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Detailed Modelling of Permanent Magnet Synchronous Motor (PMSM) for Electrical Forklifts part-IV Designing of Subsystem Model of PMSM Block

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Abstract: The research work deals with detailed modelling of permanent magnet synchronous motor for electrical drives. In this paper we have discussed about mathematical modelling of PMSM for Electrical Forklifts designing aspects of subsystem model of PMSM Block of the Main model. Permanent magnets to replace the electromagnetic pole with windings requiring a less electric energy supply source resulted in compact dc machines. Likewise in synchronous machines, the conventional electromagnetic field poles in the rotor are replaced by the PM poles and by doing so the slip rings and brush assembly are dispensed. With the advent power semiconductor devices the replacement of the mechanical commutator with an electronic commutator in the form of an inverter was achieved. These two developments contributed to the development of PMSMs and Brushless dc machines. Due to many applications of PMSM like sensor less speed control, appropriate position control, Servo motor, etc. Mathematical modelling of permanent Magnet synchronous motor is carried out and simulated using MATLAB. The most important features of PMSM is its high efficiency given with the ratio of input power after deduction of loss to the input power. There is no field current or rotor current in the PMSM.

Key words: Permanent Magnet Synchronous Motor, Electrical driven Forklifts, Modelling of Permanent Magnet Synchronous Motor, Dynamic modelling of subsystem block.

I. INTRODUCTION

Permanent magnet synchronous motors (PMSM) are widely used in low and mid power applications such as computer peripheral equipments, robotics, adjustable speed drives and electric vehicles. The growth in the market of PM motor drives has demanded the need of simulation tools capable of handling motor drive simulations. Simulations have helped the process of developing new systems including motor drives, by reducing cost and time. Simulation tools have the capabilities of performing dynamic simulations of motor drives in a visual environment so as to facilitate the development of new systems.

A closed loop control system with a PI controller in the speed loop has been designed to operate in constant torque and flux weakening regions. Implementation has been done in Simulink. A comparative study of hysteresis and PWM control schemes associated with current controllers has been made in terms of harmonic spectrum and total harmonic distortion. Simulation results are given for two speeds of operation, one below rated and another above rated speed.

The goal of the project is to investigate and develop permanent magnet synchronous motors (PMSM) for traction applications such as electric driven forklifts. An existing induction (asynchronous) traction motor that can be found in electric forklifts is used as benchmark for the study. The aim of the design is to have a high efficient permanent magnet motor drive that could be a feasible alternative to the induction motor drive in a longer perspective, despite a higher initial cost due to the expensive rare-earth permanent magnet (PM) materials that are preferably used in these types of motors.

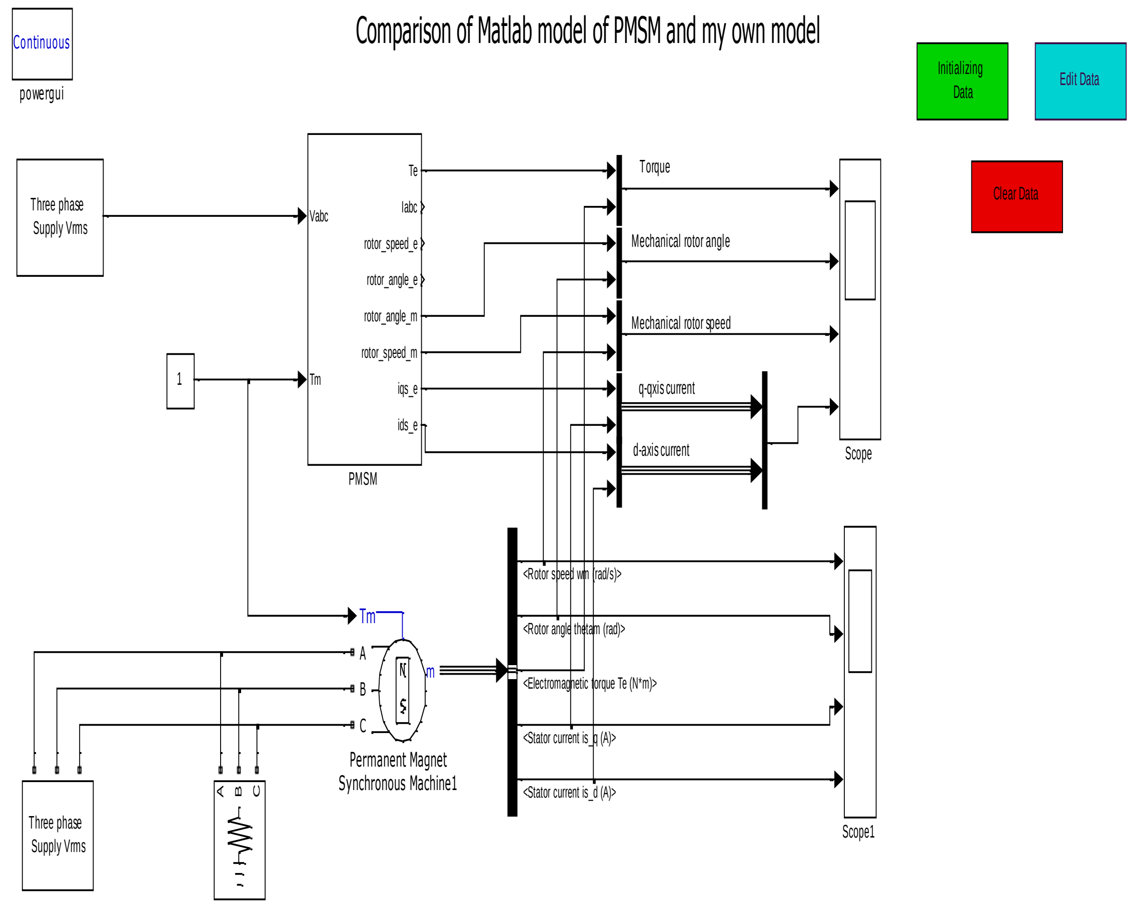

Fig. 1 Comparison of MATLAB model of PMSM and my own model

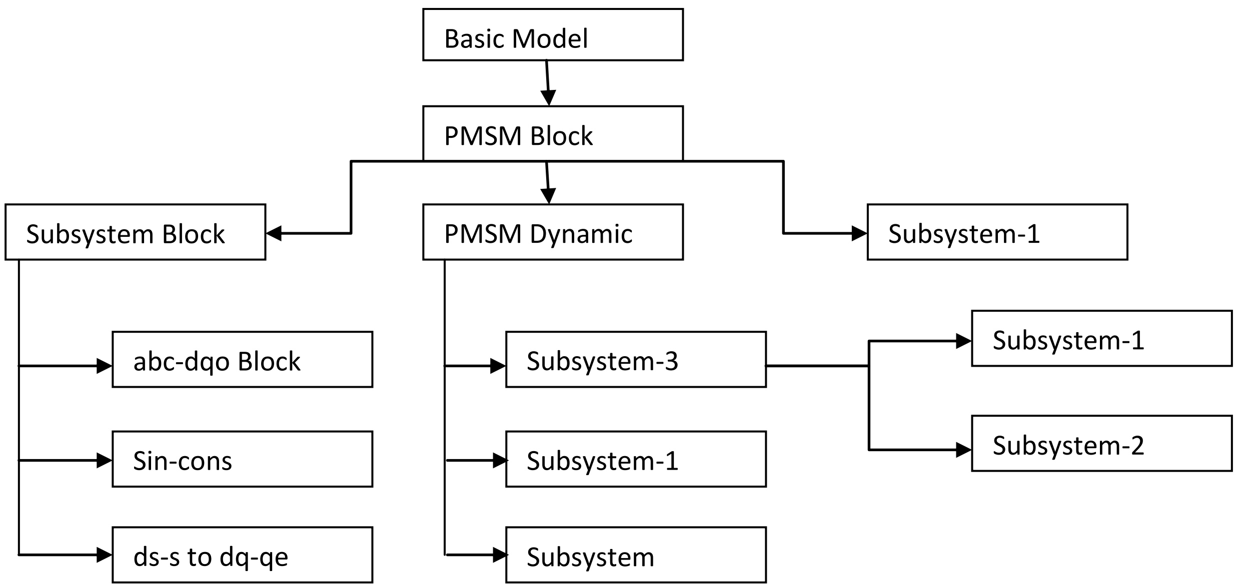

Fig. 2 Different Models in Comparison of MATLAB model of PMSM

There are multiple model inside the each block and subsequent programming has been done in order to find out or to calculate the desired parameters and characteristics. The details of various model inside the PMSM block are as shown in fig. 2. In this paper we are discussing the designing of subsystem1 block of the PMSM block.

II. THE DESIGNING OF THE SUBSYSTEM MODEL OF PMSM BLOCK IN MODELLING OF PERMANENT MAGNET SYNCHRONOUS MOTOR (PMSM)

Experiments have been carried out using a special stand with a 58 kW traction PMSM. The stand consists of PMSM, tram wheel and "continuous" rail. The PMSM is a prototype for low floor trams. PMSM parameters: nominal power 58 kW, nominal torque 852 Nm, nominal speed 650 rpm, nominal phase current 122 A and number of poles 44. Model parameters: R = 0.08723 Ω, L_d = L_q = 0.8 mH, Ψ = 0.167 Wb. Surface mounted NdBFe magnets are used in PMSM. Advantage of these magnets is inductance up to 1.2 T, but theirs disadvantage is corrosion. The PMSM was designed to meet *B* curve requirements. The stand was loaded by an asynchronous motor. The engine has parameters as follows: nominal power 55 kW, nominal voltage 380 V and nominal speed 589 rpm.

An IGBT inverter was used for feeding of PMSM. For control, a DSP TMS320F2812 by Texas Instruments was used. Maximum operation speed of drive was up to nominal speed of the motor to avoid dangerous overvoltage in dc bus during faults of inverter at speeds higher than nominal. To reach flux weakening operation, the maximum voltage threshold for flux weakening was 75 %. Also the torque rate was limited during the steps for safety reasons. To reach a dc bus voltage change during torque set point steps, a front-end resistor of 2 Ω was used. Experimental conditions were: converter switching frequency 5 kHz, nominal dc bus voltage 560 V, dead times 2 μs. For the construction of workplace the high requirements of construction had to be taken into con-side ration from viewpoint of EMC according to [4]. The reason is cooperation of the controlling and measuring microprocessor circuit. The power part is a strong source of interference because inverter with PWM generates voltage pulses with hundreds of V/μ s. Satisfactory elimination of all parasitic signals caused by the operation of power electronic converters was reached by compliance to requirements of workplace construction from viewpoint of EMC (particularly shielding of power and signal con-doctors, filtering of network currents, galvanic separation and site layout).

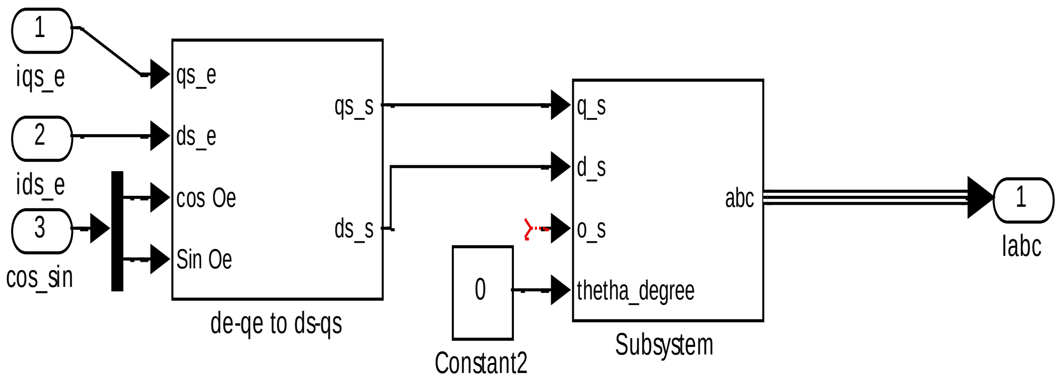

Fig. 3 Inside Model of Subsystem 1 of PMSM block of Main model from fig. 1

This is final part of designing aspects of detailed modelling of PMSM drive for Electrical Forklifts in this paper we are discussing modelling of subsystem block which is constructed of two main parts named as de-qe to ds-qs block and subsystem block which are described below.

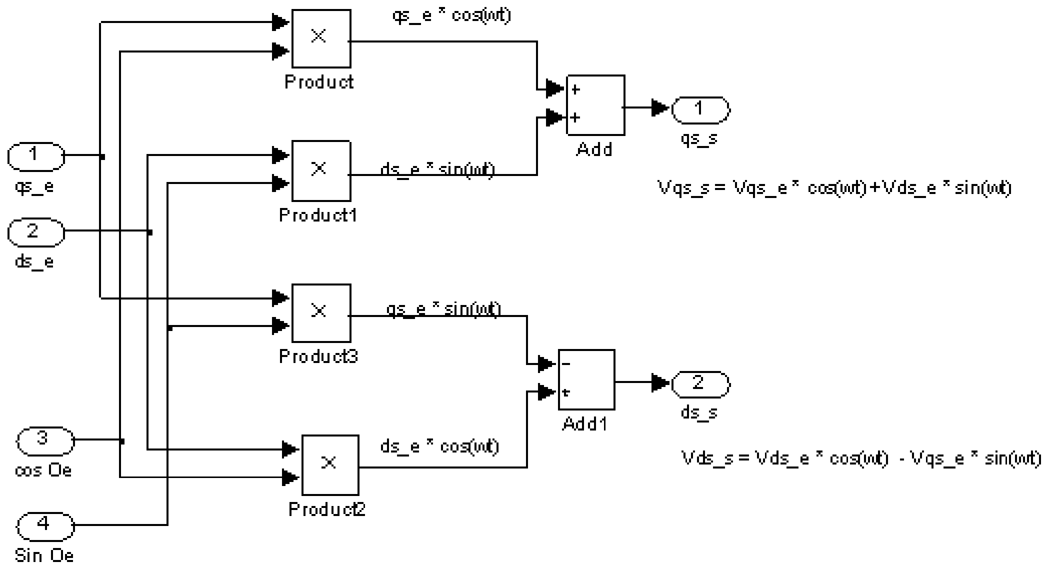

Fig. 4 Inside Model of de-qe to ds-qs in Subsystem 1 of PMSM block of Main model from fig. 3

This is the de-qe to ds-qs block inside the subsystem model. This block basically generates output signal for ds_s signal while considering input signals from qs_e, ds_e, cos Oe and sin Oe.

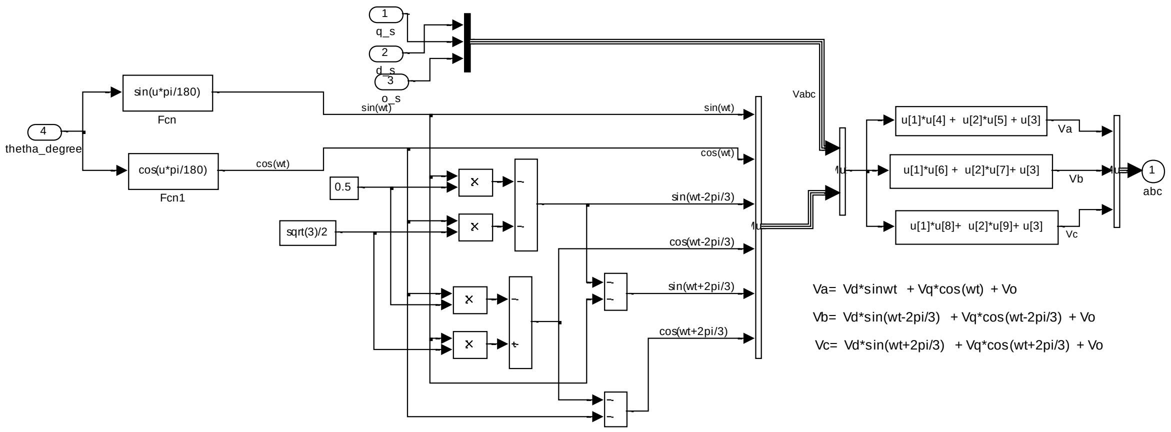

Fig. 5 Inside Model of subsystem thetha degree in Subsystem 1 of PMSM block of Main model from fig. 3

This is the subsystem thetha degree block in subsystem 1 model of PMSM block it generates three phase output voltage which behaves as an input for three phase induction motor. This block calculates the sin and cos of the thetha degree angle and supplies it to the system as per need.

III. RESULT

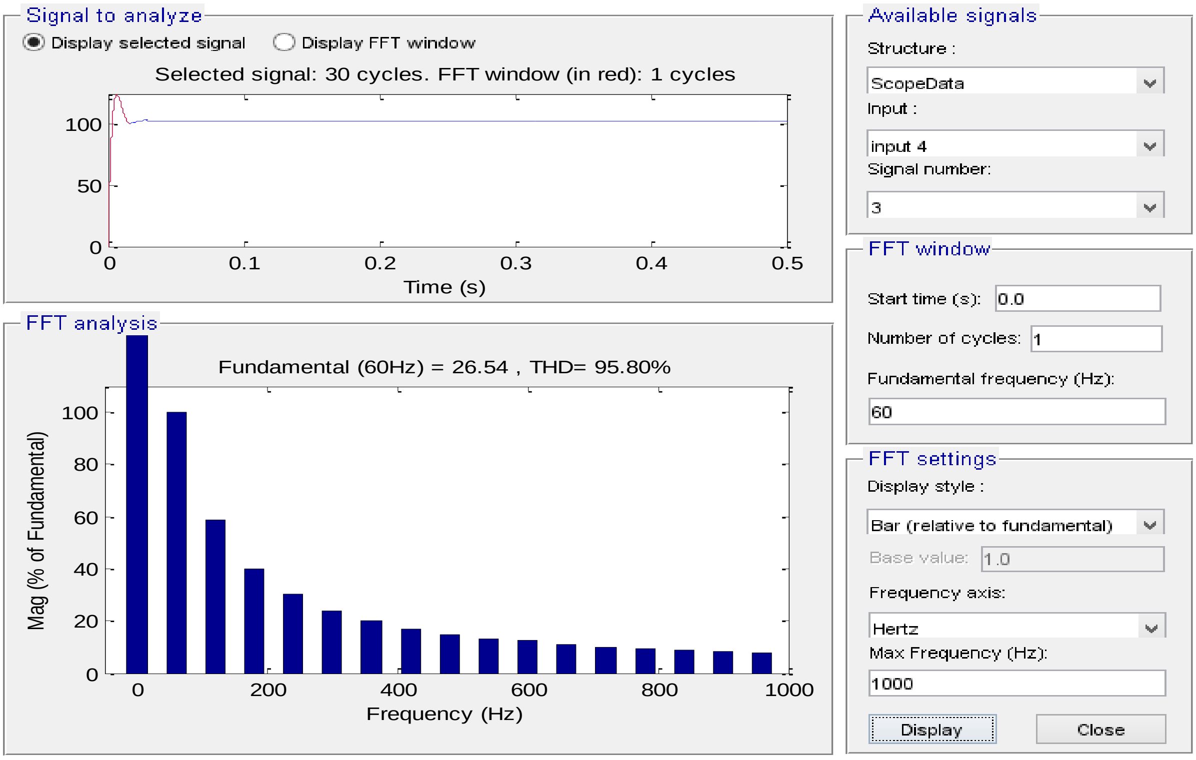

Fig. 6 Gives the Total Harmonic Distortion and Fast Fourier Analysis (FFT) for input-4, signal number 3 for 60 Hz fundamental frequency and maximum frequency of 1000 Hz.

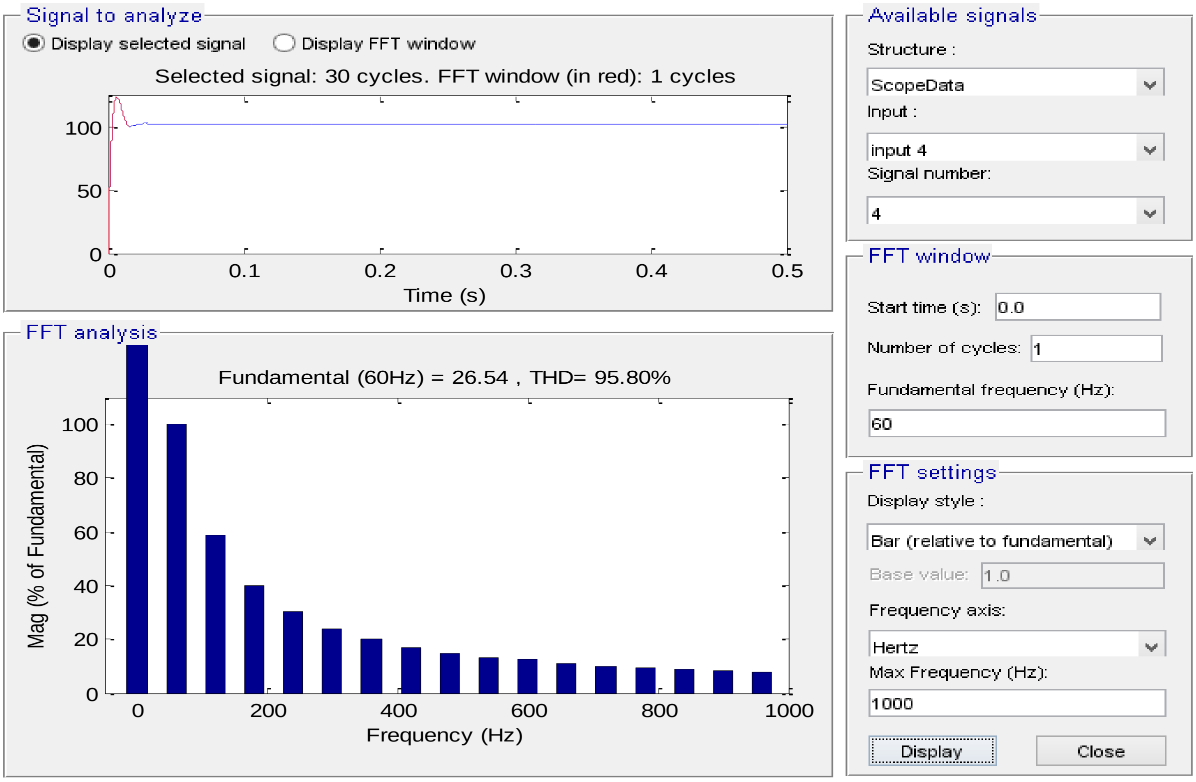

Fig. 7 Gives the Total Harmonic Distortion and Fast Fourier Analysis (FFT) for input-4, signal number 4 for 60 Hz fundamental frequency and maximum frequency of 1000 Hz.

CONCLUSION

The main aim of the paper is analysis of subsystem block of detailed modelling of PMSM for electrical forklifts. The drive using feedback based flux weakening control. Two control structures were tested. The first of them was a pure feedback based flux weakening control. Two control structures were tested. The first of them was a pure feedback control with added prediction of the id. the tests were performed on the mathematical model and also on a real PMSM drive.

The simulation shows the prediction of the id improves the dynamic behaviour of the drive. A higher setting of integrator gain may cause oscillations of id and iq during hard torque set point steps. Although the prediction brings improvement, the pure feedback control of the particular type of PMSM reaches good dynamic behaviour, too. The negative effect of the pure feedback control could be avoided by torque set point rate limitation which is necessary to limit increase of acceleration anyway. The high integrator gain causes no problem during high acceleration of the drive.

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