

MOSFET based Three-Phase Space Vector-PWM Motor Speed Controller

Mr. Raj Kumar Singh, Prof. Aziz Ahmad, Mr. Pankaj Kumar Gupta

Abstract— A 3-phase squirrel-cage motor rated 3 HP, 220 V, 60 Hz, 1725 rpm is fed by a 3-phase MOSFET inverter connected to a DC voltage source of 325 V. The inverter is modeled using the "Universal Bridge" block and the motor by the "Asynchronous Machine" block. Its stator leakage inductance L_s is set to twice its actual value to simulate the effect of a smoothing reactor placed between the inverter and the machine. The load torque applied to the machine's shaft is constant and set to its nominal value of 11.9 N-m. The firing pulses to the inverter are generated by the "Space-Vector PWM modulator" block of the SPS library. The chopping frequency is set to 1980 Hz and the input reference vector to "Magnitude-Angle".

Index Terms— Asynchronous motor, MOSFET based multilevel inverter, SVPWM modulator, V/F controller.

1 INTRODUCTION

With the development of power electronic devices like the insulated gate bi-polar transistor (IGBT), the power MOSFET and the advances in microprocessors, the ac induction motor is becoming popular in variable speed drives with PWM inverter circuits. Since the rise time and fall time of the IGBT's are less than 200 nano-seconds, the dissipation loss across the device becomes very less and there by increases the performance of the circuit. However, due to the fast switching action of the device the dv/dt of the inverter output becomes large. This high dv/dt voltage transition coupled with parasitic stray capacitance in the system causes high frequency line to ground current or common mode current and hence bearing current; introducing large EMI in the system.

Nowadays in so many applications desire controlled A.C. for controlling speed of machines like Induction Motor, Brushless D.C. Motor etc. For getting controlled A.C. nowadays inverter is used. Inverter is converting uncontrolled D.C. into controlled A.C. There are so many types of inverter like two level, three level and five level etc. The multilevel inverter [MLI] is a promising inverter topology for high voltage and high power applications [3]. This inverter synthesizes several different levels of DC voltages to produce a staircase (stepped) that approaches the pure sine waveform.

This have high power quality waveforms, lower voltage rat-

ings of devices, lower harmonic distortion, lower switching frequency and losses, higher efficiency, reduction of dv/dt stresses and gives the possibility of working with low speed semiconductors if its comparison with the two-levels inverters.

2 CIRCUIT DESCRIPTION

Speed control of the motor is performed by the "Constant V/Hz" block. The magnitude and frequency of the stator voltages are set based on the speed set-point. By varying the stator voltages magnitude in proportion with frequency, the stator flux is kept constant. A three-phase motor rated 3 HP, 220 V, 1725 rpm is fed by a sinusoidal PWM inverter. The base frequency of the sinusoidal reference wave is 60 Hz while the triangular carrier wave's frequency is set to 1980 Hz. The PWM inverter is built entirely with standard Simulink® blocks. Its output goes through Controlled Voltage Source blocks before being applied to the Asynchronous Machine block's stator windings. The machine's rotor is short-circuited. Its stator leakage inductance L_s is set to twice its actual value to simulate the effect of a smoothing reactor placed between the inverter and the machine. The load torque applied to the machine's shaft is constant and set to its nominal value of 11.9 N.m. The motor is started from stall. The speed set-point is set to 1.0 pu, or 1725 rpm. This speed is reached after 0.9 s.

The initial states required to be in steady state with a 1725 rpm reference speed and a 11.9 N-m load torque have been saved in the "power_svpwm_init.mat" file. When you open this model, the InitFcn callback (in the Model Properties/Callbacks) automatically loads into your workspace the contents of this .mat file ("xInitial" variable).

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If we modify this model, or change parameter values of power components, the initial conditions stored in the "xInitial" variable will no longer be valid and Simulink® will issue an error message.

Variable speed control of AC electrical machines makes use of forced-commutated electronic switches such as IGBTs, MOSFETs, and GTOs. Asynchronous machines fed by pulse width modulation (PWM) voltage sourced converters (VSC) are nowadays gradually replacing the DC motors and thyristor bridges. With PWM, combined with modern control techniques such as field-oriented control or direct torque control, you can obtain the same flexibility in speed and torque control as with DC machines. This section shows how to build a simple open loop AC drive controlling an asynchronous machine. Chapter 4 will introduce you to a specialized library containing 13 models of DC and AC drives[7]. These "ready to use" models will enable you to simulate electric drive systems without the need to build those complex systems yourself.

The Machines library contains four of the most commonly used three-phase machines: simplified and complete synchronous machines, asynchronous machine, and permanent magnet synchronous machine. Each machine can be used either in generator or motor mode. Combined with linear and nonlinear elements such as transformers, lines, loads, breakers, etc., they can be used to simulate electromechanical transients in an electrical network. They can also be combined with power electronic devices to simulate drives.

The Power Electronics library contains blocks allowing you to simulate diodes, thyristors, GTO thyristors, MOSFETs, and IGBT devices. You could interconnect several blocks together to build a three-phase bridge. For example, an IGBT inverter bridge would require six IGBTs and six antiparallel diodes.

3 REALIZATION AND DEMONSTRATION

Start the simulation. Since the initial states have been automatically loaded, the simulation should start in steady-state. The initial motor speed should be 1720 RPM and the rms value of the stator voltages should be 220V@60Hz.

At 0.1s, the speed setpoint is changed from 1725 to 1300 RPM. You can observe the system dynamic looking inside Scope 1. When the motor reaches a constant speed of 1275 RPM, the stator voltage rms value is down to 165.8V and the frequency to 45.2 Hz.

Stator voltage (phase AB) and phase A current waveforms

can be observed in the "V-I Stator" Scope. You can do a FFT of these two quantities using the powergui FFT Analysis.

To regenerate initial conditions:-

The initial states required to start this model in steady state with a 1725 rpm reference speed and a 11.9 N.m load torque have been saved in the "power_svpwm_init.mat" file. When you open this model, the InitFcn callback (in the Model Properties/Callbacks) automatically loads into your workspace the contents of this .mat file ("xInitial" variable).

If you modify this model, or change parameter values of power components, the initial conditions stored in the "xInitial" variable will no longer be valid and Simulink will issue an error message. To regenerate the initial conditions for your modified model, follow the steps listed below:

In the Simulation/Configuration Parameters/Data Import/Export Parameters menu, uncheck the "Initial state" parameter.

Double click on the Step block labeled "Speed Set-point (RPM)" and temporarily disable the change of reference speed by multiplying the Step time by 100.

Change the Simulation Mode from "Normal" to "Accelerator".

Start simulation. When simulation is completed, verify that steady state has been reached by looking at waveforms displayed on the scopes. The final states which have been saved in the "xFinal" structure with time can be used as initial states for future simulations. Executing the next two commands copies these final conditions in "xInitial" and saves this variable in a new file (myModel_init.mat). * >> xInitial = xFinal; * >> save myModel_init xInitial

In the File/Model Properties/Callbacks/InitFcn window, change the name of the initialization file from "power_svpwm_init" to "myModel_init". Next time you open this model, the variable xInitial saved in the myModel_init.mat file will be loaded in your workspace.

In the Simulation/Configuration Parameters menu, check "Initial state".

Start simulation and verify that your model starts in steady-state.

Double click on the Step block labeled "Speed Setpoint (RPM)" and re-enable the change of reference speed at t=0.1 s

(remove the 100 multiplication factor in the Step time).

Change the Simulation Mode back to Normal.

Save your Model

4 SIMULATION AND RESULT

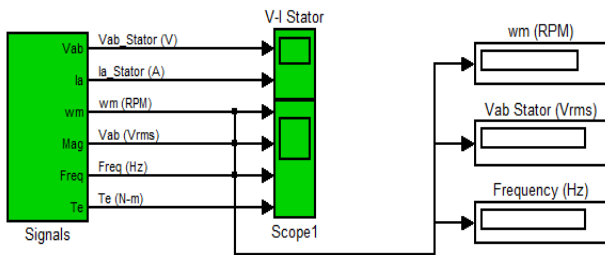


Fig 1. Schematic of scope and V-I stator

The change in speed of the motor can be shown in ω_m block w.r.t change in voltage and frequency of supply to the stator. The corresponding waveforms can be shown in scope1. From the waveforms we can concluded that speed of the motor decreases with the corresponding decrease in voltage and frequency but at constant ratio.

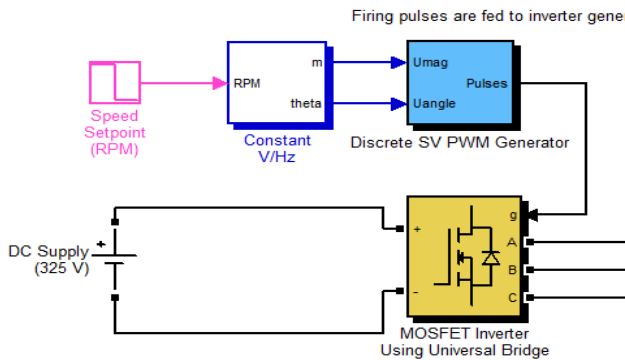


Fig 2. Connection of MOSFET and PWM Generator

In the above block shown in fig 2. the magnitude of voltage and phase angle changes according to the set-speed in constant V/Hz block. SVPWM generator generates pulses according to the output of constant V/Hz. Inverter gives output according to the pulses generated by SVPWM generator.

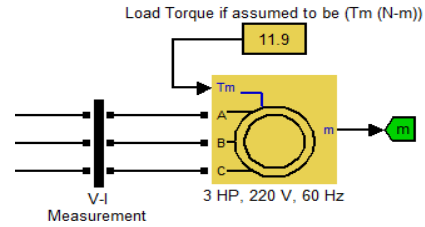


Fig 3. Connection of 3 HP motor on specified torque.

In the above block load torque is set to 11.9 N-m. Input supply is given to AC – drive which helps in starting as well as controlling the speed of the 3HP, 220V, 60Hz induction motor.

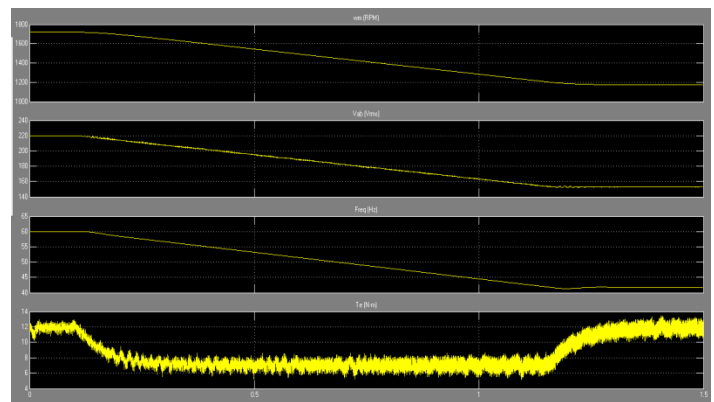


Fig 4. Plot of V-I and frequency

5 CONCLUSION

In this paper it is concluded from the above results that speed of 3-phase induction motor can be controlled by controlling voltage and frequency simultaneously so that (v/f) ratio remains constant. The stator flux is also kept constant. The motor torque decreases only for the duration when voltage decreases and attains the same value when voltage maintains constant value. This drive system can be used energy saving in variable torque load applications like boiler feed pumps conveyors, rolling mills, printing machines etc.

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