JPE 2-4-S4

Interactive Teaching and Self-Study Tools for Power Electronics

Nesimi Ertugrul

Dept. of Electrical and Electronic Eng., The University of Adelaide, Adelaide, Australia

ABSTRACT

This paper presents the principal features of the software modules developed to provide an interactive teaching/learning environment in Power Electronics that can be used by educators and students. The software modules utilize an object oriented programming LabVIEW that provides a highly flexible graphical user interface. The paper highlights the principal features the software components and illustrates a number of highly interactive graphical user interfaces of selected Power Electronics circuits and systems.

Keywords : Power electronics, object oriented programming, educational technology, and LabVIEW.

1. Introduction

Due to highly interdisciplinary nature of Power Electronics, the educators ask the same questions constantly: how to educate students, how to provide the cross-disciplinary knowledge (electrical, electronics and computer) within a limited number of contact hours, and how to make them aware about the limitations in operating conditions, and how to allow students to create alternative operating scenarios that are not possible in the conventional text books. The principal objective of this study is to provide a possible solution for the above questions.

As known, most conventional textbooks are used merely to illustrate the facts and provide theoretical knowledge. The computer-based framework however, can provide students with alternative self-study tools where they can generate infinite number of options for detail analysis. This paper successfully introduces interactive LabVIEW-based virtual instruments into the curriculum of Power Electronics and drive systems. The aims of the interactive software modules developed in this paper are summarised below.

- to use the lecturing time more effectively and to provide a self-assessment tool.
- to indicate the bridge between the theory and the simulation
- to develop the students' understanding and world-views in a well-rounded way by providing infinite combinations of operation of power electronics circuits
- to highlight the key points of the subject and to increase the students' interactions by using various mediums, such as animations, and graphs.
- to use for training purposes and/or for continuing education outside the conventional lecture theatre.
- to provide deep understanding of topics and intellectual skills while providing opportunities for staff-student interaction.
- to provide a base study for the Internet access.

Manuscript received September 15, 2002.

Corresponding Author: nesimi@eleceng.adelaide.edu.au, Tel: +61-8-8303-5465. Fax: +61-8-8303-4360

Although a number of computer-based teaching aids have been developed within the past ten years to replace or to supplement conventional teaching materials in Power Electronics and in engineering general, they have many limitations, such as: inflexible and unfriendly programming structure, which do not allow the users or designers to implement subject oriented modules. However, due to recent technological advances in computer technology and software, it is now feasible to implement even more advanced, more efficient, highly interactive and very user-friendly systems at optimum cost. In this study, LabVIEW software of National Instruments Inc. has been chosen as an enabling technology for simulation, data analysis and circuit animation.

The prime benefits of the virtual instruments (VI) provided in this paper are the deep understanding of circuits and motor drives, and observing the limitations of the conventional textbook based teaching. In the VIs provided, the operation of selected circuits and systems are monitored and computer simulations with animation features are integrated into the theory using custom written software modules. It is believed that such teaching/learning method can also provide common practical experiences to cater for students who are coming from increasingly diverse backgrounds, and whose learning is best achieved in a contextual setting.

Furthermore, traditional higher education is under pressure due to the growing impact of computerized education. Print materials are increasingly being distributed in electronic form. The future aim of this study is to provide a remote accessible teaching/learning system that may also integrate the laboratory practices to the Power Electronics curriculum. Therefore, a major emphasis in the future study is to access instructional materials via online or on CD-ROM.

This paper will focus on certain power electronics converter topologies and will give some insights into the operation of these circuits by providing a highly flexible simulation environment.

2. Common Features of Virtual Instruments

The VIs provided in this book have a varying degree of complexity and special requirements. Therefore, it is beyond the coverage of this paper to include all of the implementation details. Instead some unique approaches used in the VIs will be highlighted in the following sections. Moreover, the fundamental approach used in this study is to keep the VIs as flexible as possible enabling future and alternative developments using the principles presented here.

As a common practice in LabVIEW programming, the VIs in the book are built by designing a front panel layout which shows the inputs and outputs to the function, with a diagram layer showing the interconnections and functions implemented in the VI. An icon equipped with a set of relevant input and output terminals is then used to provide an interface, allowing this VI to be called by other VI(s). The data structures and control algorithms are developed in accordance with the theory. The formulae nodes are often used to reduce the complexity of a VI or a sub-VI. As complexity increases, such as in the discrete-time integration, multiple sub-VIs are incorporated to form a sub-VI.

Three integration methods are implemented in the VIs, which numerically solve the differential equations of a dynamic system:

- Runge-Kutta method available in LabVIEW's G-Math Tool kit.
- Runge-Kutta method implemented separately using the weighted average values and the corresponding coefficients.
- Trapezoidal integration method implemented using the shift registers.

The implementation of each simulation in LabVIEW requires several embedded loops. A large portion of these loops enable the program to be restarted, paused, quit and started from the front panel. This is necessary for when the program is repackaged and the controls used during programming will not be available to the user.

The programs start by ensuring that the chart is cleared. Then a sub-VI is used to normalize the parameters to be viewed on the same chart. The first loop of the main VI is a case loop that allows the simulation to continue until the program is stopped. This case has been set to true. So the program is stopped by other means. The main purpose of this loop is to provide the required per-unit (normalized) value array in a shift register so that when the program is reset it does not go through the whole program initialization sequence again.

The second loop that the program enters contains the sequence frames. This sequence consists of initializing the graph and the running of the program. Initializing the graph frame itself contains a second set of sequence frames to initialize the simulation. The simulation initialization sequence first waits for the start button to be pressed, after which it initializes the graph values and implements the per-unit calculation for the plot of the graph. After the initialization frame has completed the program carries out the simulation.

The simulation sequence frame contains a while loop that runs until the reset button is pressed. Inside the while loop is a case loop, which is dependent on the reset button. When the reset button has been pressed the case is true and the program is allowed to reset and restart. However while it has not been pressed the case is false. It is in this case that the program calculates the values to simulate the circuit, and the determinants of the circuit are set. These are the input values that each simulation allows the user to set. These values are then entered into a for loop. As these values are read outside the for loop, they remain the values for the entire loop. It is only when the for loop has completed that these values are re-read from the front panel. This for loop calculates one entire period. Hence the circuit specifications are used for an entire period.

The for loop that calculates an entire period contains the controls for the speed of the simulation, controls for the animation of the circuit and the ability to change the per-unit values. However the main part of this loop is the sequence frames. The first sequence frame carries out the calculations for the simulation including the supply voltages, the number of states, what state the simulation is in, and all the measured values that are plotted on the chart. All the values that are plotted are calculated in this sequence. The second sequence frame implements the pause function, the displaying of the per-unit values and the graph selection.

Another key feature of the VIs available in this book is the animation of an electric circuit and an electromechanical system, which may be linked to the operating states of the electrical circuit. The animations are achieved by using a picture ring. The visible item of this object is a single picture at any one time, out of many pictures, which are drawn, imported to the relevant front panels and linked to the programming diagrams. Each item of the picture ring is associated with an (unsigned) integer value. By making the ring as an indicator, wiring it to a different integer value displays a different item that corresponds to a state of the electric and/or mechanical system.

3. Sample Simulation Modules

In this study, a number of Power Electronics circuits and systems have been implemented[1], which are classified under three groups and are listed in Table 1. The first group covers interactive modules of two principal devices, diode and thyristor, and four main converter topologies. The second group includes the basic motor drives as well as some more complex system applications.

Table 1. The list of Power Electronics software modules.

TITLE
Diode Conduction
SCR conduction
Three-Phase Half-Way Diode Rectifier
Single phase AC chopper
Cycloconverter
PWM and Single Phase Inverter (H-Bridge) Control Methods
Dynamic Simulation of Brushless Permanent Magnet AC Motor Drives
Dynamic Simulation of Direct Current Motors
Dynamic Simulation of Induction Motor
Simulation of Stepper Motors
Steering and Control of Four-Wheel Direct-Drive Electric Vehicles
Fault-Tolerant Motor Drive System
DC Motor Control
Stepper Motor Control
Brushless Trapezoidal PM Motor Control
Starting of Wound-Rotor Asynchronous Motors
Switched Reluctance Motor Control

The third group provides the bridge between the theory and the real world using integrated software and low cost hardware modules. However, as highlighted in the table, this paper provides brief explanations and front panels of nine selected modules only. Brief explanations will be provided in the subsequent paragraphs using the name of a module as a sub title.

Educational objectives of the modules developed here are:

- To understand the basic concepts in the circuits provided and to state the meaning of the circuit parameters
- To solve and to examine the circuits for unknown quantities
- To create various scenarios with the circuits provided, and verify the results analytically.

3.1 Device and Circuit Simulation

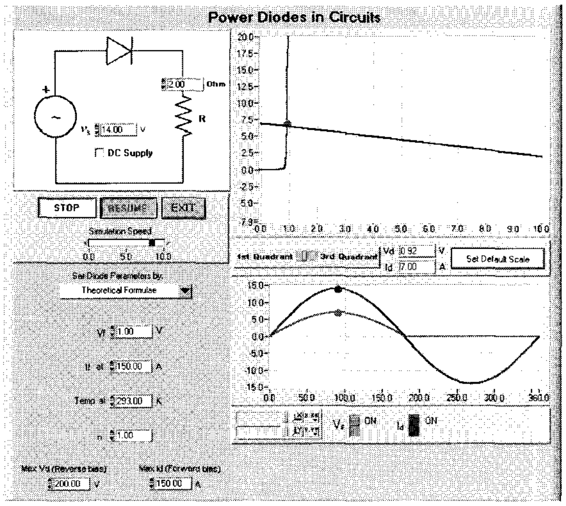
3.1.1 Diode Conduction

The diode is the most fundamental nonlinear electronic element, which forms the basis of nearly all solid-state devices. This section aims to introduce the operation of a diode and discuss the current-voltage characteristics of the diode through the examination and visual demonstration of the diode equation, test results and other circuit parameters.

The front panel for the diode module is given in Fig. 1. The figure also provides a sample explanation boxes for the front panel items: controls, indicators and graphs.

The principal features of the VI are that the user is able to control the supply voltage, the resistance, and the model used to simulate the diode. The diode can either be modeled using theoretical formulae or from values entered by the user into a look-up table. The look-up table contains some default values, but the results of an experiment have also been included on the drop-down menu. The experimental values are stored as a text file in the same directory as the simulation, formatted as a tab delimited text file with two columns (voltage and current).

There are two graphs on the front panel. The first graph displays the diode characteristic, the operating point and the load line. In addition, depending upon the setting of a switch, the graph can display either the first or the third quadrant of the voltage-current characteristics to be able to distinguish the forward and the reverse characteristics of the diode. Two indicators are also included to display the present values of the diode voltage and diode current. The second graph exhibits the source voltage and the load current (resistor current or diode current). The VI can also generate two error messages in two distinct operating conditions: when forward maximum diode current is exceeded and when maximum diode voltage in the reverse biased mode is exceeded.



R 2.00 Ohm

Vs 14.00 V

☐ DC Supply

Vd 0.92 V

Id 7.00 A

Set Diode Parameters by: Theoretical Formulae

Vf 1.00 V

If at 150.00 A

Temp at 293.00 K

n 1.00

Max Vd (Reverse bias) 200.00 V

Max Id (Forward bias) 150.00 A

The circuit parameters are displayed, where the resistance and the voltage (DC or AC) can be varied.

Start, Pause and Exit buttons can be used to start, to pause and exit the simulation respectively. Simulation speed can be altered any time, which can change the rate at which the

Here the diode parameters, the diode model (using the drop down menu) maximum reverse voltage and maximum forward current can be set.

This graph displays the diode characteristics, the diode operating point and the load line. The indicators below display the values of the voltage and the current. The switch can be used to display 1st or 3rd quadrant of the characteristic.

This graph displays the source voltage and the diode current, which can be switched on and off.

Fig. 1. The front panel and the explanations diagram of the diode simulation VI.

3.1.2 SCR Conduction

As known, a thyristor (SCR) has a p-n-p-n structure power electronic switch. However, understanding its operation, specifically distinct turn-on and turn-off conditions is complicated. The principal aim of this VI is to demonstrate to students the operation and a typical use for the thyristor within a basic electric circuit.

As a common feature in all LabVIEW programs, the front panel of the VI constructed here consist solely of a set of controls, to allow the user to select values for the circuit parameters, and indicators, to display the output parameters, which result from running the VI. In addition, various other features are added to enhance user interactivity and understanding, such as animations to illustrate all possible states of the circuit. The front panel of the SCR Conduction VI is shown in Fig. 2.

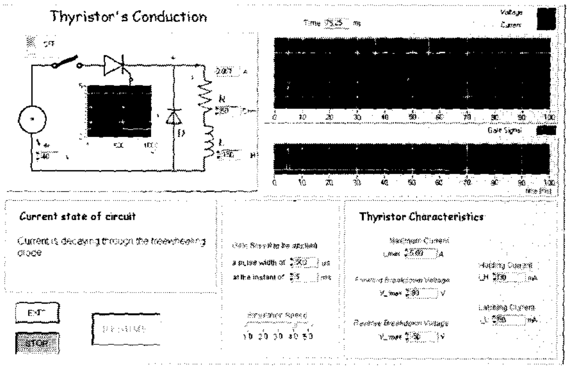


Fig. 2. The front panel of the SCR Conduction VI.

3.1.3 Three-Phase Half-Way Diode Rectifier

Rectification is the process of power flow from an ac source to a dc load. Rectification occurs naturally in the diode rectifiers, which is defined by the positive voltage across the anode and cathode terminals. Although the analysis of a multiple phase rectifier is easier, if there is a supply inductance in the rectifier circuit, the analysis becomes complex.

When the program is first started a pop up screen asks the user if they wish to use the default values for per unit values or use per unit values from a pre-saved source. The simulation is controlled by the six control buttons available on the front panel: quit, start, pause, reset, alter per unit value and simulation speed. The reset button can stop the simulation at the end of the current period that it is performing.

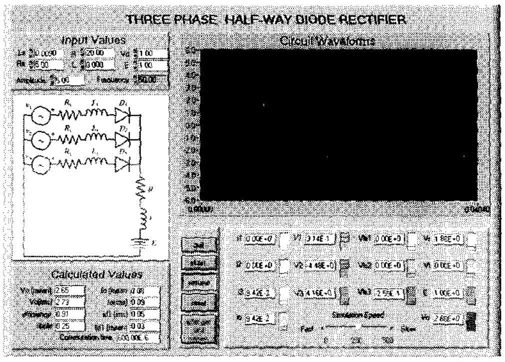


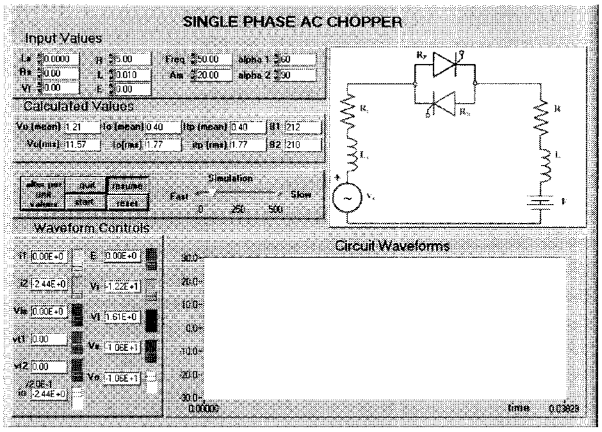
Fig. 3. The front panel of Three Phase Half Way Diode Rectifier VI.

The VI has a number of features, which includes the ability to input values for the parameters of the circuit, observation of a number of waveforms, calculation of various quantities, and a number of simulation controls. In this VI, the current flow through the rectifier circuit is shown at every instance through the animation ring. The animation shows all black as no current is flowing through the circuit, and red when there is current in the circuit.

The button Alter Per Unit Value allows the user to change the per unit value of any of the observations that can be plotted on the chart. Once pressed a pop up window lists all the observations per unit values that can be changed on a scroll down menu. The current per unit value will be displayed when each item is selected. When the done button is pressed after the new settings, a second pop up screen is activated, which can allow the user to save the per unit values for later use. The sliding bar on the front panel can control the simulation speed.

3.1.4 Single Phase AC chopper

The front panel of the sample simulation is shown in Fig. 4. This simulation demonstrates the single Phase AC chopper including possible circuit components in a practical system. Since the load is modeled by a resistor, an inductor and a constant voltage source, it represents a broad-spectrum load. In addition, the supply inductance and the resistance are also considered in the circuit. In such circuits, the continuation of current conduction beyond the zero crossings of the supply voltage is related to the value of inductance, which restrict the triggering angle control beyond a certain angle (β). In addition, due to the voltage source E in the circuit, a dc shift occurs on



SINGLE PHASE AC CHOPPER

Input Values

Ls 0.0000
R 5.00
Freq 50.00
alpha 1 60
Rs 0.00
L 0.010
Am 20.00
alpha 2 90
Vi 0.00
E 0.00

Calculated Values

Vo (mean) 1.21
Io (mean) 0.40
Itp (mean) 0.40
B1 212
Vo(rms) 11.57
Io(rms) 1.77
itp (rms) 1.77
B2 210

Waveform Controls

i1 0.00E+0
E 0.00E+0
i2 -2.44E+0
Vt -1.22E+1
Vls 0.00E+0
Vl 1.61E+0
vt1 0.00
Vs -1.06E+1
vt2 0.00
Vo -1.06E+1
io -2.44E+0

Fig. 4. The front panel of Single Phase AC Chopper VI.

the load side, which also limits the range of triggering angle.

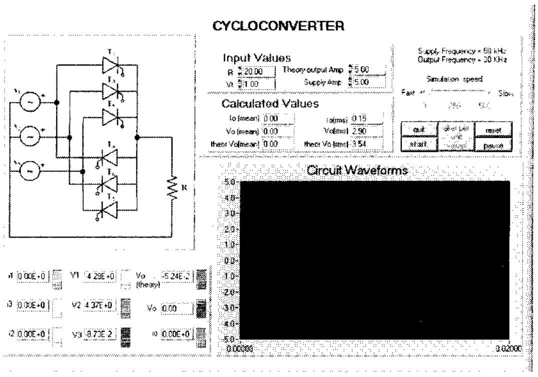
Similar to the previous VIs, a number of input values are available in this VI, where various calculations are performed and relevant waveforms are plotted.

In addition to the standard controls and indicators, there are a number of calculated values on the front panel, including the rms and mean values for the output current and voltages and for the thyristors, and the turn-off angle. These values are provided at the end of each period. The commutation time can be calculated and displayed up to three time each period and the beta values are provided when the appropriate current reaches zero.

Furthermore, since the control intervals for the triggering angles are limited under the inductive load operation, it is very likely that the user may set triggering angles which are impossible to obtain under such conditions. When this occurs an error message is also displayed and the program is terminated.

3.1.5 Cycloconverter

Cycloconverters in Power Electronics fabricate the output voltage of desired amplitude and frequency by sequentially applying appropriate segments of the input voltage waves to the output. Therefore, the output voltage waveforms are composed of segments of the input voltage waveforms. The operating principle of the single-phase cycloconverter circuit is illustrated for a pure resistive load in this study. The output voltage is constructed by changing the triggering angle in successive pulses so as to obtain the desired waveform.



CYCLOCONVERTER

Input Values

R 20.00
Vi 1.00
Theory output Amp 5.00
Supply Amp 5.00

Calculated Values

Io (mean) 0.00
Vo (mean) 0.00
theor Vo(mean) 0.00
Io(rms) 0.15
Vo(rms) 2.90
theor Vo (rms) 3.54

Supply Frequency = 50 kHz
Output Frequency = 30 KHz

i1 0.00E+0
V1 4.29E+0
Vo (theory) -5.24E-2
i3 0.00E+0
V2 4.37E+0
Vo 0.00
i2 0.00E+0
V3 8.73E-2
io 0.00E+0

Fig. 5. The front panel of Cycloconverter VI.

Due to the unlimited number of variations of input frequency and voltages and output frequency and voltages that users may wish to observe there is an infinite number of cases to program for a fully integrated cycloconverter simulation. Therefore, the VI provided here has a limited features, programmed to generate an output voltage at 30Hz for a three-phase input voltage at 50Hz. The front panel of the Cycloconverter VI is shown in Fig. 5.

3.1.6 PWM and Single Phase Inverter (H-Bridge) Control Methods

The motor control method is usually employed in dc motors and stepper motors to limit and/or regulate winding currents, and utilized in ac motor applications to approximate sinusoidal wave outputs by switching the power switches at a rate higher than the fundamental frequency. The ultimate aims in ac or dc motor control are to control torque, speed, position, acceleration and deceleration rates.

The most popular converter topology used in dc motor, stepper motor and single-phase ac motor applications is known as H-bridge circuit. In the control of these applications, the PWM method is mainly used for the output waveform shaping.

The virtual instrument designed in this section is a very comprehensive simulation tool, aimed to study PWM signal generation concept and the operation of an H-bridge in detail. The simulation tool can allow the user to program the PWM switching methods and demonstrates the harmonic spectrum associated with each output. In addition, the impact of the programmed switching on the circuit variables can be studied by observing the waveforms of the voltage and current.

There are two major VIs used in this section. In the first part, a switching method applied to a general load is simulated. The user may alter the values of the parameters of the model circuit and the switching signal (square wave generator).

The second part of the module simulates the response of the circuit given to certain programmed control signals. The spectral analysis of this desired voltage waveform is also given on the front panel of this part. Once the user satisfied about the harmonic contents of the programmed waveform above, pressing the done button advances the program to another front panel. In addition, there are three switch controls where the user can define various template features to the waveform generated. These switches and their states are: Soft/Hard, Half/Full, and Non inverted/Inverted. In the "Sine/Triangle Wave Comparison" option, the output waveform is generated by comparing a sine wave of specified frequency to a triangle wave of specified frequency.

In the subsequent front panels of Part 2, the desired load voltage waveform is processes and switching signals for transistors T1 to T4 are generated, and after viewing the switching signals and pressing the done button the user can proceed to another front panel, where the dynamic response of the H-bridge circuit is tested. The load current and the load voltage waveforms are displayed in this panel.

In addition, a second chart provided on the same panel displays the state of each diode D1 to D4 and each transistor T1 to T4. A red plot on the chart indicates that the particular component is conducting current.

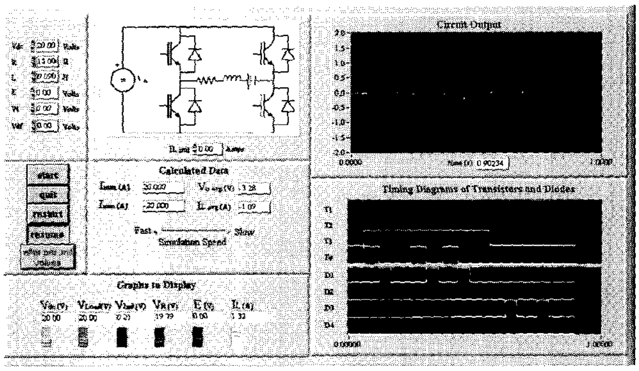


Fig. 6. A sample front panel of PWM and Single Phase Inverter Control VI in Part 2.

3.2 Motor and System Simulation

3.2.1 Dynamic Simulation of Brushless Permanent Magnet AC Motor Drives

A very flexible computer simulation is provided here, which can used to study the motor behaviour and to analyze the complete drive system (including the inverter and the controller) without implementing the hardware. In addition to this, the drive simulations can be forced to operate under the extreme conditions without damaging the motor drive. In the simulation, the dynamic as well as the steady-state operation of the three-phase permanent magnet AC motor drive can be observed in a variety of operating conditions, such as with and without current control, with sinusoidal or rectangular current excitation, and with sinusoidal or trapezoidal back EMF waveforms. One of the front panels of the PM ac motor drive is given in Fig. 7, where the electromagnetic torque, the speed and the position of the motor drive can be displayed.

After performing this experiment, students should be able to:

- Understand the operation of the Brushless Permanent Magnet Motor Drives under the transient as well as the steady-state operating conditions.
- Observe the behaviour of the complete motor drive in a closed loop control system

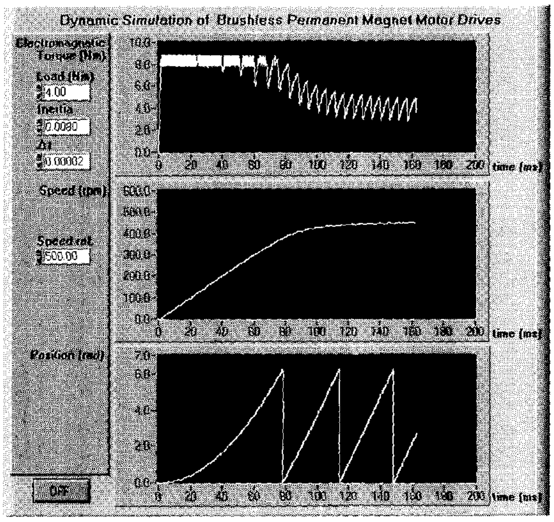

Load (Nm) 4.00
Inertia 0.0080
Δt 0.00002
Speed ref. 500.00

Fig. 7. A sample front panel of Brushless PM Motor Simulation VI.

3.3 Motor Control

The real time control of electrical machines requires a significant amount of processing power. However, in the motor control examples mentioned in this paper, the principal aim is to provide a fully functional cost-effective LabVIEW user interfaces, which primarily targets limited hardware that can be linked to a PC.

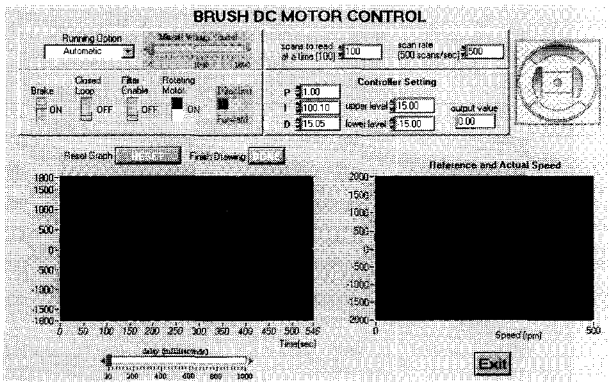
Five distinct real-time motor control concepts are covered in the original study as given in Table 1. : dc motor control, stepper motor control, brushless trapezoidal PM motor control, starting of wound rotor asynchronous motor and switched reluctance motor control.

In the first, the second and the fourth control modules, in addition to the software support, custom-built hardware solutions are also provided. However, all of the VIs in this section assume that the user has access to a lower-end data acquisition card with A/D converter and multiple digital IO ports.

3.3.1 Permanent Magnet Brush DC Motor Control

In this study, a closed-loop speed control concept of a brush dc motor is studied using an H-bridge arrangement and a custom written control software. For higher quality speed control, a tacho-generator is utilized that is attached to the motor shaft. In addition, since the characteristic of a practical tacho-generator may deviate from ideal, specifically at high speeds and may have a high level of noise due to the commutator arrangement, a simple digital filter is also included in the VI.

Building a complete H-bridge with current feedback is an expensive and laborious task, which should also include the driver circuits and the current sensing circuits.



BRUSH DC MOTOR CONTROL

Running Option: Automatic

scans to read at a time (100): 100

scan rate (500 scans/sec): 500

Brake: ON

Closed Loop: OFF

Filter Enable: OFF

Rotating Motor: ON

Controller Setting

P: 1.00

I: 100.10

D: 15.05

upper level: 15.00

lower level: -15.00

output value: 0.00

Fig. 8. The front panel of Brush DC Motor Control VI.

In addition, generating the high speed switching signals for the current control may require significant processing power in a closed loop system. Therefore, an integrated circuit (IC), LMD18245 is used here that incorporates all the circuit blocks required to drive a PM brush DC motor. In addition, the IC can accept digital signals to control the direction of the rotation and braking action. The custom built circuit board has its own in-built mains power supply

The motor's current control in the IC is achieved via a fixed off-time chopper technique. The four-bit digital-to-analog converter (DAC) in the IC provides a digital path for controlling the motor's current. In addition, two BNC connectors are provided on the circuit board to observe the motor's voltage and current in real-time. The current measurement is implemented using a low value resistance that is connected in series with the armature winding.

There are two running options in the VI: manual and automatic control, which can be switched to at any stage except when the brake is on.

In the first front panel, the user defines the speed profile that should be followed by the controller. When the user is satisfied with the speed profile pattern, the Done key should be pressed and an array containing the pattern is stored and followed by the motor. The whereabouts of the speed in the execution is displayed on the speed pattern by using a dot pointer. The time axis of the speed pattern graph can be scaled depending upon the value of delay, which can generate the same profile for any desired time period.

At any time, while the pattern is being executed, the user may terminate the graph using the Reset button. Then the drawing graph returns to the previous state and the motor ceases rotating. If the graph is allowed to finish executing then it automatically returns to the drawing graph. In each case the motor speed returns to zero.

To obtain an optimum response, the PID controller settings on the front panel must be adjusted carefully. The upper and lower level output controls have been specified to account for the max digital input to the controller chip. The rotating motor animation on the front panel aims to provide some insight for the user on how quickly the motor is rotating at any one time. The animation is connected directly to the execution loop, which rotates one step in each loop iteration. However, the animation does not function in the manual control mode.

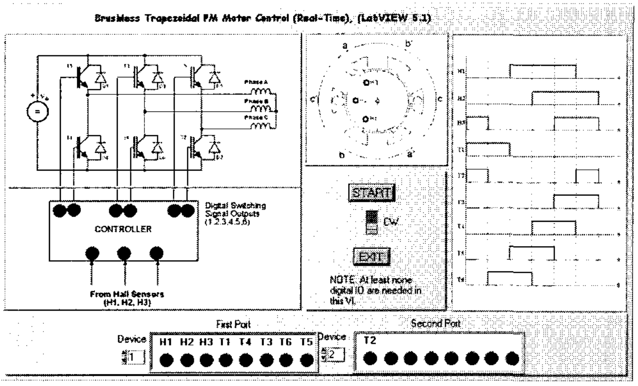
3.3.2 Brushless Trapezoidal PM Motor Control

In this section, the operation principles of Brushless Trapezoidal Permanent Magnet Motors (or simply Brushless DC motors) are studied using two separate VIs : a computer simulation module and a real-time control module. The front panel of the real-time VI is shown in Fig. 9.

In the control module, for every set of rotor position inputs, H1, H2, H3, a set of switching signal outputs for the transistors, T1, T2, ..., T6 is produced. The direction of rotation of the motor is changed within the controller, which in turn reverses the phase energizing sequence.

It should be emphasized here that practical motor drives require current feedback, which is used to regulate the phase currents as close as possible to the ideal reference currents that are generated by the rotor position data. The real-time control VI, however has a very limited power designed based on a slow speed digital I/O ports, and does not use current feedback from the real motor. The minimum number of digital I/O required in this study is 9, three assigned as inputs from Hall-Effect sensors and six assigned as outputs for the inverter switches. A three-phase inverter and a Brushless PM Motor are required to obtain a functional real-time control VI.

Unlike the simulation VI, in the real-time control VI the motor states are not stored. Therefore, each iteration of the outermost loop of the VI reads the current value of the Hall-Effect sensor inputs and, dependent on these values, produces the required output transistor switching signals. Similar to the simulation VI, the front panel of the VI shows the corresponding animation of the rotor, the inverter and the truth table.



Brushless Trapezoidal PM Motor Control (Real-Time), (LabVIEW 5.1)

NOTE: At least none digital IO are needed in this VI.

Fig. 9. The front panel of the real-time control panel VI.

4. Conclusions

This paper specifically focuses on certain power electronics converter topologies to give an insight into the operation of these circuits by providing a highly flexible simulation environment in LabVIEW, which closely integrates the real operation and the theoretical studies. A number of fundamental circuits and converters are simulated. Although not all the design and structure related questions are addressed in the paper, the principal objective is to provide basic simulation ideas that easily can be adapted to other more complex circuit topologies. The details of the Vis including the codes and a number of other VIs can be found in reference [1]. The most of the VIs provided in this reference have been implemented at the University of Adelaide. The survey results carried out within the last two years indicate that the method has a high educational value and it was strongly indicated by the students that they would like to see similar tools in other subjects. However, it should be noted that using a simulation without understanding the basic theory results in serious problems since it will be only a simple toy, not an essential tool. Therefore, the basic theoretical concepts should be adequately reinforced in the lectures with the associated simulations.

It should be emphasized here that when technology intensive teaching tools become widely available, the traditional roles of the university lecturers may change from pure classroom-based teaching to one of consultation, advice and direction giving. However, our believe is that the technology-based course will not eliminate the educators, instead it will change the type of activities the educators carry out.

References

[1] N. Ertugrul, "LabVIEW for Electric Circuits, Machines, Drives and Laboratories", Prentice Hall PTR., USA, ISBN: 0-13-061886-1, First Edition, 2002.

[2] N. Ertugrul, "New Era in Engineering Experiments: An Integrated Interactive Teaching/ Learning Approach and Real Time Visualisations", International Journal of Engineering Education, Vol. 14, No. 5, pp. 344~355, 1998.

[3] N. Ertugrul and M. Rameez, "Development of An Interactive Teaching/Learning Tool for an

Interdisciplinary Course, Power Electronics", IASTED International Conference on Computers and Advance Technology in Education, May 24-27, Mexico, 2000.

[4] N. Ertugrul, "Cost Effective and Advanced Teaching Laboratory Development at The University of Adelaide", IASTED International Conference on Computers and Advance Technology in Education, May 24-27, Mexico, 2000.

[5] N. Ertugrul, S. Padde, and A. Santoso, "An Application of Remote Area Experimentation in Electrical Engineering", IASTED International Conference on Computers and Advance Technology in Education, May 24-27, Mexico, 2000.

Nesimi Ertugrul received the B.Sc. and M.Sc. degrees in Electrical and in Electronic and Communication Engineering from the Istanbul Technical University, in 1985 and 1989 respectively, and received Ph.D. degree from the University of Newcastle upon Tyne, UK, in 1993. Dr. Ertugrul joined the Adelaide University since 1994, where he is a Senior Lecturer. His research topics include rotor position sensorless operation of brushless permanent magnet and switched reluctance motors, real-time control of electrical machines, motion control, fault tolerant motor drives, condition monitoring and predictive maintenance, power electronics systems and electric vehicles.

He is currently engaging in research in the development of interactive computer-based teaching/learning systems involving object-oriented programming and data acquisition. His recent interests also include augmented reality and human machine interfaces. Dr. Ertugrul a member of IEEE and the author of a book titled "LabVIEW for Electric Circuits, Machines, Drives and Laboratories" Prentice Hall. 2002.