Detailed Modelling of Permanent Magnet Synchronous Motor (PMSM) for Electrical Forklifts Part-II 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 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.

Keywords:- *Permanent Magnet Synchronous Motor, Electrical driven Forklifts, Modelling of Permanent Magnet Synchronous Motor, Distributed Magneto motive force.*

I. INTRODUCTION

Electric motor drives are used in a very wide power range, from a few watts to many thousand kilowatts, in applications ranging from very precise, high performance position controlled drives in robotics to variable speed drives for adjusting flow rates in pumps. In all drives where the speed and position are controlled, a power electronic converter is needed as an interface between the input power and the motor. Above a few hundred watts power level, there are basically three types of motor drives: DC motor drives, Induction motor drives, and Synchronous motor drives. AC motor drives have replaced DC drives in most applications as they have more advantages to offer. The application or process determines the requirements of the motor drive. For example, a servo-quality drive is needed in robotics, machine tools, paper mill or steel mill drives whereas only an adjustable speed drive is needed in air conditioning system.

For a suitable drive to be selected for a specific load or application, complete information about load requirements should first be obtained. A motor having speed-torque and speed current characteristics that suit the load requirements is chosen. A motor will have characteristics compatible to the load if it satisfies the speed and torque requirements of the load without exceeding the current limitation imposed either by the motor rating or the source capacity. Usually the natural speed-torque characteristic is not compatible with the load requirements and a power electronic converter is used to interface the motor and the source. Further, a control strategy that ensures that the drive and load characteristics are well matched is employed. The control strategies most commonly employed with modern electric drives can be grouped into scalar and vector control schemes in the case of AC drives.

II. MODELLING OF THE PERMANENT MAGNET SYNCHRONOUS MOTOR (PMSM) FOR ELECTRICAL FORKLIFTS PART-II DESIGNING OF SUBSYSTEM OF PMSM BLOCK

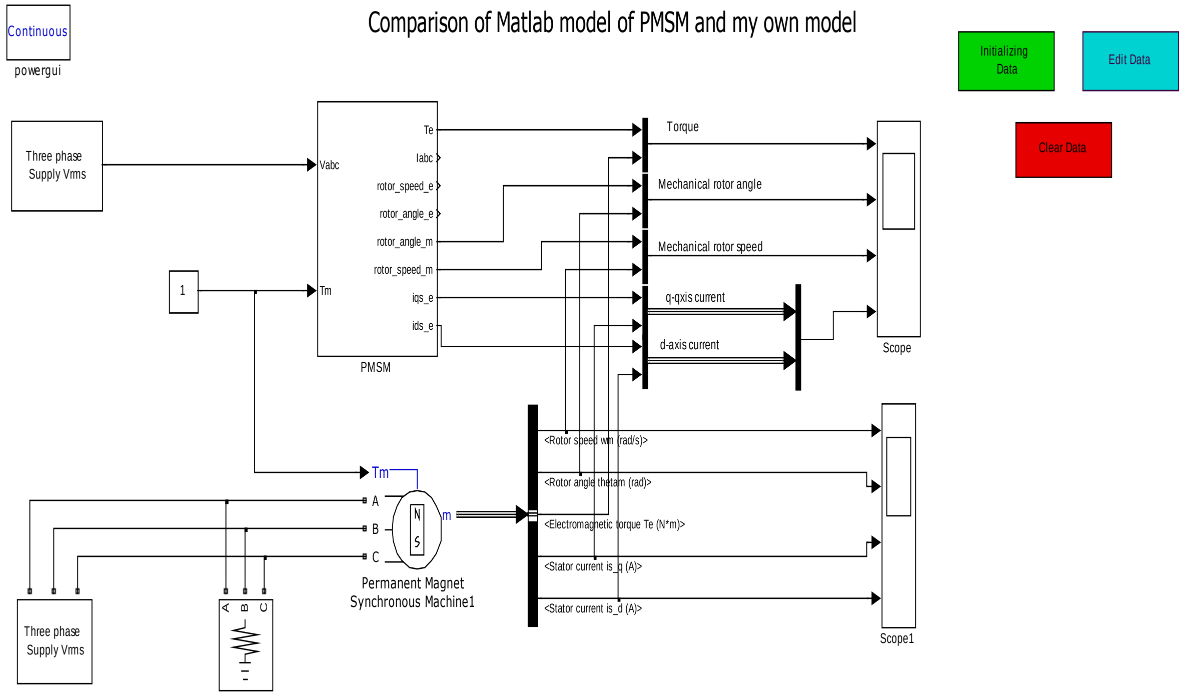

Fig. 1 :Comparison of MATLAB Model of PMSM and My Own Model

The goal of the project is to investigate anddevelop permanent magnet synchronous motors(PMSM) for traction applications such as electricdriven forklifts. An existing induction(asynchronous) traction motor that can be found inelectric 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.

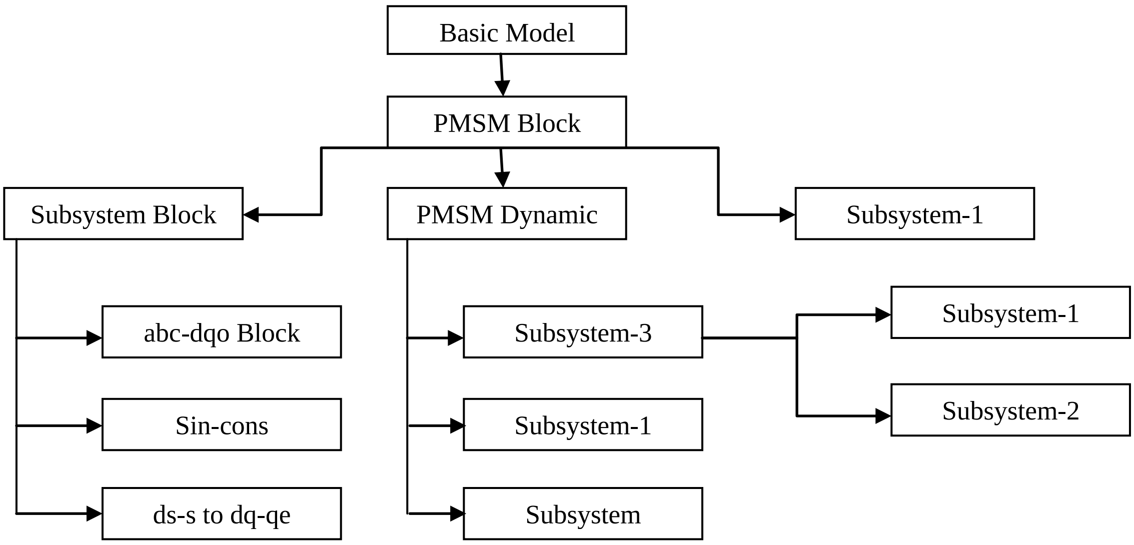

Fig. 2 Different Models in Comparison of MATLAB Model of PMSM

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 subsystem block of the PMSM block.

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

In this section, the simulation of the subsystem model of PMSM block in modelling of permanent magnet synchronous motor is developed using simulink. The simulation circuit includes all realistic components of the drive system. modelling of a permanent magnet synchronous motor is performed using the machine equations; with some assumptions like: saturation is neglected; the induced EMF is sinusoidal; Eddy currents and hysteresis losses are negligible; there are no field current dynamics; all motor parameters are assumed constant; Leakage inductances are zero. The d-q model has been developed on rotor reference frame. This dynamic simulation of PMSM subsystem block is done with the aid of SIMULIN in MATLAB package. The PMSM motor drive simulation was built in several steps like abc phase transformation to dqo variables, calculation torque and speed, and control circuit. The abc phase transformation to dqo variables is built.

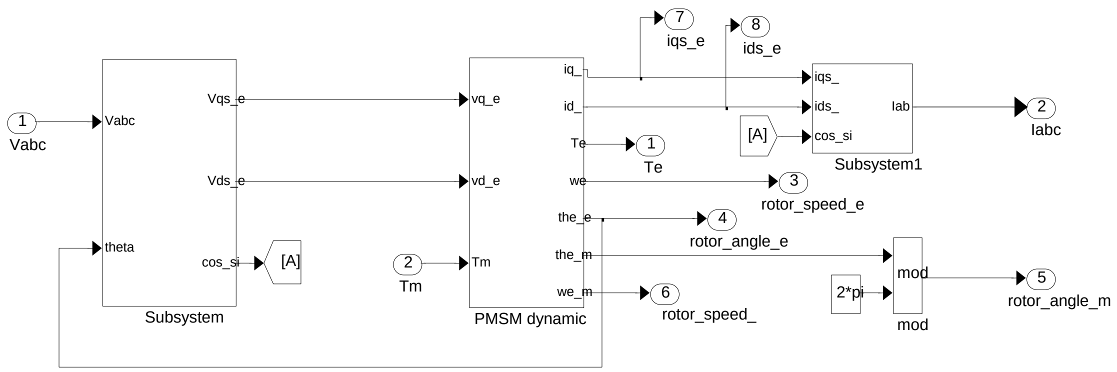

Fig. 3 Inside Model of PMSM block of Main model from fig. 1

The PMSM block of the main model figure 1 comprises of sub blocks named as Subsystem, PMSM dynamic model and Subsystem 1these blocks are also subdivided into various blocks. This block provides the relationship between these blocks & various other signals which are generated or taken as input and fed to these blocks to process are to produce the desired output.

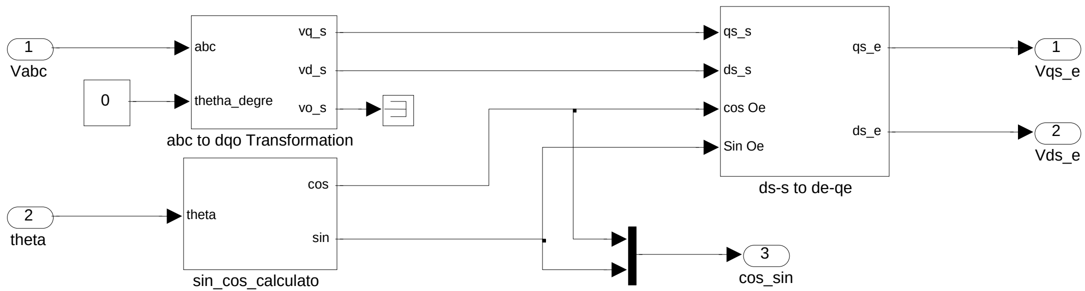

Fig. 4 Inside Model of Subsystem Block of PMSM Block from Fig. 3.

The subsystem block of PMSM main model is further divided into 3 sub models named as abc to dqo transformation, sin-cos calculator, ds-s to de-qe model these models calculate for their respective outputs and which in turn becomes output of subsystem block.

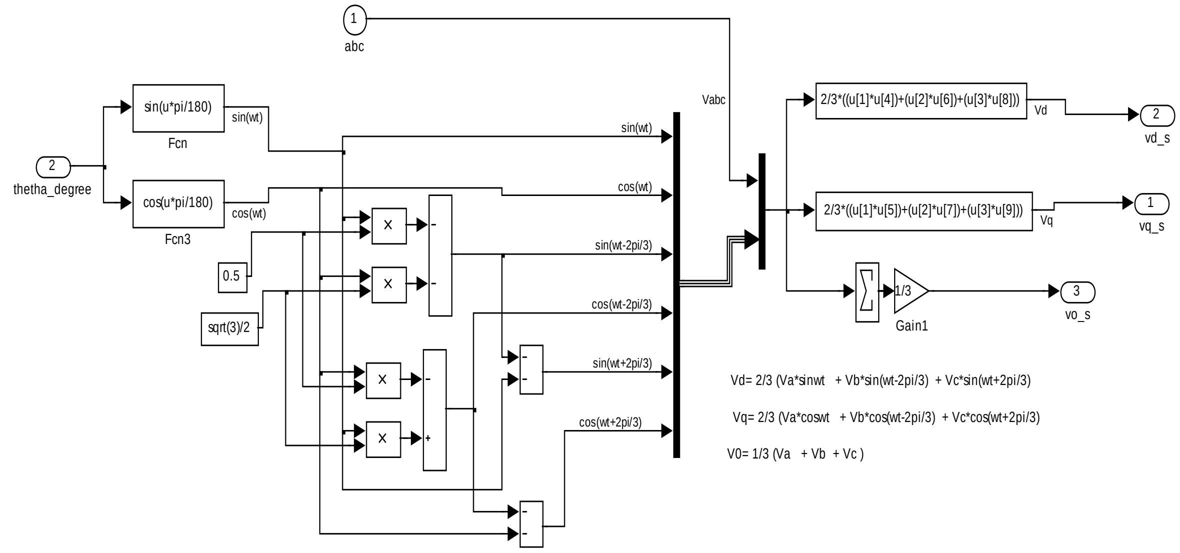

Fig.5 Inside Model of abc to dqo Transformation of Subsystem block fig. 4.

PMSM motor drive simulation was built in several steps like abc phase transformation to dqo variables, calculation torque and speed, and control circuit. For simulation purpose the voltages and currents are taken as inputs and output and one can use Parks transformation for conversion of Vabc to Vdqo.

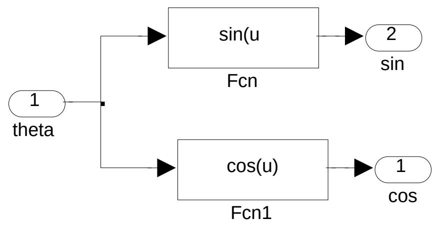

Fig. 6 Inside Model of sin cos Calculator of Subsystem Block Fig. 4.

This is abc to dqo transformation of subsystem of PMSM block which calculates the different voltages which in turn have been used to fed to the ds-s to de-qe block as input in order to calculate output of subsystem block.

This is sin, cos calculator of subsystem of PMSM block which calculates the values of sin & cos of the theta angle which is used as input to ds-s to de-qe block to calculate Vqs_e , Vds_e outputs of subsystem block.

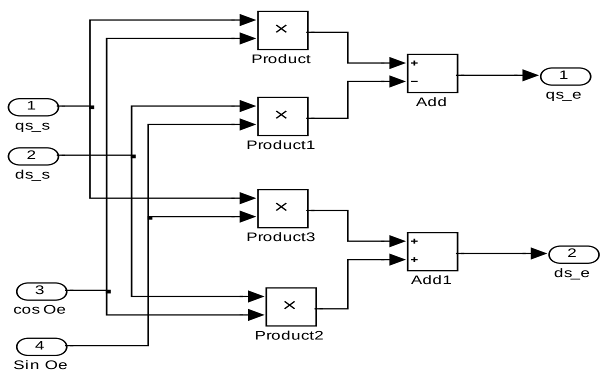

Fig. 7 Inside Model of ds-s to de-qe Calculation of Subsystem Block Fig. 4.

This block known as ds-s to de-qe is the third sub block of subsystem of PMSM block. which receives the Inputs from abc to dqo transformation & sin cos calculation to generate output as qs_e & ds_e.

To generate output of qs_e this block Adds product and product1 block. In this qs_s and cos Oe signals are fed to product and ds_s and Sin Oe are fed to Product1 which are added to produce results of qs_e.

Similarly to generate output of ds_e we add Product 2 and Product 3 block. In this ds_s and cos Oe signals are fed to product2 and qs_s and Sin Oe signals are fed to Product 3 block which are added to produce results of ds_e.

IV. RESULTS

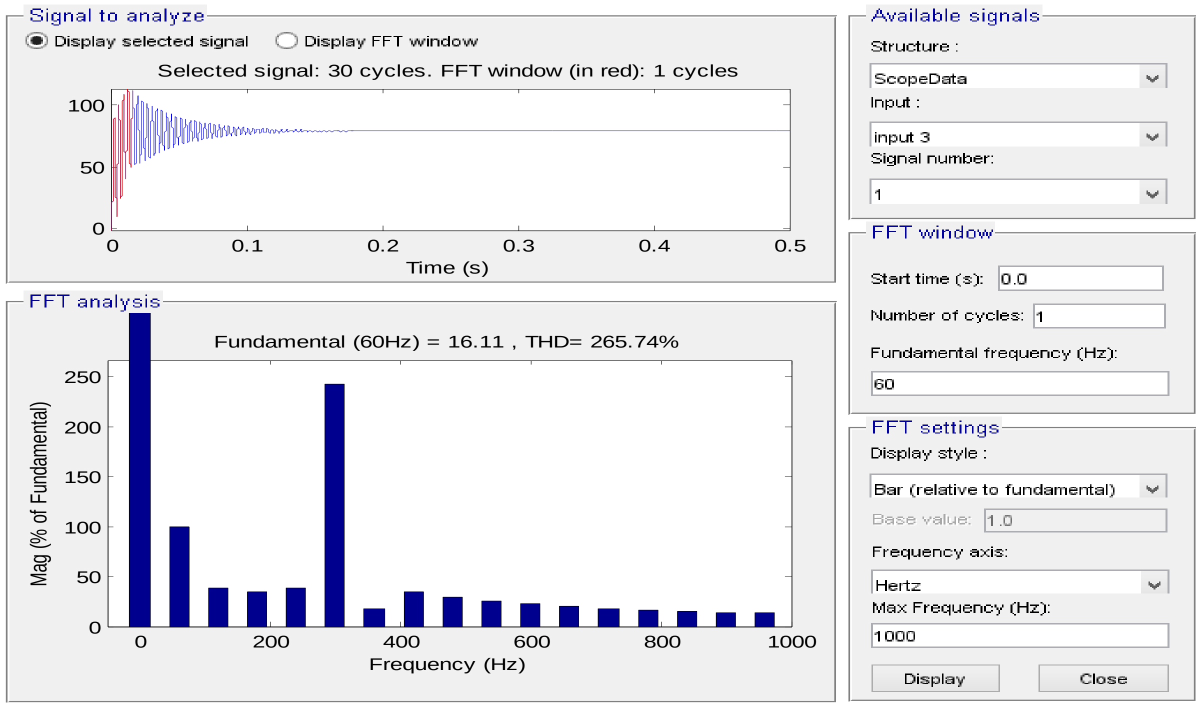

Fig. 8 Gives the Total Harmonic Distortion and Fast Fourier Analysis (FFT) for input-3, Signal Number 1 for 60 Hz Fundamental Frequency and Maximum Frequency of 1000 Hz.

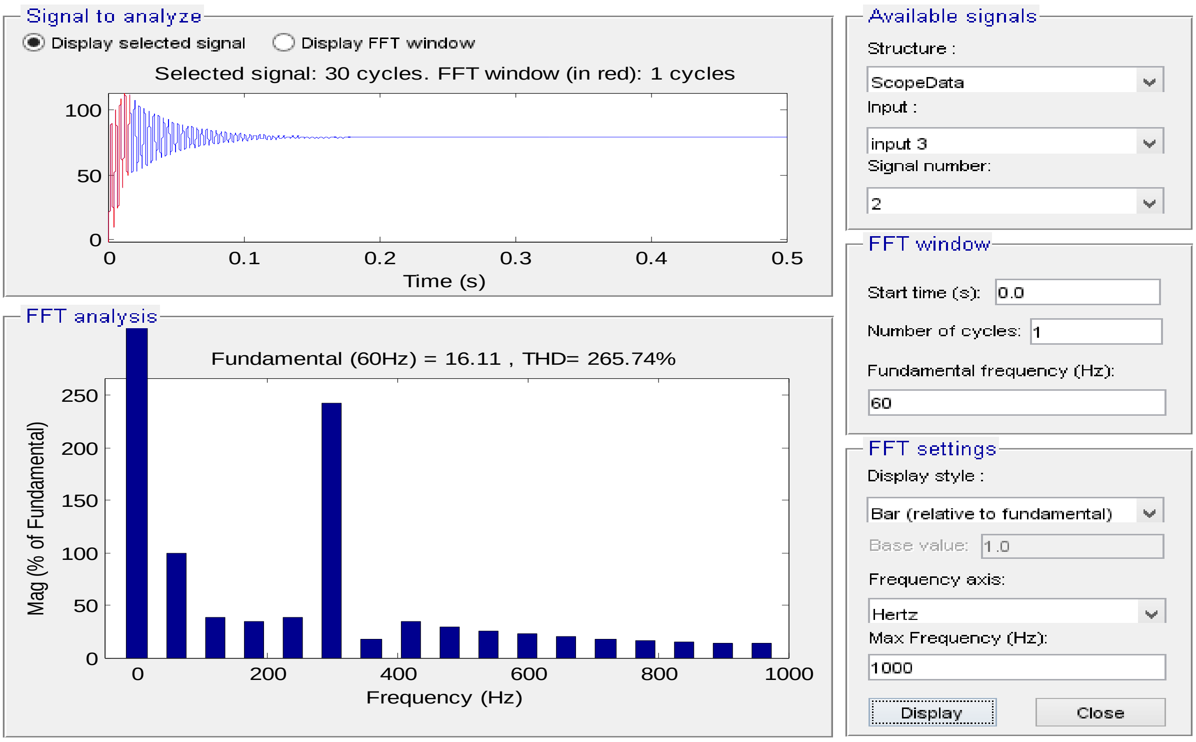

Fig. 9 Gives the Total Harmonic Distortion and Fast Fourier Analysis (FFT) for Input-3, Signal Number 2 for 60 Hz Fundamental Frequency and Maximum Frequency of 1000 Hz.

V. CONCLUSIONS

A detailed Simuliink model for a PMSM block in detail modelling of PMSM drive system for electrical forklifts with field oriented control has being developed and operation at and above rated speed has been studied using two current control schemes. Simulink has been chosen from several simulation tools because its flexibility in working with analog and digital devices. In the present simulation measurement of currents and voltages in each part of the system is possible, thus permitting the calculation of instantaneous or averages losses, and efficiency. Usually in such a drive system the inverter is driven either by hysteresis or by PWM current controllers. A speed controller has been designed successfully for closed loop operation of the PMSM drive system so that the motor runs at the commanded or reference speed.

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