VI BASED PARAMETER IDENTIFICATION OF INDUCTION MOTOR

R.Subasri¹, B.Meenakshipriya² and R.Narmadha³

¹Assistant Professor, Department of Electronics and Instrumentation Engineering, Kongu Engineering College, Perundurai, Erode - 638 052, Tamilnadu, India.
²Lecturer, Department of Mechatronics Engineering, Kongu Engineering College, Perundurai, Erode - 638 052, Tamilnadu, India.
³Corresponding author: P.G. Student, Department of Mechatronics Engineering, Kongu Engineering College, Perundurai, Erode -638 052, Tamilnadu, India.
¹Phone: 9894255890,
¹,²,³ Email: soamisuba@yahoo.com, devameena@rediffmail.com, narmadha1109@yahoo.co.in

Abstract

This paper considers the problem of parameter identification and speed estimation of a three-phase squirrel-cage induction motor using Virtual Instrumentation. LabVIEW is the graphical development environment for creating flexible and scalable test, measurement, and control applications rapidly and at minimal cost. With LabVIEW, interface with real-world signals, analyze data for meaningful information, and share results and applications. The LabVIEW graphical development environment, combined with DAQmx, gives the tools needed to easily construct applications using counters to generate PWM signals. This lab provides a practical application of an induction motor. The transient speed responses of the motor, for different values of stick deflection (operator’s control) are measured and the corresponding dynamical equations are solved using Runge-Kutta numerical method that is implemented using the tools available in LabVIEW. The stator current and rotor current in both d - q axis (i_{sd}, i_{sq}, i_{rd} and i_{rq}), the stick deflection and the corresponding speed are found.

Keywords: Parameter identification, Virtual Instrumentation, Runge-Kutta Numerical Method, Speed Estimation

1.0 Introduction

The Induction motor is a three phase motor and is the most widely used machine, has been favored because of its good starting capability, simple and rugged construction, low cost and minimum maintenance, high reliability and sufficiently high efficiency, needs no extra starting motor and need not be synchronized etc. Along with variable frequency AC inverters, induction motors are used in many adjustable speed applications which do not require fast dynamic response. The main obstacles in using induction motor drives are the high cost of conversion equipment, the complexity of signal processing and poor precision. Nevertheless, control schemes have been developed which provide a feasible approach of speed control to induction motors (R.Subasri, et al 1996). Accurate speed information is necessary to realize high performance and high precision speed control of an induction Motor. The speed is achieved by using mechanical sensors such as resolvers or pulse encoders. However these sensors are usually expensive and bulky. Therefore, the cost and size of the drive systems are increased.

The electrical signals generated by the transducers must be optimized for the input range of the DAQ board. The SCXI signal conditioning accessory amplifies the low-level signals, and then isolates and filters them for more accurate measurements. Several special computer assisted measuring programs were written in LabVIEW8.0, which coordinate all the data acquisition and the test measurement processes. LabVIEW is a powerful graphical programming development for data acquisition and control, data analysis, and data presentation. LabVIEW gives the flexibility of a powerful programming language without the associated difficulty and complexity because its graphical programming methodology is inherently intuitive to the users. The LabVIEW programs are simply made by assembling using drag-and-drop methods software objects called virtual instruments (VIs) (Johnson G.W 1994). The virtual instrument created for the purpose of processing and analyzing the acquired data from the test bench is easy to use and flexible. The front panel user interface elaborated assures an interactive control of the entire acquisition software. The assembled block diagram ensures its functionality. The acquired data are stored in simple ASCII-type text files in order to be easy imported in any other program. (Szabó L et al,2001) The program provides a powerful interface between the operator who co-ordinates the tests and the test bench because it can be manipulated easy and simply. Recently, the use of virtual instrumentation identify and control non-linear dynamic systems has been proposed (Szabó L et al.,2004) because they can approximate a wide range non-linear functions to any desired degree of accuracy. Identification of a system
requires picking one class of functions (or models) so as to approximate the input-output behavior of the system in the best possible manner.

In this paper, a new parameter identification procedure for a squirrel-cage induction motor is proposed. The squirrel-cage induction motor under test is modeled with the help of Lab VIEW tools. The transient speed responses of the motor, for different values of stick deflection (operator’s control) are measured and the corresponding dynamical equations are solved using Runge-Kutta numerical method. The stator current and rotor current in both d - q axis \((i_{sd}, i_{sq}, i_{rd}, i_{rq})\), the stick deflection and the corresponding speed are found. The on-line learning ability of the Virtual instrumentation studied using the parameter uncertainty in stator resistance.

2.0 Motor Parameters

The circuit parameters of the induction motor \(R_s, R_r, L_s, L_r\) and \(L_m\) can be determined from the results of a no-load, a blocked-rotor test and from measurement of the dc resistance of the stator winding. The no load test on an induction machine, like the open circuit test on a transformer, gives information about exciting current and rotational losses. This test is performed by applying balanced three-phase voltages to the stator windings at the rated frequency. The rotor is kept uncoupled from any mechanical load. The smaller power loss in the machine at no load is due to the core loss and the friction and windage loss. (R.Subasri, et al 1996)

The blocked rotor test on an induction machine, like the short-circuit test on a transformer, gives information about leakage impedances. In this test the rotor is blocked so that the motor cannot rotate, and balanced three-phase voltages are applied to the stator terminals. The blocked rotor test should be performed under the same conditions of rotor current and frequency that will prevail in the normal operating conditions. The stator resistance can be determined by stator resistance test using multi-meter. (R .Subasri, et al 1996) The following test results are obtained from the reference three phase squirrel cage induction motor rated with 5 H.P, 415V, 50Hz, 1480 rpm, 4 poles and 7.9A

\[
\begin{array}{c|c|c|c|c|c|c|c}
\text{Parameter} & R_s \ (\Omega) & R_r \ (\Omega) & L_s \ (\text{mH}) & L_r \ (\text{mH}) & L_m \ (\text{mH}) & p & J \ (\text{Kg-m}^2) \\
\hline
\text{Value} & 4.5 & 10.56 & 54 & 27 & 4 & 549 & 0.01425 \\
\end{array}
\]

3.0 Dynamic Model of Induction Motor

The LabVIEW VI, Dynamic Induction Motor can be used to investigate the dynamic operation of three-phase asynchronous motors. In the LabVIEW simulation, the asynchronous motor is powered from a three-phase sinusoidal voltage source and the motor is started from standstill.

In the VI, the motor is modeled in the d-q reference frame by five non-linear differential equations, and the simulation uses the stationary reference frame of the induction motor. In the simulation, the fluxes are selected as the state space variables. The non-linear differential equations are as follows.

\[
\frac{d\psi_{qs}}{dt} = \omega_b \left[ v_{qs} - \frac{R_s X'_{rr}}{D} \psi_{qs} - \frac{\omega}{\omega_b} \psi_{ds} + \frac{R_s X_m}{D} \psi_{qr} \right] 
\]

\[
\frac{d\psi_{qs}}{dt} = \omega_b \left[ v_{ds} + \frac{\omega}{\omega_b} \psi_{qs} - \frac{R_s X'_{rr}}{D} \psi_{ds} + \frac{R_s X_m}{D} \psi_{qr} \right] 
\]

\[
\frac{d\psi_{qs}}{dt} = \omega_b \left[ v_{qr} + \frac{R_s' X_m}{D} \psi_{qs} - \frac{R_s' X_{ss}}{D} \psi_{qr} - \frac{\omega}{\omega_b} \psi_{dr} \right] 
\]

\[
\frac{d\psi_{qs}}{dt} = \omega_b \left[ v_{dr} + \frac{R_s' X_m}{D} \psi_{ds} + \frac{\omega}{\omega_b} \psi_{qr} - \frac{R_s' X_{ss}}{D} \psi_{dr} \right] 
\]

\[
\frac{d\omega_r}{dt} = \left( T_e - T_L \right) \left( \frac{p}{2} \right) \left( \frac{1}{J} \right) 
\]

Where, \(D = X_{ss} X'_{rr} - X^2_m\), \(p\) - number of poles of the motor, \(J\) - moment of inertia, The electromagnetic torque developed by the machine is given as

\[
T_e = \frac{3}{2} \left( \frac{p}{2} \right) \frac{X_m}{D \omega_b} \left( \psi_{qs} \psi_{dr} - \psi_{qr} \psi_{ds} \right) 
\]
The previous differential equations are solved by the Runge-Kutta numerical method that is implemented using the tools available in LabVIEW. The Runge-Kutta method does not need a special starting arrangement, the step width can be changed easily and the storage requirement is minimal. The Runge-Kutta formula used in the numerical solution involves weighted average values taken at different points in the interval \( t_n \leq t \leq t_{n+1} \), and is given by

\[
y_{n+1} = y_n + \frac{k_1 + 2k_2 + 2k_3 + k_4}{6}
\]

where the coefficients

\[
k_1 = t \, \Gamma(x_n, y_n)
\]

\[
k_2 = t \, \Gamma(x_n + \frac{t}{2}, y_n + \frac{k_1}{2})
\]

\[
k_3 = t \, \Gamma(x_n + \frac{t}{2}, y_n + \frac{k_2}{2})
\]

\[
k_4 = t \, \Gamma(x_n + t, y_n + k_3)
\]

Where \( n \) is the time step,

\[
t = t_{n+1} - t_n, \quad \Gamma(x_n, y_n) = \frac{dy}{dx}.
\]

The simulation also provides an inverse transformation to determine the abc reference frame which corresponds to the real parameters of the motor for easy comparison. Conversion to the abc reference frame is achieved by using the following transformations.

\[
f_{abc} = (K^{-1}) \, f_{qdos}
\]

where \( f_{abc} = [f_a f_b f_c]^T \) and \( f_{qdos} = [f_q f_d f_o]^T \).

Here, \( f \) can be either the voltage, the current, or the flux linkage of the machine.

\[
K^{-1} = \begin{bmatrix}
\cos\theta & \sin\theta & 0 \\
\cos(\theta-2\pi/3) & \sin(\theta-2\pi/3) & 0 \\
\cos(\theta+2\pi/3) & \sin(\theta+2\pi/3) & 0
\end{bmatrix}
\]

In the previous formula, \( \int \omega \, dt \) is used for the stator transformations, and \( \int (\omega - \omega_r) \, dt \) is used for the rotor transformations.

### 4.0 Virtual Model of Squirrel Cage Induction Motor

In this work, a new estimation procedure for a squirrel cage induction motor is proposed. The following equipment was used when the data for the LabVIEW simulation was taken:

- Slip-ring Induction Machine: 415 V, Y, 3 ~, 11 A, 1410 rpm, 5.5 kW,
- \( \cos = 0.85 \), 50 Hz, ROTOR: 170 V, Y, 22 A.

Part-I represents the PWM inverter block uses sinusoidal pulse-width modulation. The base frequency of the sinusoidal reference wave is set at 50Hz and the triangular carrier wave’s frequency is set at any desired value. This corresponds to a frequency modulation factor \( m_f \). This block converts the stick deflection in p.u (per unit) to reference three phase input voltage to the motor. Stick deflection is set by the operator to get the required speed. The operator is given information only about the movement of the stick in p.u, which relates with the required speed (Required speed (\( N \)) = rated speed (\( N_r \) ) * stick deflection (p.u)).

In part-II, the voltage (peak to peak) corresponds to the required speed is converted in to RMS value using the Fourier block. The Fourier block performs a Fourier analysis of the input signal over a running window of one cycle of the fundamental frequency of the signal. The Fourier block can be programmed to calculate the magnitude and phase of the Input signal.

Part-III represents model of the three phase squirrel-cage induction motor under test. All stator and rotor quantities are in the arbitrary two-axis reference frame (\( d-q \) frame). The squirrel-cage induction motor is rated with 5H.P, 415V, 7.9A, 50Hz and 1430 rpm. The output of the motor contains vector of 21 parameters such as rotor current, stator current, rotor flux etc. Any of the 21 parameters can be selected by demultiplexing these variables by using the Machines Measurement or data acquisition unit (Part-IV).

### Response of speed in rpm for Rs=4.3Ω, \( \eta=0.001 \), and no. of epochs=100

![Diagram](image-url)
4.1 Lab procedure

Table 2 Virtual instrumentation lab procedure

<table>
<thead>
<tr>
<th>Enter the load parameters here.</th>
<th>Use the pull-down controls to display the desired simulated motor parameters on the graph given on the right hand side.</th>
<th>Electromagnetic torque versus speed and electromagnetic torque versus time graphs are displayed here.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The instantaneous speed-time characteristic is shown in this graph.</td>
<td>Direct and quadrature axis instantaneous currents of the motor are shown here.</td>
</tr>
<tr>
<td></td>
<td>This graph illustrates the above current waveforms in the abc reference frame (after the inverse transformation).</td>
<td></td>
</tr>
</tbody>
</table>

First Launch LabVIEW and Open Dynamic Induction Motor. Before starting the simulation, enter the motor and the load parameters, and set the time step from the front panel. After the VI starts, the graphs display the estimated values. The motor parameters entered are practical. Vary the equivalent rotor resistance of the motor and observe the changes on the torque-speed characteristics. Run the model until the steady-state speed is reached and comment on the above characteristics.

5.0 Result and Discussion

The Dynamic Induction Motor observes the changes in the electromagnetic torque, the speed, and the line currents. Vary the total moment of inertia and the load torque (only one at a time) and observe the changes on the speed-time characteristic. Vary the equivalent rotor resistance of the motor and observe the changes on the torque-speed characteristics. Run the model until the steady-state speed is reached and comment on the above characteristics.
6.0 Conclusion

The Virtual Instrumentation has been performed either on-line or off-line. For the sake of improving the disadvantages of the control of motor, an identification strategy has been presented here in which currents and speed are used as inputs and outputs to create a model. Model by means of data collection over a wide range of speed improves the accuracy, reduces the complexity, increases the immunity to the noise and fewer controllers are needed. In many applications, the model has to emulate nonlinear and time varying functions where the functions might change depending on the plant operating condition and parameter variation. In such cases the model requires continuous training on-line so that it correctly emulates the model. The presented results shows that the Virtual Instrumentation approach can be used to estimate the speed of squirrel cage induction motor accurately without the application of speed sensor and also used for on-line training.

References