

THE PERFORMANCE ANALYSIS OF HIGH SPEED PERMANENT MAGNET AC SYNCHRONOUS DRIVES USING DIGITAL SIGNAL PROCESSING

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Abstract

This work is improving the speed of Permanent Magnet Synchronous Motor (PMSM) using the Digital Signal Processing (DSP), TMS320LF207. This new family of DSPs enables cost-effective design of intelligent controllers for brushless motors which can fulfill enhanced operations, consisting of less system components, lower system cost and increased performances. The control method presented relies on the field orientated control (F.O.C.). This algorithm maintains efficiency in a wide range of speeds and takes into consideration torque changes with transient phases by controlling the flux directly from the rotor coordinates. In the first part there is account working principle and design of PMSM. Below there is mathematic model of PMSM, which is used in calculation of behavior PMSM. The second part is deal with parameters influence on transient phenomenon, especially his starting and synchronization process. Within this report different enhanced algorithms are presented. Among the solutions proposed are ways to suppress phase current sensors and using a sliding mode observer for speed sensor less control. third case is an IGBTs Inverter with supply cable applied to a PMSM and the last case is Influence of quality of supplied electricity on the behavior of PMSM.

Keywords: Permanent Magnet Synchronous Motor (PMSM), Digital Signal Processing (DSP), TMS320LF207, Rectifiers, Gate Drive, Voltage Source Inverter, Sensor and Interfacing card.

1. Introduction

The Permanent magnet synchronous motors are increasing applied in several areas such as traction, automobiles, robotics and aerospace technology. The Motor control industry is a strong aggressive sector. For each industry to remain competitive they must not only reduce costs imposed by governments and power plant lobbies but also answers to power consumption reduction and EMI radiation reduction issues. The power density of permanent magnet synchronous motor is higher than one of induction motor with the same ratings due to the no stator power dedicated to the magnetic field production. Nowadays, permanent magnet synchronous motor is designed not only to be more powerful but also with lower mass and lower moment of inertia. This model is the results of these constraining factors are the need of enhanced algorithms. DSP technology allows both a high level of performance as well as system cost reduction. Texas Instruments launches a new DSP, the TMS320LF207, specifically designed for the Digital Motor Control segment. This device combines a 16-bit fixed-point DSP core with microcontroller peripherals in a single chip solution and is part of a new generation of DSPs called the DSP controllers. The Block diagram of PMSM Drive using digital signal processing are given below.

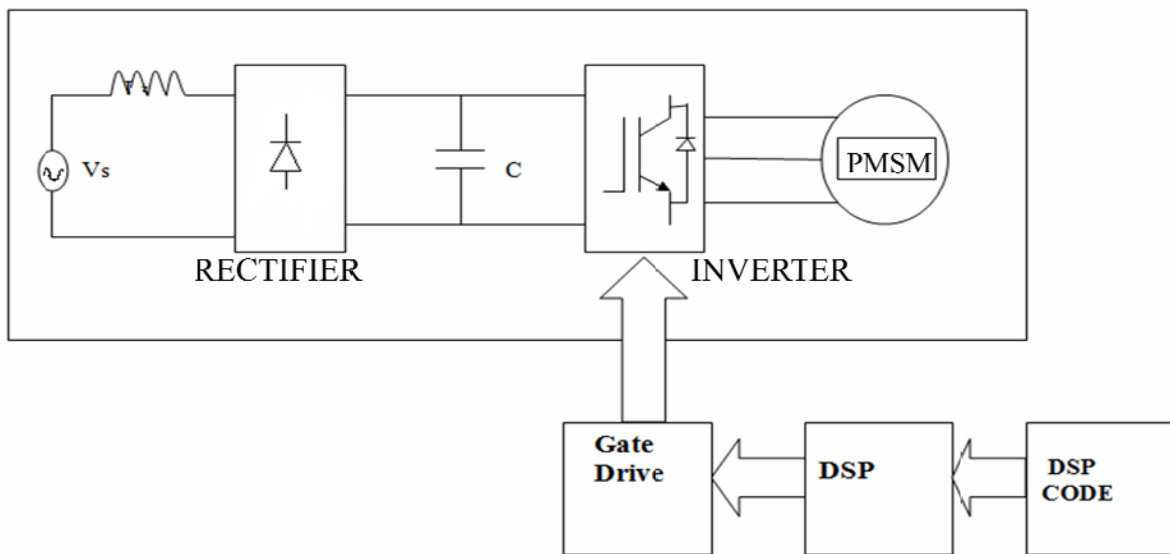
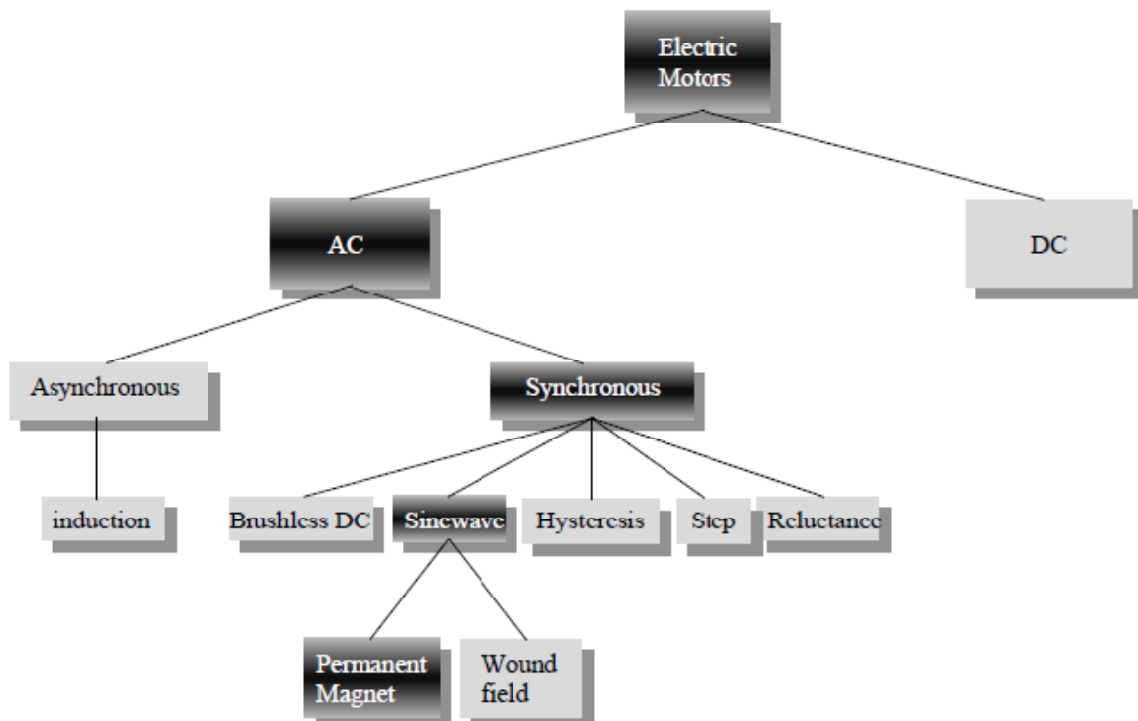


Fig.1 Block diagram of AC PMSM Drive

2. Electric Machines

There are various type of motor studied in this application note is part of the Alternative Current supplied motors. It is synchronous as its speed may directly be determined by the stator frequency and the number of poles. when a magnet was placed so that its field was perpendicular to one face of a thin rectangle of gold through which current was flowing, a difference in potential appeared at the opposite edges. He found that this voltage was proportional to the current flowing through the conductor, and the flux density or magnetic induction perpendicular to the conductor. When a current-carrying conductor is placed into a magnetic field, a voltage will be generated perpendicular to both the current and the field. This principle is known as the Hall effect.

The Classification of electric motors are as given below



a. Permanent magnet synchronous motor (PMSM)

The PMSM basically a synchronous motor but in place of dc field winding in rotor permanent magnet is replaced. that way the elimination of field copper loss, it possible

- a) higher power density
- b) lower rotor inertia
- c) robust construction of rotor

As with most motors, the synchronous motor (SM) has two primary parts. The non-moving is called the stator and the moving, usually inside the stator, is called the rotor. SM can be built in different structures. To enable a motor to rotate two flux are needed, one from the stator and the other one from the rotor. For this process several motor configurations are possible. From the stator side three-phase motors are the most common. There are mainly two ways to generate a rotor flux. One uses rotor windings fed from the stator and the other is made of permanent magnets and generates a constant flux by itself.

The use of magnets enables an efficient use of the radial space and replaces the rotor windings, therefore suppressing the rotor copper losses. Advanced magnet materials such as Sm₂Co₁₇ or NdFeB permit a considerable reduction in motor dimensions while maintaining a very high power density. In the case of embedded systems where the space occupied is important, a PMSM is usually preferred to an AC synchronous motor with brushes. In high-speed regions a point is reached where the supply voltage is maximum and the rotor field has to be weakened as an invert to the angular speed. In the high-speed region also called the field-weakening region, while a PMS motor needs an angle shift to demagnetize the stator windings, the SM with rotor windings maintains maximum efficiency by regulating the rotor currents and then the flux. For high-speed systems where high efficiency is required, AC synchronous motors with rotor windings may be a good compromise. the figure are as.

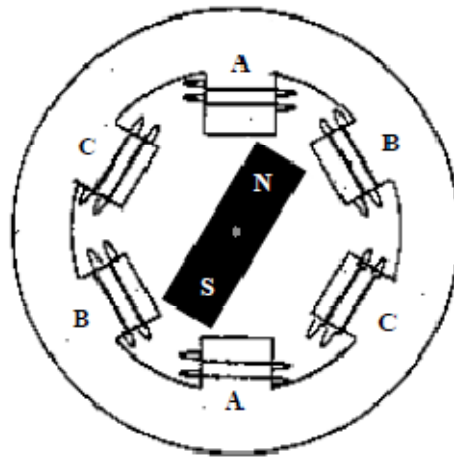


Fig.2 The Cross section of a three-phase synchronous motor with a one permanent magnet pair pole rotor

b. Dynamic model state space equ. of PMSM

3. Digital Signal Processing System

The DSP family is subdivided into three different types: the combination of an integration of a 32Bit RISC processor and several advanced DSPs like the TMS320C8x family, the 32Bit Floating Point Devices e.g. TMS320C3x, and the 16Bit Fixed Point DSPs. The Digital Signal Processors provide high-speed, high-resolution and sensor less algorithms in order to reduce system costs. Providing a more precise control to achieve better consumption or radiation performances often means performing more calculations. The use of some 1-cycle multiplication & addition instructions included in a DSP speeds-up calculations. Generally fixed point DSPs are preferred for motor control for two reasons. Firstly, fixed point DSPs cost much less than the floating point DSPs. Secondly, for most applications a dynamic range of 16 bits is enough. If and when needed, the dynamic range can be increased in a fixed-point processor by doing floating-point calculations in software. The performances of an AC synchronous motor are strongly dependent on its control. DSP controllers enable enhanced real time algorithms as well as sensorless control. The combination of both allows a reduction in the number of components and optimizes the design of silicon to achieve a system cost reduction. A powerful processor such as a DSP controller does the following:

- i. favours system cost reduction by an efficient control in all speed ranges implying right dimensioning of power device circuits
- ii. performs high-level algorithms due to reduced torque ripple, resulting in lower vibration and longer life time enables a reduction of harmonics using enhanced algorithms, to meet easier requirements and to reduce filters cost
- iii. removes speed or position sensors by the implementation of sensor less algorithms decreases the number of look-up tables which reduces the amount of memory required.
- iv. real-time generation of smooth near-optimal reference profiles and move trajectories, resulting in better-performing
- v. controls power switching inverters and generates high-resolution PWM outputs
- vi. provides single chip control system

b.DSP Block Diagram

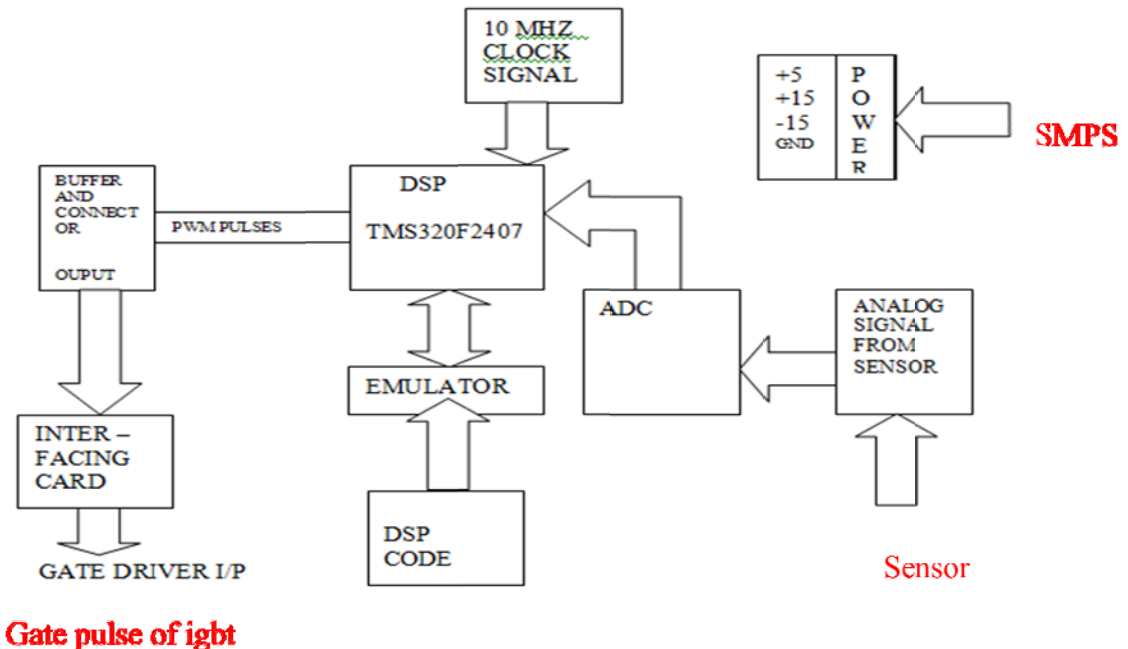


Fig 4

C. Digital signal processor (TMS320F2407)

DSP Part number	TMS320LF207	
Manufacturer	Texas instruments	
No of pin	144	
Total internal	EEPROM 16 bits	
Memory	RAM 16 bits	
Instruction cycle	33 ns	time
Emulator	XDS510USB	
On board clock	10MHz	
Analog to	AD7864AS1	
digital converter		



Fig 5

4. Voltage source IGBT inverter using sinusoidal PWM

The high switching frequency inverters are desirable for ac motor drives, as they permit the operation of the drive with practically sinusoidal stator current and fast current control for high dynamic performance. In addition the audible noises can be reduced at switching frequencies of the order of 20 kHz. Until recently, power bipolar transistors and MOSFET's have been commonly used for inverters driving ac motors. As a third possible alternative, insulated-gate-bipolar transistors (IGBT's) have emerged recently. IGBT's offer low on resistance and require very little gate drive power.

A 1.5-kW prototype PWM inverter using GE IGBTs Type 6E20 is reported in this paper. A gate-drive circuit which provides fast turn-on and turn-off, and adequate protection against overload/shoot through faults is presented. Switching aid networks (snubbers) are necessary to limit the stresses on the IGBTs at turn-on and turn-off. At high switching frequencies, the snubber losses become an appreciable portion of the output power, necessitating an energy recovery circuit to improve the efficiency. A simple and efficient energy recovery circuit which operates reliably at 20 kHz switching frequency is reported.

5. Voltage and Current Sensor

The Sensor is electronic measurement of current and voltage. These sensors can be used for measuring DC and AC voltages & current with different wave forms. This Hall Effect Voltage & current sensors are based on Hall Effect and magnetic compensation principle. They have high electric isolation, high reliability, good overload capability, small sizes.

	Current sensor	Voltage sensor
Measuring Range	±60A	±14V
Conversion ratio	1:1000	2500:1000

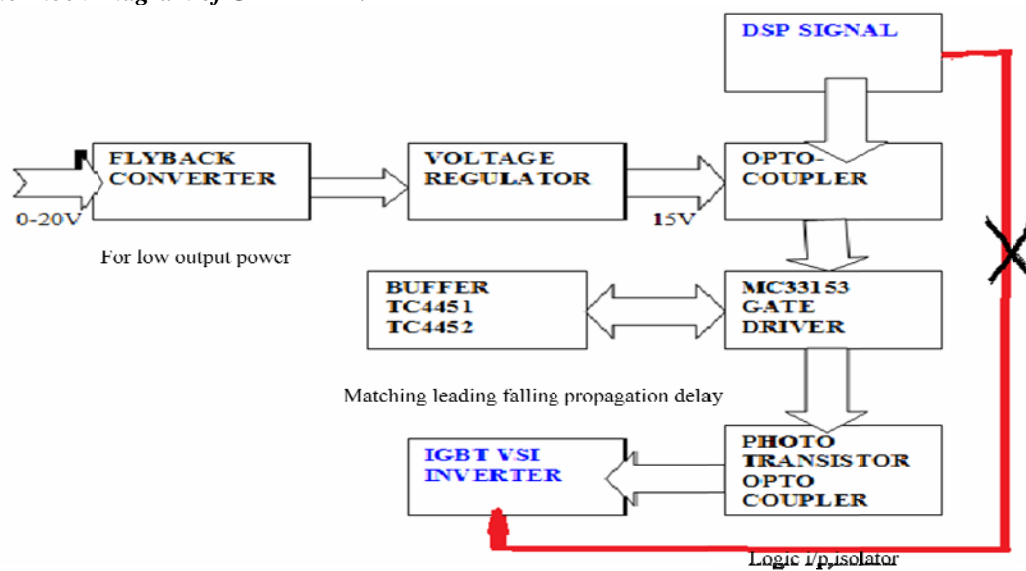
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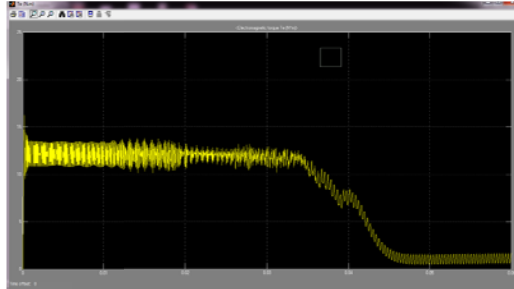
6. GATE DRIVER

The High Current Output Stage: 1.0 A Source/2.0 A Sink. The Protection Circuits for Both Conventional and Sense IGBTs. The Programmable Fault Blanking Time. The Protection against over current and Short Circuit. The Under voltage Lockout Optimized for IGBT's. Negative Gate Drive Capability.

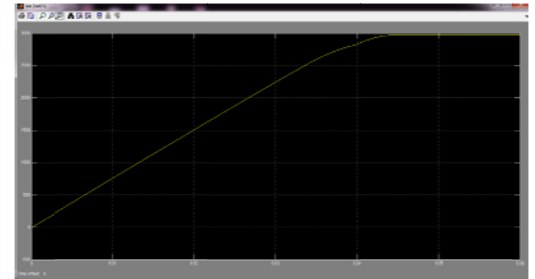
The Block Diagram of GATE DRIVER



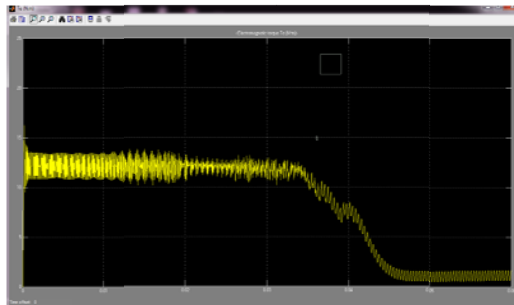
7. Simulation on PMSM Motor Without PWM Control



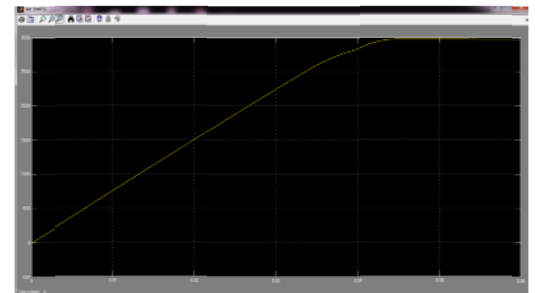
Torque at 3000 rpm



Speed at 3000rpm

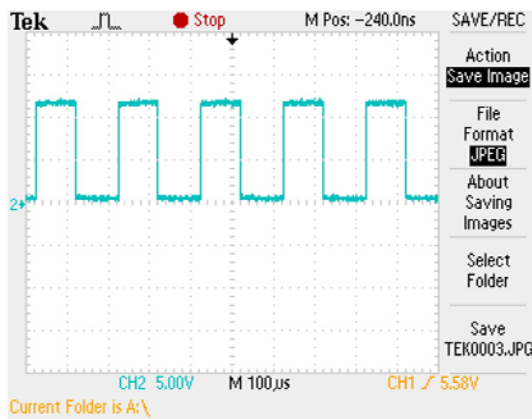


Torque at 3500 rpm

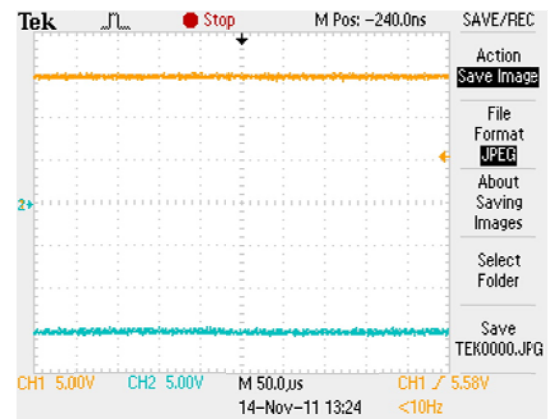


Speed at 3500 rpm

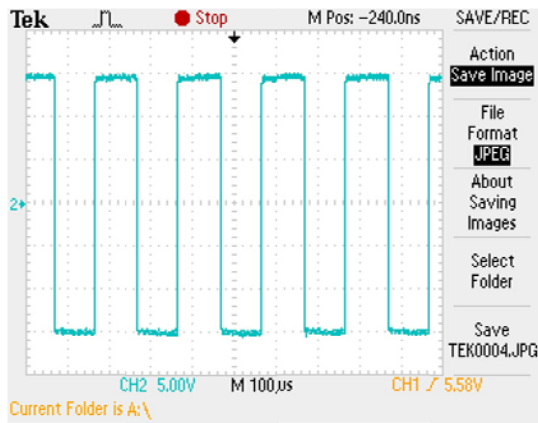
8. Experimental Results:



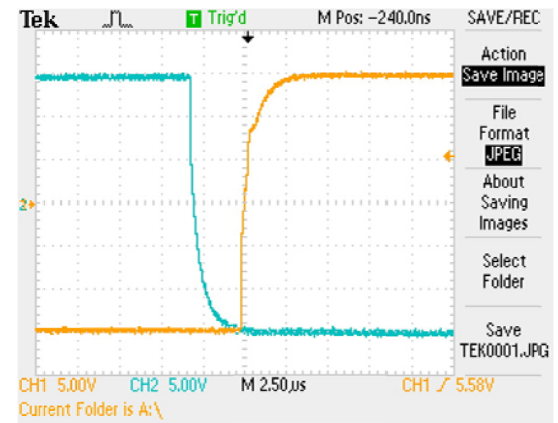
Dsp output pulse



**Gate driver 15v output
Without any pulse**



Dsp Output pulse of gate driver



Ignt gate emitter output pulse

9. Conclusion

In this paper, the proposed resolver algorithm has been verified in the current controlled drive system of PMSM. Both simulation and experimental results are presented. According to these results, the resolver algorithm can force the angle error to zero. Thus, the computed angle can eventually match with the actual rotor angle. Then, the correct rotor speed computation is guaranteed. In the future works, this algorithm will be extensively tested in the speed controlled drive system of PMSM. The DSP-Controller TMS320LF207 combines the performance of DSP architecture with the optimized peripherals of a Microcontroller. With the DSP-Controller an intelligent control approach is possible to reduce the overall system costs and to improve the reliability of the drive system. The paper includes a short overview of sensorless control concepts focused for 3 phase PMSM and induction cage motors. For two sensorless control strategies practical examples of its implementation and its results were given.

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