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CLOSED LOOP CONTROL OF PMSM MOTOR DRIVE USING DSPACE.

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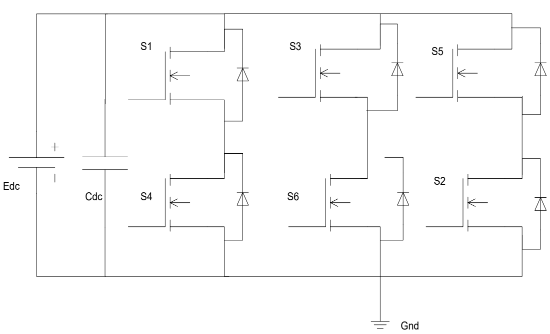
1. Abstract:

The motive of this paper is to talk about the rapid manipulate prototype implementation of closed loop pace manipulate for a PMSM motor force the use of the dSPACE DS1103 controller board. In general, manage algorithms created for motor drives may additionally produce practical simulation outcomes underneath steady-state and transient situations; nevertheless, real-time overall performance of the force is pretty dependent. On real-time manage software program execution, pace and role measurements, and facts acquisition are the authentic hardware challenge. The key to profitable implementation is the decision of splendid hardware tools and the proper setup of the gear with the controller board. Because it can seriously change MATLAB/Simulink blocks into DSP successful embedded code, the dSPACE DS1103 controller board is perfect for excessive overall performance electric powered motor control. This learns about gives a thorough strategy for exact controlling the PMSM motor pressure in real-time.

2. Three Phase PWM Inverter

We use inverters to convert the DC supply into AC supply at rated frequency and required power. The inverters are classified into some categories which is given as below. Based on the categories, they are classified into VSI and CSI (based on source), Half Bridge and Full Bridge(topology), 180^{o} and 120^{o} conduction mode other types and etc. PWM inverters are used widely than the other type of the inverters. To explain briefly about the construction of the inverter, it is the build of switches which is MOSFET or IGBT and the switching function takes place to get the desired output voltage. It is commonly understood that some switching devices exist between the source and the destination. The number of switches is depending on the type of the load. The load increases and the switches are increases in the inverter.



3. PMSM MOTOR

3.1. Introduction

A synchronous electric powered powered motor is an alternating modern (AC) motor in which the rotation of the shaft is

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synchronised with the frequency of the furnish present day in constant state; the rotation size is exactly equal to a vital vary of AC cycles. Synchronous motors have multiphase AC electromagnets on the stator that generate a magnetic situation that spins in time with the line cutting-edge oscillations. These motors are moreover divided as Non-excited and DC excited synchronous motors work primarily based completely on the magnetic electrical energy of the motor. Under Non-excited dc synchronous motors consist of reluctance motors, hysteresis motors, and eternal magnet motor. In this paper, we will go via the strolling thinking of a PMSM motor in brilliant depth. In PMSM motor Permanent magnets are used that create sinusoidal lower back EMF to spark off the self-discipline in a PMSM motor.

3.2. Working Principle

The operation of an eternal magnet synchronous motor is similar to that of a synchronous motor. It is determined with the useful resource of the spinning magnetic field, which creates electromotive stress at synchronous speed. When the stator winding is powered with a 3-phase supply, a spinning magnetic difficulty is fashioned between the air gaps. When the rotor concern poles proceed the revolving magnetic region at synchronous pace and the rotor rotates constantly, this creates torque. Because they are now now not self-starting motors, a variable frequency electrical energy provide is required.

3.3. Torque and Speed characteristics of PMSM

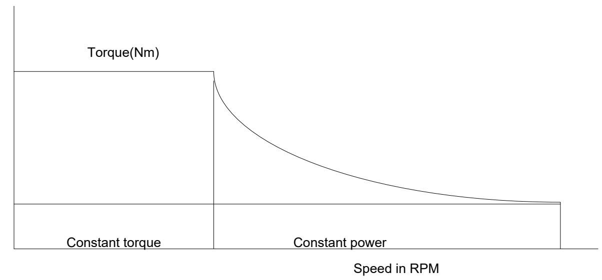


Fig: Graph between speed and torque.

To acquire consistent torque, the PMSM motor requires sinusoidal stator currents. Because there is no want to feed electric powered present day to the rotor, there is no want for a commutator with brushes, which makes the sketch greater dependable. However, due to the fact everlasting magnet motors lack commutators, they have to be managed by means of electrical circuitry. The manipulate device ought to be successful of handing over appropriate sinusoidal electric powered modern to the motors. In torque pace traits if velocity is elevated past the factor there is chance of over cutting-edge due to the fact the terminal voltage stays steady due to modern-day is nearly a pure reactive cutting-edge flowing from motor again to the supply.

3.4. Parameters of PMSM motor

The parameters and the total details of the PMSM motor are given below. The model number of the given PMSM motor is T85.SR.2.2.E.H.14.003.A.16.104 and the classification of the model represents TETRA series, 85 represents the type, SR represents the sine wave, 2.2 represents the nominal torque, E represents the Encoder, H represents the high moment of inertia, 003 represents the Transducer model. The ratings of the PMSM motor are as follows:

S.no	Parameter	Values	Symbols	Units
1	No. of Poles	4	P	---
2	Damping Constant	0.018	T_d	Nm
3	Weight	3.2	M	kg
4	Rated Voltage	250	V_n	V ac
5	Rated Current	2.5	In	A
6	Operative time	1	ms	---
7	Static torque	4.5	C_0	nm
8	Input Power	12	P_n	W
9	Engaging time	7	T_r	ms
10	Release time	35	Ti	ms
11	Moment of inertia	1.3/0.9	J_m	Kgcm2

4. Real time implementation (Hardware)

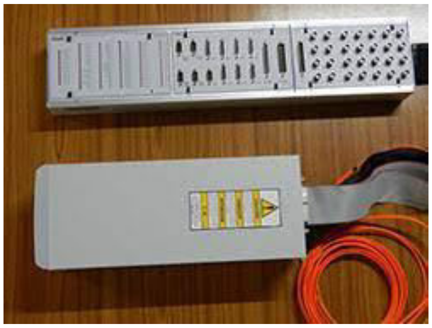
The DS1103 PPC Controller Board is in unique designed for enchancment of high-speed multivariable digital controllers and authentic time simulations in a range of fields. It is a complete real-time control computer that is powered via a PowerPC processor. The board consists of a slave-DSP subsystem principally primarily based on the Texas Instruments TMS320F240 DSP microcontroller for most effective I/O.

4.1. DS1103R&D Controller Board

Single board manipulate device at a low price for single board manage improvement The DS1104R&D Controller Board converts a PC into a improvement system, permitting for fast manage prototyping. The board is like minded with simply any PC that has a free PCI or PCIe slot.

4.2. DS1103 PPC Controller Board

A study controller board for speedy manipulates prototyping. The controller board is supposed to meet the wants of cutting-edge speedy manage prototyping and is well-suited for purposes such as induction motor control.



4.3. Control Desk Environment

You need to sit down in the front of a laptop that has the dSPACE programme and the DS1103 board installed. The intention of this first part is to stroll you via the method of beginning up the programme and appreciation its most important functionalities. In the following section, we will display how to use software program and hardware to create a very easy manipulate system. To begin, the following shortcut from the PC working device lets in get right of entry to to the dSPACE. If the Control Desk shortcut does now not show up on the desktop, please begin it from the "dSPACE Tools" folder below "Start / Programs". Control Desk is a graphical person interface. The DS1103 board is a platform for jogging simulations, tons as Matlab is a platform for going for walks non-real-time simulations. As a result, you will see icons for each the DS1103 and MATLAB on the Navigator's Platform tab. They

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are each simulation structures to which Control Desk may additionally connect; however, for the functions of this project, we will pay attention on utilising Control Desk with the DS1103. You will be capable to down load apps to the DS1103, configure digital instrumentation to control, monitor, and automate operations, and boost controllers from this environment. There are three areas proven in the view proven above (the Control Desk's default window settings). In any case, once you get there,

You'll see the following window:

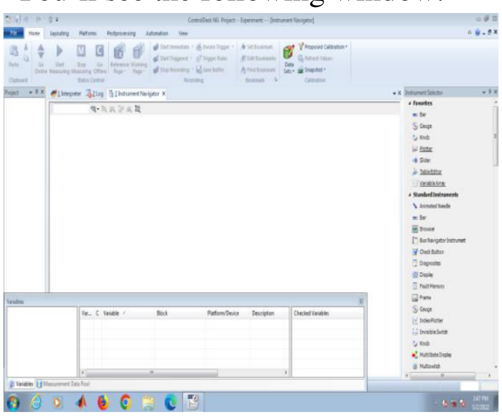

Fig: Control Desk environment

4.4. Design Steps in Matlab and Control Desk

In MATLAB model, the following steps should be observed for configuring parameters and interfacing the manage desk:

Step 1: MATLAB lanching.

Step 2: Construct a new Simulation model.

Step 3: Design and shop the Simulink mannequin

Step 4: Set the cease time as (inf)

Step 5: Edit the configuration parameters as given in step 6.

Step 6: Set the solver parameters as

a. Solver_ ode1 is stored (Euler)
b. Fixed step dimension multiples of pattern time
c. Uncheck optimization

Step 7: Lay the hardware configuration as.

a. Device dealer is given as (Generic)
b. Device kind is given as (Custom)
c. Integer is saved (int)
d. floating factor as (float)
e. Byte ordering as (BigEndien)
f. Signed integer division rounds to (zero)

Step 8: Click observe and ok.

Step 9: construct the Simulink mannequin and affirm the steps in diagnostics viewer.

The construct technique ought to be one hundred percent successful.

Step 10: An .sdf file will be generated after completion of construct process.

On profitable technology of .sdf file, the outcomes will be validated in dSPACE controldesk.

4.5. dSPACE Control desk

Step 1: Check the pulse effects in the slave I/O connector.

Step 2: MATLAB simulation block can be determined in "all variable descriptions".

Step 3: Select .sdf file and pick mannequin root.

Step 4: Drag and drop MATLAB blocks to dSPACE domestic screen.

Step 5: Choose excellent dimension indicators.

Step 6: Launch manipulate desk on desktop.

Step 7: Create a new mission and

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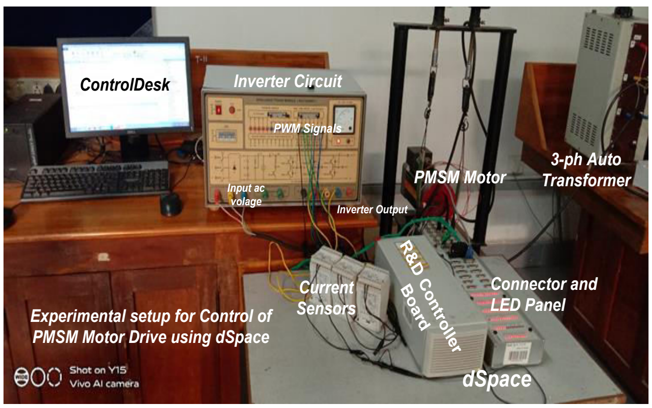
experiment.
Step 8: Choose names for project, root listing and experiment.
Step 9: Add platform machine DS1103 from the list.
Step 10: Import .sdf file (it will be on hand in MATLAB file store location).
Step 11: After completion of above steps click on on "go online".

4.6. Experimental Setup for dSpace:



The equipment that is used in experimental setup are

i. Control Desk platform.
ii. Power module with inverter circuit.
iii. Auto transformer.
iv. Current sensors.
v. dSpace equipment.
vi. R&D controller board.
vii. Connector and LED panel.
viii. PMSM motor.

From the experimental set up shown in the above figure, the inverter output is controlled by the pwm gate signals generated by dSpace. Control Desk platform is used to execute the blocks of dSpace. Input to the rectifier is AC which is given by auto transformer with the ratings of (0-440V) AC gives DC output. The output of inverter is connected to motor. The output currents of inverter are measured in control desk by using current sensors that are connected in series in between inverter and motor load. Sensors having input ratings as (0-10 A) AC gives proportional DC voltage with the range of (0-10V). First, we use matlab to construct the simulation diagram which is converted into .slx file. Later it is connected to the control desk and thereby we can convert the digital signal into the analog signal with the help of DS1103 controller board. To explain briefly, we have to open the matlab and followed by the Simulink and they are matlab libraries which connects the dspace and these library blocks are will be in presence of the license key only. After building the circuit, we have to convert the matlab file into slx file. Then we have to open the control desk and upload the given file place the plotter. When we go online and start the measurement it transfers to the analog ports also the pulses are sent to the power module with the help of slave i/o and o/p port. Finally with the given data the pmsm motor will rotate and the output can show in the plotter. In the DS1103 controller board we can analog to digital and digital to analog signals. The dspace equipment and connector and LED panel are connected through ribbon cable. All the libraries are installed to pc through a licence key. Dspace is connected to CPU through cable. Matlab code is developed to the given model. sdf file is generated. Open control desk and import sdf file to controldesk. Run the project and get the output waveforms.

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4.7.Inverter circuit output waveforms:

The below wave form represents waveforms of three-phase currents with respect to time. The red colour wave form represents the phase A and the green represents the phase B blue gives to phase C. These currents are 120 degrees phase shift because of R load is applied.

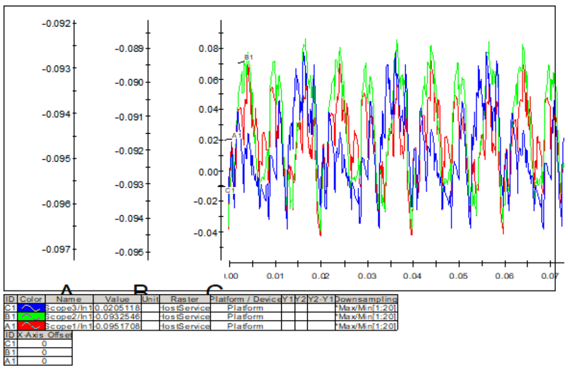

Fig: Inverter currents Ia, Ib , Ic.

4.8. Block diagram of closed loop control of PMSM motor

From the simulation shown in below figure, a closed loop control of pmsm motor is executed. The output voltages, currents, torques (motor, load) and speed are taken out. From beginning of the block, reference speed is given as a one input to adder block and the other input to adder is the actual speed of the motor converted from radian per sec to rpm taken as feedback from mux. This adder output is given to pi controller in which it reads the error of speed. The pi controller calculates the required speed and generates the required current Iq, which is given to current controller (Iq). Similarly for Id current zero is taken as reference and Iabc is taken from the motor output both given to adder, which generates required current Id. From the given Simulink block diagram, reference speed is given as 1200 rpm given to adder and actual speed is given feedback to the adder. output of the adder is given to PI Controller. The output of reference speed and actual speed can be seen in scope1.

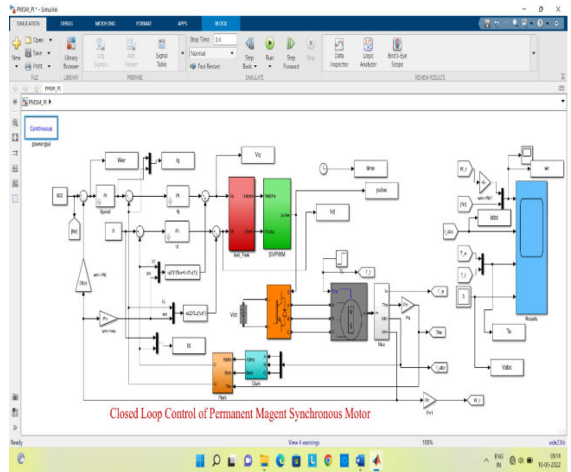

Fig: Simulation block diagram

5. Results and discussion

The graph is drawn in between speed vs time. From the graph shown, initially the speedincreases gradutly and reaches 110% of reference speed and decreases to reference speed and at 0.2 secd it follows the reference speed., so speed is constant. This is beacause of closed loop control of pmsm motor.

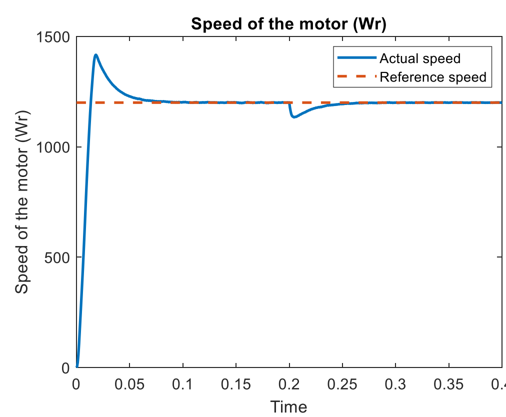

Fig: speed vs time graph for reference speed of 1200 RPM

The graph is drawn in between torque vs time. From the graph shown, initially the

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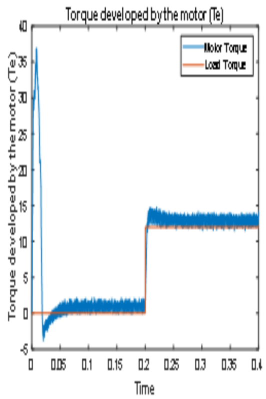
torque required to start the motor is high and then gradduually it decreases and becomes zero. After 0.2 seconds the torque risies due to applying the load and initially the inertia is more. And The graph is drawn in between voltages va, vb, vc vs time.



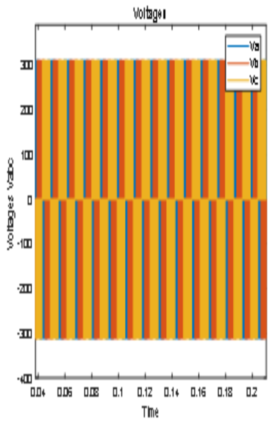
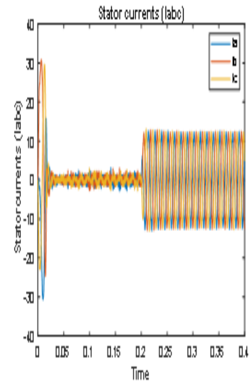


Fig: Torque vs time graph for reference speed of 1200 RPM Fig: voltage vs time graph for reference speed of 1200 RPM

The graph is drawn in between current vs time. Initially the current required to start the motor is high and then gradually it decreases and becomes zero. After 0.2 seconds the curent risies due to applying the load. Initially, the motor is at rest position. So, the inertia to the motor is very high which leads to draw a very large current initially. A resistive load is applied to the inverter at 0.2 seconds. As load increases the current drawn from inverter circuit also increases. All the three phase currents follow 120 degrees phase shift.



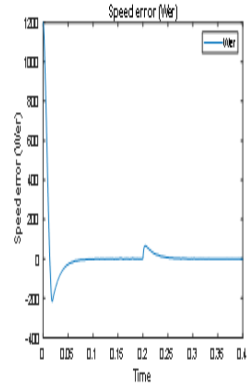


Fig: Current vs time graph for reference speed of 1200 RPM Fig: Speed error vs time graph for reference speed of 1200 RPM

The graph is drawn in between speed error vs time. From the graph shown, initially the speed error is very high because there will be no action of feedback loop gradually the time goes on the speed error becomes zero due to feedback loop. The feedback speed is in radian per sec. This speed is conveted to rpm with appropiate convertion so that the difference is will be zero. Initially the error is high beacause there is no feedback initially, as time goes on the feed back sensors sends the speed signals to the PI controller and then it compares the actual speed and the motor speed which is given by the feed back sensor and generates the required currents to control the motor.

The graph is drawn in between pulses vs time. There are total six switches to the inverter circuit. There will be six gate pulses that to be given through PWM technique.

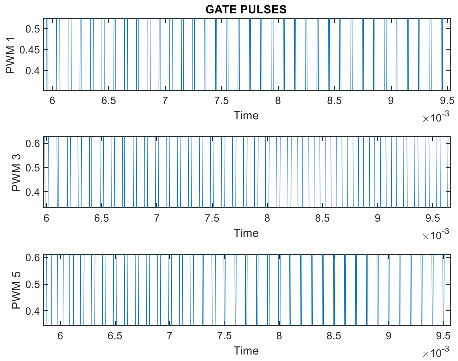


Fig: Pulses vs time for reference speed of 1200 RPM

6. Conclusion:

The use of a dSPACE DS1103 controller board for fast manage prototyping for closed loop manipulate of a PMSM has been examined. The designed scheme has been efficiently examined at speeds ranging from 15 rpm to 2500 rpm. The effectivity of the proposed technique has been investigated for a number reference speeds. The overall performance of proposed approach has been determined to be honest in all circumstances. The key gain of this learn about is that it reduces the trying out time of the proposed manage algorithms for PMSM motors, and a comparable strategy can be used for any different electrical machine.

As a result, it can be mentioned that enforcing a speedy manage prototyping technique for pace manipulate of a PMSM motor utilising dSPACE DS1103 minimises experimental time and effort.

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