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Sensorless Control Algorithm For High Dynamic Performance PMSM

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--ABSTRACT--

A low-time-consuming and low-cost sensorless-control algorithm for high-dynamic performance permanent-magnet synchronous motors, both surface and internal permanent-magnet mounted for position and speed estimation is introduced. This control algorithm is based on the estimation of rotor speed and angular position starting from the back electromotive force space-vector determination without voltage sensors by using the reference voltages given by the current controllers instead of the actual ones. This choice obviously introduces some errors that must be vanished by means of a compensating function. The novelties of the proposed estimation algorithm are the position-estimation equation and the process of compensation of the inverter phase lag that also suggests the final mathematical form of the estimation. The mathematical structure of the estimation guarantees a high degree of robustness against parameter variation. The proposed low-cost sensorless-control algorithm shows the high dynamic performances of the sensorless-control system also with reduced equipment.

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I. INTRODUCTION

Permanent magnet synchronous motor drives are becoming more popular in industrial applications, machine tools and residential applications. In a PMSM the excitation is provided by means of using permanent magnets mounted on the rotor. PMSM present numerous advantages such as high efficiency, high torque to inertia ratio, high power density, reliability and long life. Industrial applications require variable speed drive systems. In order to optimally control a PMSM, the position and or the speed of the shaft must be known. The position and speed of the shaft is usually determined using a position transducer or encoder. By knowing the rotor position, the PMSM can be controlled in such a way that it provides full torque at zero speed. This is achieved by maintaining an appropriate angle between the stator and rotor magnetic fields. However the use of a position encoder adds some important disadvantages to the PMSM drive system including increased drive system cost, increased complexity and maintenance, reduced reliability and increased size of the drive system.

In order to solve these problems related to the use of position transducers, the sensor-less control of PMSM has been proposed. The idea is to get rid of the position transducer and try to determine the actual rotor position by measuring other variables such as voltages and currents in the PMSM.

In the proposed scheme, a low-time-consuming and low-cost sensorless-control algorithm for high-dynamic performance permanent- magnet synchronous motors, both surface and internal permanent-magnet mounted for position and speed estimation is introduced. The sensorless-control system is based on the back EMF space-vector estimation. The use of the back EMF space vector is advantageous with respect to any other system using flux estimation because of the integrator elimination avoiding the problem of integration drift that requires opportune devices or subsystems for its compensation. The mathematical structure of the estimation guarantees a high degree of robustness against parameter variation.

II. PROBLEM DEFINITION

High performance control of AC machines requires the information of several electromagnetic and mechanical variables including currents, voltages, fluxes, speed and position. Current and voltage sensors are robust and give sufficiently accurate measurements, and so are adopted for closed loop control. The speed and position sensors are more delicate and often pose serious threats to control issues, so speed sensorless operation is sought in many applications that require open loop control. To extract speed and position information without using speed sensors, back emf sensorless control algorithm has been proposed.

III. METHODOLOGY

Description of the Estimator :

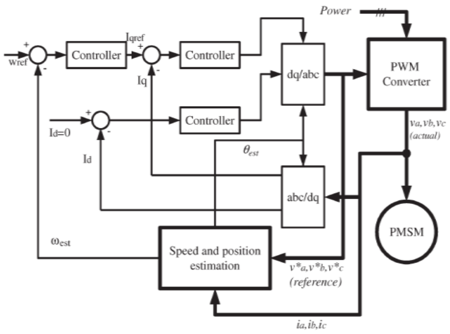


Fig. 1. Electrical-drive machine block diagram with sensorless control for PMSM.

The proposed sensorless-control technique is the determination of the back EMF space vector without voltage measurements by using the reference voltages instead of the actual ones so that the system is a low-cost and reliable one. In the control system, whose block scheme is shown in Fig. 1, the motor supply voltage values that constitute some inputs of the estimator are replaced with reference-voltage signals (v_a* ,v_b* and v_c*) generated by the current regulator. Considering the inverter reference-voltage signals instead of the real supply voltages implies, obviously, some approximations in the back EMF determination. It is worthwhile to observe that better performances are obtained if the rotor position and speed determination would be committed directly to the determination of the back EMF space vector e_S and not to the determination of the flux space vector. This is essentially due to the absence of flux signal integrator. Furthermore, elimination of analog integrators improves the benefits in analog circuitry due to the absence of components suffering from thermal drift.

In the proposed estimator, the error signal is processed by the PI compensator to derive the speed of the rotor and the angle of the rotor is calculated by integrating the estimated speed. This makes the vulnerable to noise. The experimental research has shown that the proposed estimator provides very accurate and robust speed information for the application. But at zero and low speed, the back emf voltage is not enough for the proposed vector control. Hence for the seamless operation from zero speed, the current has been controlled with a constant magnitude and a pre-patterned frequency. Here the synchronous reference frame is derived by integrating the frequency.

MACHINE DETAILS

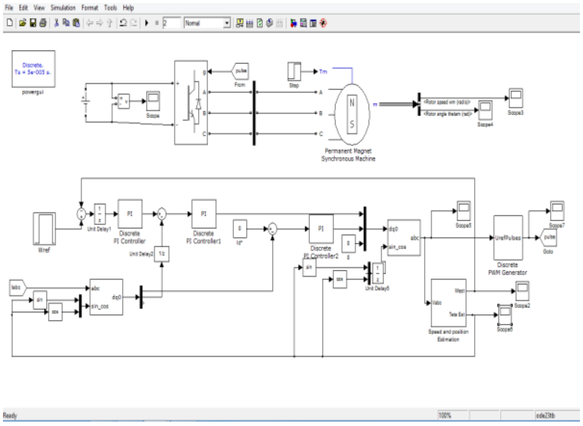
maximum speed [rpm]	4000
rated current [A]	3.6
phase rated voltage [V]	77
rated torque [Nm]	1.8
Number of poles	6
Stator phase resistance [Ω]	2.21
Direct axis inductance [mH]	9.77
Quadrature axis inductance [mH]	17.94
permanent magnet flux [Wb]	0.084
Friction Torque [Nm]	0.04

IV. MATLAB MODEL

Simulations been made in order to validate the proposed estimation algorithm under two conditions;
1) step change in motor speed from 400 up to 4000 r/min (nominal speed) and back again to 400 r/min;
2) sudden application of a 1.8-N · m load torque while the motor runs at 4000 r/min speed;

SIMULATION RESULT

1) When step change in motor speed from 400 up to 4000 r/min (nominal speed) and back again to 400 r/min, the control block and the simulation s are shown



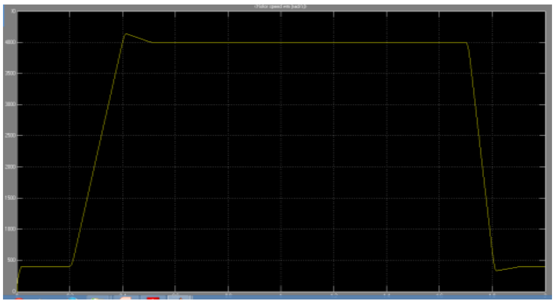


Fig 2.Real &estimated speed for step change in motor speed from 400 up to 4000rpm

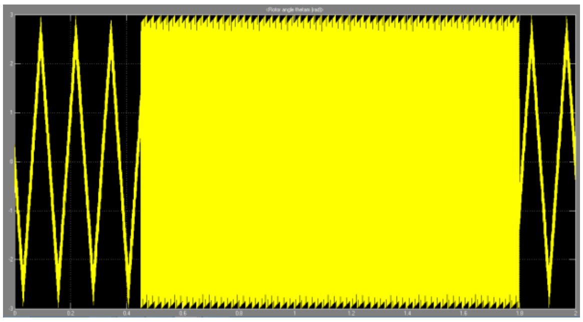
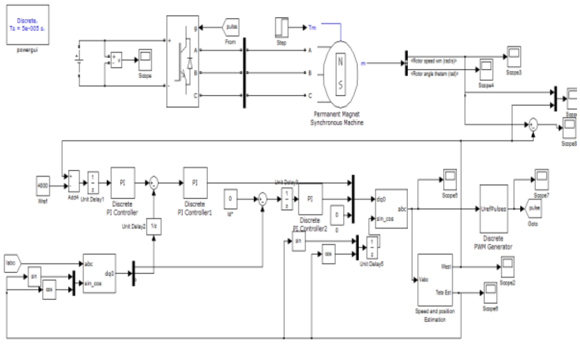


Fig.3 Real& estimated position for step change in motor speed from 400 up to 4000rpm

2)During sudden application of a 1.8-N · m load torque while the motor runs at 4000 r/min speed , the control block and the simulations are shown:



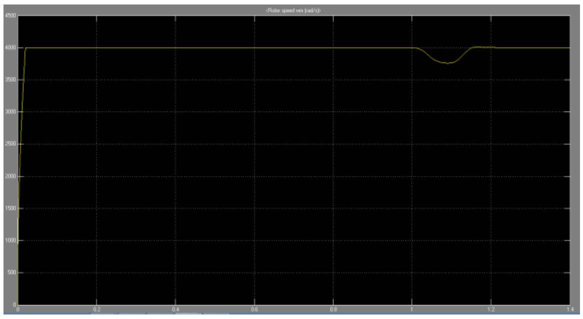


Fig.4 Real &estimated speed & position when the motor runs at 4000rpm

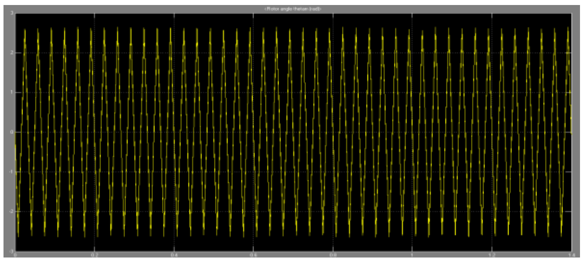


Fig.5 Real &estimated position when the motor runs at 4000rpm

V. CONCLUSION

Back EMF determination shows the high dynamic performance of the proposed algorithm. The proposed scheme make the electrical drive cheaper and suitable for industrial drives both surface and internal mounted PM. The algorithm is considered a very good alternative in terms of economy and precision without lack of performances and exhibits an increase in reliability.

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