that stator section; if, on the contrary, the directions of the stator magnet field points against the rotor magnet field, the total magnet flux density decreases and the magnetic paths of that stator section are unloaded.

Overall goal of the proposed method is not the precise information of the rotor position. Since for both type of brushless permanent magnet motors, BLDC and PMSM, the start-up is done with rectangular current waveforms, i.e. block commutation, an angular resolution of only 60° is required. A further advantage in doing so when using PMSM-drives is a higher torque output at the same current peak level compared to a sinusoidal current waveform. One approach in order to get information on the saturation level is to apply a voltage pulse and to measure at the end of the voltage pulse the amplitude of peak phase current. By comparing the current amplitudes of different voltage pulses the information on the rotor position can be estimated. The drawback of that solution is the necessity of the precise current measurement information, high noise sensitivity and a stiff voltage source when the phase currents are impressing.

The approach proposed here only needs the information on the relative change of motor inductances and does not require knowledge of any motor parameter. The main idea of the approach is to use the motor as a part of a measuring bridge, the motor is one half of the bridge, the other half is built by two additional resistors. The phases which are in the bridge are selected by the power switches of the motor electronics. For the measurement, the voltage input to the bridge is a voltage pulse generated by the power switches which select as well the motor phases; the output of the bridge is the voltage measured between the neutral point of the motor and the middle of the resistive divider. Thus, when a voltage pulse is applied to the bridge a change

in the inductances of the connected motor phases due to change of magnetic saturation has a direct effect on the output of the bridge, i.e. the voltage *VST*.

The voltage pulses on the inductive part of the bridge are generated by the switches of the motor power electronics. According to the six available switching states of the inverter six voltage pulses are applied to terminals labeled R, S, T. The time durations for the on- and off-times of the pulses are equal and constant during all measurements. The cycling of the voltage pulses are done in a fashion that minimum rotor movement will occur.

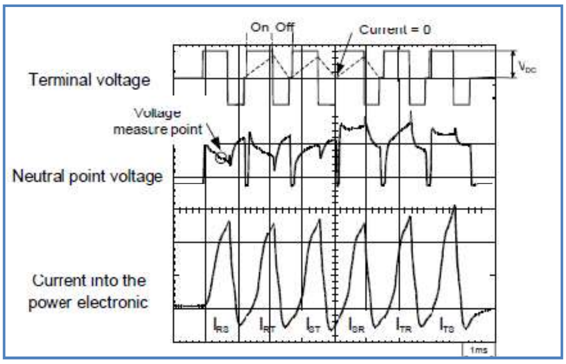

Figure 3: Measured terminal voltages, neutral point voltages and input current waveforms of the power electronics during experimental rotor position detection.

3. CLOSED LOOP SPEED CONTROL OF PMSM

The Schematic scheme of the closed loop speed control system for PMSM Drive is shown in Fig. 3. The constant torque method of vector control scheme has been examined for analysis. In this method, the angle between the rotor field and stator current phasor is called as a torque angle and is maintained at900so that flux is kept constant, then the torque is controlled by the stator current (is) magnitude [1]. The machine, speed and position feedback, speed and current controllers, and inverter constitute the PM Synchronous motor drive. The error in between the reference and actual speed is given the input to the speed controller, which creates the torque reference and is proportional toKt , by substituting id=0, equation and is obtained.

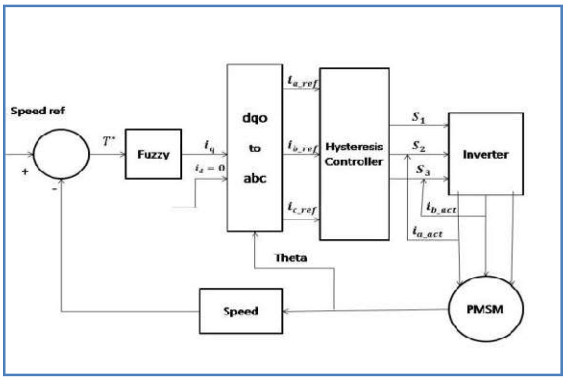

Figure 4: Block Diagram of Closed Loop Speed Control of PMSM.

In order to specify automotive systems with the component-based approach it is necessary to specify some aspects of the behavior of the components as well. More precisely, the interface descriptions of the components have to be enhanced with additional information, mainly timing aspects1. Just when the interfaces fit together, a feasible component structure arises. After connecting the components, a large component structure may arise and therefore a very complex structure of connected behavior models emerges. This complexity may lead to several problems, because a wrong definition of the behavior models may invoke a not wanted behavior. At a specific degree of complexity, an engineer is not able to control the connected components and guarantee that no unwanted behavior will happen. So, some kind of automatic tests is needed, e.g. model checking. This paper addresses one problem occurring when such reusable software components are used: How can be checked whether a system constructed from black boxes whose internals are unknown to him meet important constraints? This holds especially true for temporal requirements.

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.

The mathematical model of PMSM is available in the existing literature [1] and [5] has been presented in this section to provide a basis for the succeeding sections. The stator of the PMSM and the wound rotor synchronous motor are similar. The permanent magnets used in the PM Synchronous motor are of a modern rare-earth variety with high resistivity, so induced currents in rotor are very small amount so they are negliable. In addition, there is no dissimilarity between back EMF developed by a permanent magnet and that developed by an excited coil are same. Hence the mathematical model of a PM Synchronous motor is similar to that of the wound rotor SM. The rotor reference frame is selected because the position of the rotor magnets determines the immediate induced emf and subsequently the stator currents and torque of the machine independent of the stator voltages and currents. The following assumptions are considered in the derivation.

- Saturation and parameter changes are negligible

- Stator windings are balanced with the induced EMF is sinusoidal
- Eddy current and hysteresis losses are negligible or neglected.
- There are no field current dynamic
- There is no cage on the rotor.

4. Conclusion

An advanced simulation model of closed loop PM Synchronous Motor drive system has been developed by utilizing the mathematical model of PM Synchronous Motor and hysteresis current controlled three phase VSI inverter. The developedsimulation system model has been verified by circuit simulation model of the similar scheme which shows the accuracy of the developed model.It has been observed that the torque and the stator flux ripples are significantly reduced and a constant switching frequency is achieved in fuzzy controller. Other improvements observed in fuzzy controller are the reduction in phase current distortion, fast torque response and increase in efficiency of the drive. This developed model can be well utilized in the design and development of closed loop PM synchronous motor drives system for experimenting with different control algorithms and topological differences but with a much reduced computational time and memory size.

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