Virtual Instrumentation of AC and DC Motor Drives for a State of the Art Engineering Education

P.Murari(student)
Dept. of EEE
GVP college of engineering(A)
Vizag,India.
murari208@gmail.com

D.Siva Kumar(student)
Dept. of EEE
GVP college of engineering(A)
Vizag,India.
sivadumpala7@gmail.com

K.Aruna(student)
Dept. of EEE
GVP college of engineering(A)
Vizag,India.
kasturi.aruna.eee@gmail.com

Sastry V.Vedula(Senior Professor)
Dept. of EEE
GVP college of engineering(A)
Vizag,India
sastryvvv@gvpce.ac.in

***Abstract*- This paper gives the concept of virtual instrumentation and simulation of Power Electronic converters fed AC/DC motor drives using LabVIEW (Laboratory Virtual Instrument Engineering Workbench) software. Virtual instruments developed using National Instruments (NI) software "LabVIEW" give opportunity for students to deal with effective instrumentation within a software environment, with its sensors integrated with hardware like myDAQ/DAQ. Mathematical models of electric drives, using an Induction motor or a DC motor, have also been implemented to study and analyze the dynamic characteristics and help develop effective designs for such drives.**

keywords- LabVIEW, Virtual Instrumentation, DAQ, Mathematical modeling, Induction motor, Dc Motor, PE converters

1. INTRODUCTION

Understanding instrumentation and making measurements is important for all engineering students. In many cases, knowing how an instrument works, aids in understanding the limitations of instruments. Virtual Instruments replace the use of expensive laboratory equipment like oscilloscopes, multimeters and other analog measuring instruments.

The objective of this publication is to analyze and visualize the parameters like voltage, current, frequency, power(active, reactive, apparent) and power factor for AC and DC drives using virtual instrumentation [1] (i.e. without using any analog and digital meters). This was done in LabVIEW software environment with myDAQ /DAQ hardware along with voltage and current sensors.

For Data Acquisition, closed loop hall effect sensors are used which avoid the use of additional isolation amplifier [1]. The paper [2] describes the data acquisition using electronic interfacing of motors with LabVIEW by using some converters. Our paper avoids the additional hardware circuitry like true RMS converter card. The dynamic model of the induction motor [3] is modeled and simulated. The model of DC motor also built in LabVIEW for a three phase fully controlled converter fed DC motor drive model.

In AC drives the data acquisition and simulation is done for inverter fed induction motor drive and AC voltage controller fed induction motor drive. In DC drives the ac/ dc converter fed DC motor drive is implemented. In this paper, discussion is around the inverter fed induction motor drive and converter fed DC motor drive.

For the dynamic analysis of motor drives, an induction motor model in stationary reference frame and DC motor model are built in LabVIEW on the lines of [2], [3], [4], [5] and [6]. The power electronics converters like inverter, rectifier and AC voltage controller are built in Multisim and are co-simulated with the motor models built in LabVIEW [7 and 8].

In reference [4] authors build a mathematical model to design a robust controller for the speed control and simulated the model in MATLAB/SIMULINK and observed the results. The same model built in LabVIEW and validated it with MATLAB model and in future uses this model to develop controllers in run time.

The behavior of motor drives are observed in front panel of LabVIEW using virtual instrumentation and the simulation results for the dynamic motor models are also observed for an effective engineering education using current trends in the industry world over.

2. HARDWARE FOR DATA ACQUISITION

The hardware involved for the process of data acquisition is Transducers, myDAQ/DAQ devices, and a PC loaded with LabVIEW software.

Transducer: A transducer converts an electrical or physical phenomenon into a measurable electrical signal. The transducers used to measure the signal are

i. LV-25P Voltage Transducer (LEM make)
ii. LA-100P Current Transducer (LEM make).

NI myDAQ: A low-cost portable data acquisition (DAQ) device that uses NI LabVIEW-based software instruments, allowing students to measure and analyze real-world signals.
NI DAQ: A multifunction DAQ that measures digital frequency. DAQ can concurrently transfer analog, digital data in both directions.
Computer: With LabVIEW software, controls the operation of the DAQ device and is used for processing, visualizing, and storing measured data. Different types of computers are used in different types of applications. A laptop may be used in the field for its portability, a desktop computer may be used in a lab for its processing power, or an industrial computer may be used in a manufacturing plant because of its ruggedness.

3. DYNAMIC DATA ACQUISITION OF MOTOR DRIVES

Data acquisition is the process of measuring an electrical/physical phenomenon such as voltage, current, sound, temperature, or pressure with a computer to store, analyze and visualize data. A data acquisition system consists of DAQ measurement hardware, sensors, and a computer installed with programmable software. When compared to traditional measurement systems, PC based data acquisition systems exploit the processing power, display, productivity, and connectivity capabilities of industry standard computers providing a more powerful, flexible, and cost-effective solution of measurements and display.

3.1AC Drives

3.1.1 Measurements of Currents and Voltages for Inverter Fed Induction Motor Drive in Laboratory

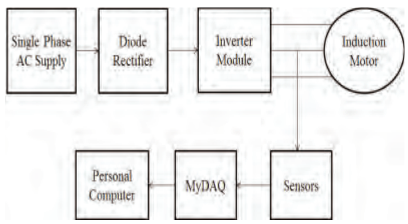

Fig. 1 Block Diagram of hardware Arrangement

Figure1 shows schematic hardware arrangement of an inverter fed induction drive for acquiring data. From the Fig. 1, the auto transformer feeding single phase AC supply to smart power module is converted to DC by a diode rectifier. The control module is used to produce triggering pulses to drive the inverter switches to produce a sinusoidal wave to control the induction motor. In between the inverter power module and an induction motor voltage and current parameters are measured by properly connecting the transducers to myDAQ/DAQ and PC. Graphical programming arrangement in LabVIEW software needs to be effectively coded so that there may not be any wrong display of readings.

Here, measurements like stator line voltage and the line current are measured and the results are displayed in a PC.

Display of Results in a PC:

a) Dynamic Behavior:

Figure 2 shows the dynamic behavior of stator line-line voltage and stator current at the time of starting of an inverter fed induction motor drive.

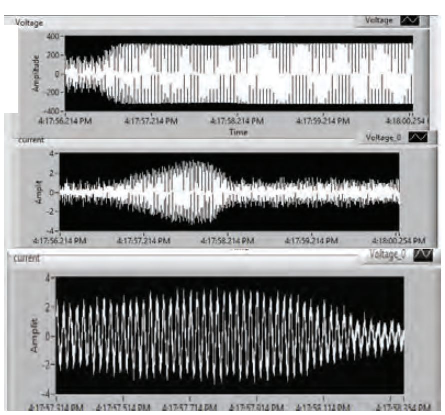

Fig. 2 Stator Line- Line Voltage and Stator Current as seen on a PC monitor

b) Steady State Behavior:

Fig 3 shows the steady state behavior of stator line-line stator voltage, stator current and stator line to neutral voltage of an inverter fed induction motor drive.

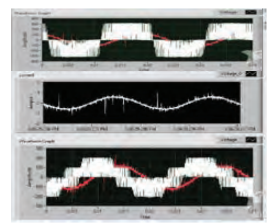

Fig.3 Steady State Behaviors of Stator Line- Line Voltage and Stator Current in a PC

3.1.2 *Measurements of Currents and Voltages for AC Voltage Controller fed Induction Motor Drive*

A typical block diagram of connections is shown in Fig.4

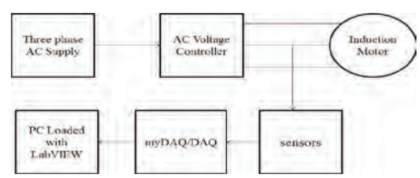

Fig. 4 Block Diagram of hardware Arrangement

a) Steady state results

With a load torque of 5.25N-m, and firing angle 40 degrees, slip is 6%, here line to line voltage and currents are represented and currents waveform is observed in the front panel.

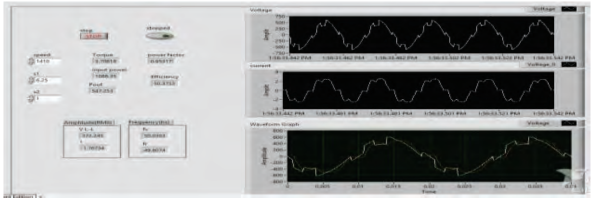

Fig. 5 Stator line to line voltage and stator current

3.2 DC Motor Drive

Here a DC generator with resistive load box is connected as an electrical load for a separately excited DC motor and the motor is fed from a DC drive. The Block diagram for the experimentation is shown in Fig.6

Fig. 6 DC drive hardware Arrangement

By building virtual instruments in LabVIEW we can observe the DC motor dynamics. Figure 7 shows the different parameters of DC shunt motor when a load of 2 Amps is applied on the generator using a resistive load bank.

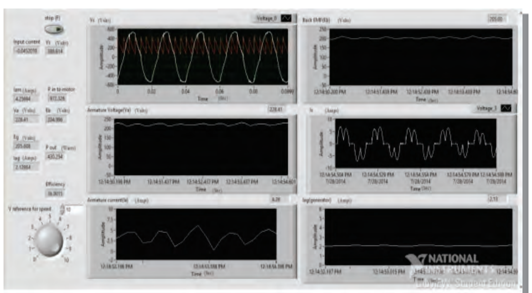

Fig. 7 Front Panel of Virtual instrumentation for experiment on DC motor

4. SOFTWARES USED FOR MODELING & ANALYSIS

LabVIEW is a system-design platform and development environment for a visual programming language from National Instruments.

It is a graphical language quite unique in the method by which code is connected and saved. There is no text based code, but a diagrammatic view of how the data flows through the program. An engineer can often visualize data flow rather than how a text based conventional programming language must be built to achieve a task

NI Multisim (formerly MultiSIM) is an advanced, industry-standard, powerful teaching, research, and electronic schematic capture software on the lines of SPICE simulation environment. Multisim is widely used in academia and industry for electric & electronic circuits' education, schematic design and simulation.

Many electronic / power electronic circuits can be simulated and analyzed using Multisim by dragging and dropping the elements into the design board.

5. MODELING & ANALYSIS OF MOTOR DRIVES USING LabVIEW/MULTISIM

5.1 Dynamic model of Induction Motor

The motor model presented is based on the d-q model of the squirrel cage induction motor in the stationary reference frame with all quantities are referred to the stator. The saturation of both magnetizing and leakage inductances as the function of magnetizing current is neglected.

The commercial software package, LabVIEW allows electrical engineers to model dynamical systems with ease using a block diagram approach that can be constructed fast and efficiently. By using the differential equations of voltage and current in a stationary reference frame along with the torque equation that describes the operation of an induction motor-drive system.

With the theory of induction motor control and advances in power electronic converters, the motor control system is becoming complex and more versatile. The simulation of induction motor's dynamic process with the computer can reveal the dynamic characteristics of induction motor and its parameter changes.

A block diagram approach is used in the construction of the motor model shown in Fig. 8 that will allow students to understand reference frame theory concepts

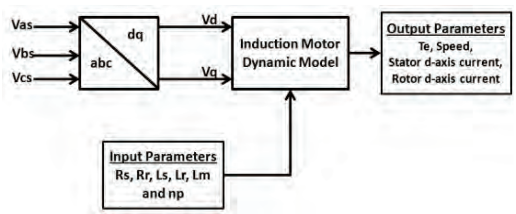

Fig. 8 Block-diagram representation of Induction Motor model

Description of ports of fig.8:

Vas, Vbs, Vcs: Supply Voltage ports. (Electrical Inputs)
Rs, Rr: Stator and Rotor resistances
Ls, Lr: Stator and Rotor Inductances
Lm: magnetizing inductance
np: Pole pairs
Te: Electromagnetic Torque. (Internally calculated-Mechanical port
W: Output speed of induction motor (Output-Mechanical port)
Ids, Iqs, Idr, Iqr: d-q Stator and Rotor currents (Output ports-electrical)

5.2 Mathematical equations for modeling [1], [2]

a) Voltage and flux linkage equations

D-Q Voltage and Flux linkage equations based on stationary reference frame.

$$V_{ds} = r_{ds} i_{ds} + p\lambda_{ds} \qquad \text{----- (1)}$$
$$V_{qs} = r_{qs} i_{qs} + p\lambda_{qs} \qquad \text{----- (2)}$$
$$V_{dr} = r_{dr} i_{dr} + p\lambda_{dr} - w_r \lambda_{qr} \qquad \text{----- (3)}$$
$$V_{qr} = r_{qr} i_{qr} + p\lambda_{qr} + w_r \lambda_{dr} \qquad \text{----- (4)}$$

Where

$$\lambda_{ds} = L_{ds} i_{ds} + L_m i_{dr} \qquad \text{----- (5)}$$
$$\lambda_{qs} = L_{qs} i_{qs} + L_m i_{qr} \qquad \text{----- (6)}$$
$$\lambda_{dr} = L_{dr} i_{dr} + L_m i_{ds} \qquad \text{----- (7)}$$
$$\lambda_{qr} = L_{qr} i_{qr} + L_m i_{qs} \qquad \text{----- (8)}$$

and

$$pi_{ds} = (1/\Delta)(L_r V_{ds} - L|rr_s i_{ds} + w_r L_m^2 i_{qs} + w_r L_m L_r\, i_{qr} + L_m r_r i_{dr}) \qquad \text{----- (9)}$$

$$pi_{qs} = (1/\Delta)(L_r V_{qs} - L|rr_s i_{qs} - w_r L_m^2 i_{ds} - w_r L_m L_r\, i_{dr} + L_m r_r i_{qr}) \qquad \text{----- (10)}$$

$$pi_{dr} = (1/\Delta)(-L_m V_{ds} + L|mr_s i_{ds} - w_r L_m L_s\, i_{qs} - w_r L_r\, L_s\, i_{qr} - L_s r_r i_{dr}) \qquad \text{----- (11)}$$

$$pi_{qr} = (1/\Delta)(-L_m V_{qs} + L|mr_s i_{qs} + w_r L_m L_s\, i_{ds} + w_r L_r\, L_s\, i_{dr} - L_s r_r i_{qr}) \qquad \text{---- (12)}$$

Where $\Delta = L_r * L_s - L_m^2$

b) Dynamic Torque Equation:

$$Te = \left(\frac{3}{2}\right) * \left(\frac{P}{2}\right) * L_m * \left(i_{qs} i_{dr} - i_{ds} i_{qr}\right) \qquad \text{---- (13)}$$

In this template Vqs and Vds are obtained from the line voltage using the transformation.

$$\begin{bmatrix} V_{qs} \\ V_{ds} \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} cos\theta & cos\left(\theta - \frac{2\pi}{3}\right) & cos\left(\theta + \frac{2\pi}{3}\right) \\ sin\theta & sin\left(\theta - \frac{2\pi}{3}\right) & sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} \qquad \text{---- (14)}$$

In stationary reference frame for a balanced poly-phase input supply the d-q voltages are given by

$$Vqs = Vas \qquad \text{---- (15)}$$
$$Vds = \frac{Vbs - Vcs}{\sqrt{3}} \qquad \text{---- (16)}$$

Such an algebraic relationship reduces the number of computations and thus leads to real time control applications in high performance variable-speed drive requiring the computation of stator currents, stator flux linkages and electro-magnetic torque for both control and parameter adaptation.

c) Mechanical Torque Equation:

$$Te = Tl + \frac{\frac{J}{np} * dw}{dt} \qquad \text{---- (17)}$$

Where J = Moment of inertia(kg-m2)
Tl = Load Torque(N-m)

5.3 Design of Sinusoidal PWM controller for inverter fed induction motor drive in LabVIEW:

The sinusoidal reference signal is compared with the high frequency triangular carrier signal in order to generate the trigger signal. The sine signal and triangular signal are generated by using the signal generator block in LabVIEW and corresponding amplitude, frequency and phase angle are controlled using the control blocks in LabVIEW. These two signals are compared using the arithmetical operator such as greater than or equal to. The output of the arithmetical operator is a function of Boolean which is converted into a numeric value by using Boolean to a numeric block in LabVIEW to trigger the switch. Such a block diagram is shown in Fig 9.

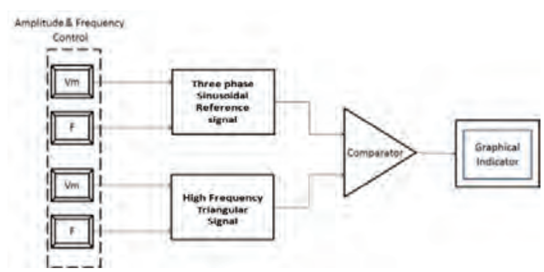

Fig. 9 Block Diagram representation of the Design of a Sine Wave PWM Controller in LabVIEW

Sinusoidal PWM Output:

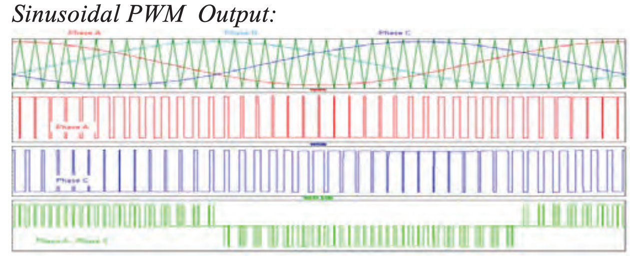

Fig. 10 Three Phase Sine PWM

5.4 Open loop speed control of Inverter fed Induction motor Drive:

The speed of the induction motor model is controlled by using PWM controller designed in LabVIEW.

Co-Simulation:

It is the handshake between two different softwares where two way data communication is done in parallel. Here an inverter circuit designed in Multisim software environment is brought into the LabVIEW environment and is simulated by means of co-simulation

Interfacing of LabVIEW PWM controller, Multisim inverter Circuit and induction motor dynamic model arrangement is done in LabVIEW block diagram panel and the controlling is done from the LabVIEW front panel.

5.5 Multisim Inverter Circuit:

Figure 11 shows the simulation diagram of the inverter circuit in Multisim design board with input and output connectors. These connectors are very useful to make the data flow through LabVIEW.

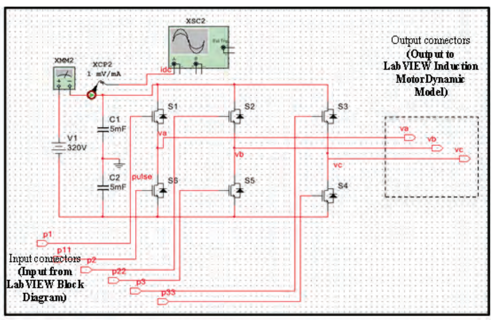

Fig. 11 Multisim Inverter Circuit

5.6 Simulation Results

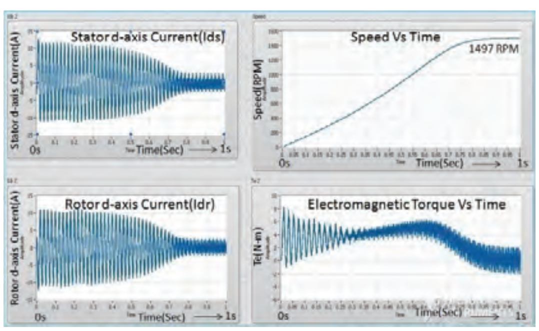

Fig. 12 a) Stator d-axis Current b) Speed vs. Time
c) Rotor d-axis Current d) Torque vs. Time

The simulation results for the dynamic model of an inverter fed induction motor drive are shown in Fig 12. The output like speed, torque, stator and rotor currents, voltage and frequencies are observed and analyzed.

5.7 Separately excited DC motor modeling

Assuming the magnetization curve is taken as linear, the equations for the armature circuit and field circuit are given as

$$\frac{dI_a}{dt} = \frac{1}{L_a}(V - E_b - I_a R_a) \quad \text{------- (18)}$$

$$E_b = K_e * w \quad \text{------- (19)}$$

$$\frac{dI_f}{dt} = \frac{1}{L_f}(V_f - I_f R_f) \quad \text{------- (20)}$$

$$\frac{dw}{dt} = \frac{1}{J}(T_e - Bw - T_l) \quad \text{------- (21)}$$

$$T_e = Ke * I_f * I_a \quad \text{------- (22)}$$

Where I_a, I_f, V, E_b, w, L_a, L_f, R_a, R_f, T_e, T_l, K_e, J and B represent the motor armature current, field current, armature voltage, back emf, armature inductance, field inductance, armature resistance, field resistance, electromagnetic torque, load torque, motor constant, moment of inertia and damping constant, respectively.

Since the field was excited by a constant voltage source, the field flux is constant and the armature voltage is given as a control input. By varying the armature voltage, the speed of the motor can be controlled up to rated speed.

5.8 Simulation Results

In Fig. 13 the dynamics of the DC motor model have been observed. For this dynamic analysis a sudden step change of armature voltage to its rated voltage (180) from zero at t=1 sec at no load torque (T_L), and a sudden step change in load torque from zero to rated value (5 N-m).

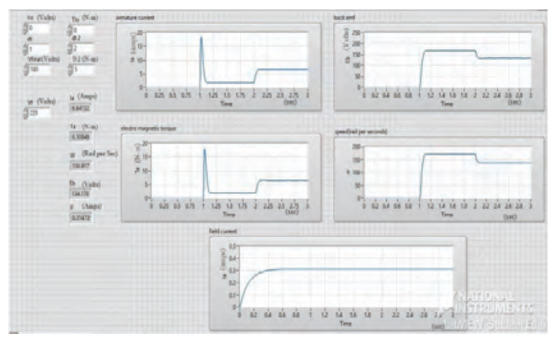

Fig. 13 output waveforms for the DC motor model for dynamic analysis

6. CONCLUSIONS

This publication gives a clear view of advanced learning by virtual instrumentation for the engineering graduates making use of LabVIEW - graphical programming software. AC and DC motor drive models are developed with the use of LabVIEW and Multisim

In virtual instrumentation the real-time data is acquired and displayed in PC with validation of voltage and current sensors. Dynamic analysis for practical hardware AC & DC motor setups in the laboratory is observed and the steady state behavior is also studied.

7 ACKNOWLEDGEMENTS

The authors would like to thank the Head .EEE department and Principal of GVP college of Engineering (A), Visakhapatnam, India for the facilities provided. Special thanks to National Instruments, India for providing the student version of LabVIEW13.

REFERENCES

[1] Halit Eren and Chun Che Fung, “A Virtual instrumentation of electric drive systems for automation and testing”, Proceedings of the 17th IEEE Instrumentation and Measurement Technology Conference (IMTC), Baltimore,MD,Volume-3, 2000, pp 1500-1505.

[2] Li Qianxiang and Hu Jingtao, “Simulation model of induction motor based on LabVIEW”, 2010 third international conference on intelligent network and intelligent systems, IEEE, Shenyang, pp 273-276, Nov 2010.

[3] P.C. Krause, Second Edition “Analysis of Electric Machinery” McGraw-Hill International Editions, Electrical Engineering Series, 1986, pp.164-179

[4] Jianguo Zhou, Youyi Wang and Rujing Zhou, “Global speed control of separately excited DC motor drive”, Power Engineering Winter Meeting, Columbus, Vol 3, pp1425-1430, Jan 2001

[5] Ned Mohan, “Power Electronics Converters, Applications, and Design”, Wiley India Pvt. Ltd., Third Edition, 2006, pp.200-234

[6] R.Krishnan, “Electrical Motor Drives Modeling analysis and control”, PHI Learning Private limited, New Jersey, 2001, pp.196-226

[7] Jovitha Jerome, “*Virtual instrumentation using LABVIEW*”, PHI Learning Pvt. Ltd.,
New Delhi 2010/2013

[8] www.ni.com