Numerical simulations of three-phase induction motor driving fans using SimPower Systems in Matlab-Simulink environment

Module ENEE2408 – Electrical Machines
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1. Introduction

This tutorial helps you to familiarize with one of the speed control methods of three-phase induction motor using numerical simulations. This could be very useful for understanding the operating principle of induction motors driving fans and how the motor speed can be controlled by changing the line voltage.

2. Learning objectives

In this exercise, you will examine some of the common blocks used in SimPower Systems building a simple simulator of three-phase induction motor driving a fan load.

Upon successful completion of the exercise, you should be able to:

- Construct a simple power circuit connecting together Simulink blocks;
- Build a simulator of 3-phase induction motor;
- Understand the stator voltage variation method as a speed control method for the three-phase induction motor;
- Be able to plot the torque-speed characteristic of the motor using MATLAB M-file.

3. Project

A 7.5 kW, three-phase, 400 V, 50 Hz, 4-pole, 1440 rpm, star-connected induction motor has the following parameters referred to the stator side:

$$R_s = 0.7384\ \Omega,\ R_r' = 0.7402\ \Omega,\ L_s = 3.045\ \text{mH},\ L_r' = 3.045\ \text{mH},\ L_m = 0.1241\ \text{H}$$

$$J = 0.0343\ \text{kg. m}^2,\ F = 0.000503\ \text{N.m.s}$$

The speed of the motor is controlled by stator voltage variation method. The motor is driving a fan load its characteristic is given by: $T_{Load} = C\,\omega_m{}^2$

Calculations

a) Calculate the rated torque, slip, current, efficiency, slip at maximum torque, and maximum torque

b) Calculate the torque, slip, current, efficiency, slip at maximum torque, and maximum torque if the line-to line voltage across the motor windings is changed to 150 V.

Simulation

c) Simulate the motor with the fan load using Matlab-Simulink

Development of the model

- From the SimPower system menu, select “Electrical Sources” and then “AC voltage source”. Add three sources to your model and then connect them in star configuration.

Source 1: Set the peak amplitude to 400*sqrt(2) V, the phase to 0 and the frequency to 50 Hz.
Source 2: Set the peak amplitude to 400*sqrt(2) V, the phase to -120^o and the frequency to 50 Hz.
Source 3: Set the peak amplitude to 400*sqrt(2) V, the phase to 120^o and the frequency to 50 Hz.

- From the SimPower system menu, select “Machines” and then “Asynchronous Machine SI Units” Select “squirrel-cage” as rotor type. Select “10 HP (7.5 kW), 400 V, 1440 rpm, 50 Hz” as a squirrel cage preset model. Leave the other parameter unchanged and click “Apply” or “OK”.

- Select “Measurements” and then the blocks “Three-Phase V-I measurement”. Connect the block in series between sources and motor. Connect each of the outputs of the measurement block to a scope (you can find it in “Simulink” -> “Sinks).
- Connect the terminal ‘m’ of the motor to a bus selector (you can find it in “Simulink” -> “Signal Routing). Click on the bus selector and select both rotor speed and torque to measured them, and then connect each of the outputs of bus selector to a scope (you can find it in “Simulink” -> “Sinks).
- Connect the terminal ‘Tm’ of the motor to the fan load.
- Insert the “Powergui” and click on “Initial States Setting”. Into the right section of the window, select “Force initial electrical states” to Zero.

Configuring simulation parameters

- In the pull-down menu click “Simulation” and then “Configuration parameters”. Select “ode 45” as a solver and set the maximum step to 1e-4. Select 1 as stop time.
- Click on the scopes and uncheck “Limit data points to last” in the tab “History” inside “Parameters”. In this way, you should be able to see the whole waveform captured by the scope.

Running the simulation

You should be able to run the simulation and observe the shape of the waveforms of voltages, currents, speed, torque, and mechanical power. Set the peak amplitude of the three sources to 150*sqrt(2) V and run the simulation again. Comment on the result obtained in comparison with the previous case.

Torque-speed characteristic

Create a MATLAB M-file to plot the torque-speed characteristic of the load and the torque-speed characteristic of the motor when the peak amplitude of the three sources is 400*sqrt(2) V and when it is changed to 150*sqrt(2) V.