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Using a Virtual Platform for Teaching Electrical Machines and Power Systems Courses

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Using a Virtual Platform for Teaching Electrical Machines and Power Systems Courses

Abstract

Study of electrical power systems and electric machines requires a good background on advanced calculus and electromagnetics. But many engineering and engineering technology students lack the required background, and as a result, they have difficulties to learn these subjects. Another issue for electric power system or electric machines students is finding the textbook problem solutions through the use of routine problem-solving techniques, such as equations and formulae. But the students' reliance on formulae and routine use of techniques in problem solving too often leads to poor performance in real-world scenarios. On the other hand, the laboratory sessions in any engineering program particularly in electrical power engineering are critical as these labs are designed for students in accordance with theoretical course work. Setting and running electric machines, energy conversion and power systems laboratories put several challenges and requirements, such as cost, space, limited equipment access, equipment size and similarities with real equipment, safety, students' supervision, etc. Virtual laboratories can become important components of the teaching process, because using them some of the above challenges can be avoided, while several experiment-oriented problems can be solved easily and also from the distance. Software based laboratory experiments have become current day need due to its impacts on flexible learning of students and understanding abilities. Also, the students' lack of solid comprehension of mathematical and/or physics concepts results in wasted time during laboratory experiments, misinterpretations of experiment results and data, etc. This motivation deals with simulation of electric machine and power system experiments which are part of lab work at undergraduate Electrical Engineering level using Laboratory LabVIEW and MATLAB/Simulink software packages. The selection of these software packages among others is based in part on their strong graphical interface capabilities, symbolic computation, user friendly tools and highly understandable approach. Moreover, LabVIEW and MATLAB based electric machines and power systems laboratories and simulation experiments are economical and user friendly. We strongly believe that graduates trained in such virtual laboratories are better trained when they enter the job market. This paper will discuss design and development of interactive instructional virtual instrument (VI) modules for studying the most common experiments in electric machines and power systems laboratories.

1. Introduction

Traditionally, in the development of engineering education the key objectives are to enable the teachers to convey knowledge and insight to the students. The main element was (and still is) the lecture, in which the teacher explains, gives examples, shows calculations, discusses physical principles or mathematical derivations, etc. However, the accent was mainly on the oral communication, which was supported usually by hand written messages using the blackboard and chalk. During the last two decades, computing, information technology (IT), simulation and visualization tools, virtual experiments, distant and remote laboratory, multimedia, the Internet and the World Wide Web (www) have fundamentally changed the practice of engineering education, teaching and learning[1-8]. Different terminologies have been used for online learning, a fact that makes it difficult to develop a generic definition. Terms that are commonly used include e-Learning, Internet learning, distributed learning, networked learning, distant learning, virtual learning, computer-assisted learning, web-based learning, or distance learning. All of these terms imply that the learner is at a distance from the tutor or instructor. Information and communication systems, whether networked or not, serve as specific media to implement the learning process. E-Learning is essentially the way that computer and network enabled transfer of skills and knowledge, referring to the use of the electronic applications and processes to learn.[4-12] Today, education and especially engineering and science education are strongly influenced by the emerging e-Learning and the accent is in skills and (deep) understanding rather than knowledge. E-Learning plays by this development an important role.

The engineering, science, and technology fields, at present, are very dynamic fields due to the recent advances in computer and IT technologies, simulation and modeling techniques. These have resulted in numerous software packages to solve traditional and novel engineering and science problems. These software packages and programs use the advanced computational capabilities to assist in the design, development, modeling, simulation or control of complex systems. Automation is becoming a part and parcel of every industry, and industries need a trained workforce to manage this new developments and tools. As a result, engineering, technology, and science programs are under pressure to incorporate the use of new advances in computing, simulation and visualization packages, or computer technologies into their curriculum so their graduates can be well-trained in the use and the application of these technologies and serve the needs of the industry. The complexity in all areas of the electrical power (generation, transmission, distribution, monitoring, control, protection, reliability, electric machines, power economics, etc.) has increased, and the engineering graduates must be well-trained to address the needs of the industry. In this regard, most of the programs have introduced and/or revitalized courses and laboratories in electric machines, energy conversion or power systems to provide the graduates with the theoretical and practical knowledge. The study of electric machines, energy conversion and electrical power systems requires a good background on advanced mathematics and electromagnetics. However, most of the engineering technology programs do not require advanced mathematics and electromagnetics making difficult to teach electric machines, energy conversion or electrical power systems in these programs.

Learner-centered methodologies usually place the student as the main actor of the teaching–learning process by increasing his interactivity and participation, proposing activities where the teacher acts as a guide in the students' constructive process. However, the teaching process should be centered not only on the learners' activities, but also on the learner satisfaction considering what is relevant for the student. In fact, learner satisfaction becomes a more general concept which includes interactivity and participation as one of the aspects of satisfaction. From this approach, the learner satisfaction measurement is the evaluation function that guides a closed-loop process (shown in Fig. 1) of educational innovation and improvement.

During the last ten years, the Internet and the World Wide Web have fundamentally changed the engineering, science and technology education, especially the practice of distance teaching and learning. Different terminologies have been used for online learning, a fact that makes it difficult to develop a generic definition. Terms that are commonly used to define the online learning include: e-Learning, Internet learning, distributed learning, networked learning, tele-learning, virtual learning, computer-assisted learning, web-based learning, or distance learning. All of these terms imply that the learner is at a distance from the tutor or instructor. Information and communication systems, whether networked or not, serve as specific media to implement the learning process. E-learning is essentially the computer and network enabled transfer of skills and knowledge. E-learning refers to using electronic applications and processes to learn[1-3]. E-Learning can provide benefits for organizations and individuals such as improved performance, increased access, convenience and flexibility to learners. Computer-based training also offers some additional advantages over traditional classroom training. These are reducing and extending overall training time, easy tracing the progress, accessibility, reusability, reducing the cost, participating in class activities when convenient, etc. [4-8].

A proper definition should demand that the electronic media give specific support to the learning process itself, which probably could not be achieved by other media (else we would have a case of electronic media just emulating traditional media). Many e-Learning projects seem to subscribe to the definition we just characterized as being too wide. Their program of action is just to import existing standalone mechanisms of content distribution and communication into a didactical environment without ever truly justifying their relation to and benefit for the learning process. Using hyperbole to make our point, we are tempted to say that a conflict which is being slugged out by throwing books does not constitute a literary contest at all. Alternative definition of e-Learning has been that e-Learning is an aggregation of all kind of learning which use the computer for medial support of the learning process. In contrast, others only see e-Learning where all real business process of learning, teaching and organization has been migrated into the digital environment. According to Rosenberg (2001)[6] e-Learning depends on internet technology and is typically a networked form of learning based on a more general concept of learning which transcends the traditional paradigms. Access to information is as essential for learning as instruction. He also stated that ‘‘knowledge management supports the creation, archiving, and sharing of valued information, expertise, and insight within and across communities of people and organizations with similar interests and needs’’[6] (p. 66). The benefits include the facilitation of learning with specific information needed at a specific time for a specific purpose and the ability to leverage and grow the collective knowledge of the organization. An important component is the inclusion of performance support components designed to enhance performance. Rosenberg stresses the research on the importance of using communities of interest to support and enhance the learning process.

2. On-site Laboratory vs. Virtual Laboratory

Laboratory work classes are an integral part of any engineering, science or technology educational program and their purpose is bringing the students closer to real situations of the area of studies. The typical traditional laboratory consists in sharing and grouping the students, discussing the theoretical problems together, working directly on a set of equipment and apparatus following a set of written guidelines, evaluating the results and elaborating personal conclusions[4-12, 17-31]. The major shortcomings of the traditional laboratories: (a) the sets of equipment can be significantly high and the institution can't modernize them in a timely manner; (b) the students access to laboratories is restricted only to the laboratory periods; (c) since the students can see only the inputs and outputs of the system, those laboratories cannot fully backup the understanding / intuitiveness of the physical phenomena illustrating the functionality of electrical machines, energy conversion devices or power system components; and (d) operating under unfamiliar conditions, accidents may happen.

Considering the new developments and trends in the IT, www and computing systems, the above listed educational shortcomings can be avoided by replacing traditional laboratories with virtual ones. A virtual laboratory is the space where the elements are expressed virtually using interactive graphics, and a conceptual and interactive design. The modular content of a virtual laboratory, organized as a database, permits a quick access to the structured information. However, the concept of a Web-based laboratory is not new since it has been introduced in the early 1980s. The fast progress of Internet-based networking technologies allows the development of distance and/or remote experiments and applications with significant and secure data flow rate. Since the research in all engineering areas should combine both theory and practice, the principle of the virtual laboratory is very useful to provide researchers and engineers with the Internet access to various expensive but up-to-date setups located indifferent laboratories. In this way, many institutions and universities have developed remote applications for monitoring and operating sensors, electric machines, control schemes, power converters. Researchers could have access to data coming from sensors, experimental settings or field experiments using virtual instruments (VIs) developed within the LabVIEW and MATLAB environments[18, 38-50]. The main objective of virtual laboratories is to introduce students to experimentation, problem solving, data gathering and scientific interpretation. Educators, students and researchers, crunched between demand for effective and up-to-date education, technological advances and budgetary constraints can use virtual instrumentation to automate routine tasks, accomplish new objectives, replace outdated and expensive equipment, and/or to demonstrate students the potential of high technology.

3. MATLAB and Graphical Programming Tools

The LabVIEW programming is extremely intuitive. Disposing of various objects, such as terminals, constants, structures, functions and subVIs (sub-virtual instruments), LabVIEW allows users to define the behavior of their applications by dragging and dropping these objects onto a diagram, and connecting them through wires, as necessary. Each terminal in the block diagram has a correspondent on the front panel window (the graphical user interface of the virtual instrument), which acts either as a data input or a data output. Generally, this programming approach is very well received by students, many of them stating that the LabVIEW platform is highly accessible and efficient for learning. LabVIEW comes with hundreds of ready-to-use example VIs. Moreover, it integrates configurable Express Vis that significantly reduces the development time and complexity associated with adding analysis and signal processing algorithms into user applications. Finally, instructors and students may save time and acquire new ideas by visiting the National Instruments' academic web site, where they can access labs, exercises and tutorials covering a large number of electrical engineering disciplines. One can program instrumentation, equipment or courseware using the LabVIEW's highly effective graphic programming tools, enabling users to integrate the applications of physical instruments on the basis of having grasped theoretical knowledge, and also encourages them to create new virtual instruments by themselves. In this way, we can cultivate hands-on ability and creative thinking, which in turn can raise their whole learning level. LabVIEW software developed by the NI Corporation is based on computer's visual virtual instrumentation, providing a very flexible platform for measurement technology. Remote real-time control of processes is receiving considerable attention in the academic and industrial communities. Various technologies are developed to perform the remote real-time control using Internet-based technology[13-19]. LabVIEW is one of the well-known software packages used in process control applications. LabVIEW uses various protocols such as TCP/IP, DataSocket, etc. that allow remote control using Internet. Several universities have developed Internet-based process control laboratories for distance education using LabVIEW and its communication protocols[11]. Due to his versatility and capabilities LabVIEW is one of the most used packages for development of Remote Labs. Most of the work reported so far uses Internet Toolkit, DataSocket, and so forth for developing Remote Labs, which require clients to have software developed in LabVIEW[11-20].

LabVIEW environment is currently used by engineers and scientists to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart. It offers unrivaled integration with thousands of hardware devices and provides hundreds of built-in libraries for advanced analysis and data visualization – all for creating virtual instrumentation. The LabVIEW platform is scalable across multiple targets and OSs, and, since its introduction in 1986, it has become an industry leader. The programming that is done in this LabVIEW software is mainly **Graphical Programming that is** an environment with drag-and-drop, graphical function blocks instead of writing code lines. **The representation is mainly Dataflow Representation which is** easily developed, maintain, and understand code with an intuitive flowchart representation. LabVIEW is the centerpiece of graphical system design and provides engineers and scientists with the tools you need to create and deploy measurement and control systems. One can get more done in less time with LabVIEW through its unique graphical programming environment; built-in engineering-specific libraries of software functions and hardware interfaces; and data analysis, visualization, and sharing features. Moreover, one can bring own world vision with LabVIEW, while making complex systems simple and accessible.

LabVIEW is very easy to learn and it can rapidly be applied in regular teaching and in practical applications[9-12]. LabVIEW is a programming language, equivalent to C++, Visual Basic, or any other language[10-13, 36-38]. However, it is the *only* widely accepted graphical programming language. Graphical programming is the language of the future and carries with it many important advanced programming concepts. The visual/graphical representations bring programming closer to the human side of the human–machine interface, just as high-level languages tipped the accessibility scales relative to assembly languages. Moreover, LabVIEW has proven to be an invaluable tool in decreasing development time in research, design, validation, production test, and manufacturing. Besides this, the major advantages of LabVIEW include: ease of learning, using and debugging, the simplicity of using the interface (front panel of a LabVIEW program) particularly for a user with little knowledge of LabVIEW programming, modular development, complete functionality, available tools and resources, reliable performance and the capability of controlling equipment. There are four critical elements of the LabVIEW development platform[11-13]:

1. Intuitive graphical programming language
2. High-level application-specific tools
3. Integrated measurement and control-specific capabilities
4. Multiple computing targets

MATLAB, as a high-performance language for technical computation, integrates calculation, visualization and programming in an easy-to-use environment, thus becomes a standard instructional tool for introductory and advanced courses in mathematics, engineering and science in the university environment[18, 32-35, 42-50]. Most of the students are familiar with it. MATLAB is effectively a very high level language and SIMULINK is an additional module which was developed for simulating dynamic systems. SIMULINK has a graphical user interface which is mouse driven and includes a library of functions which are the building blocks for the model. Each function has its own icon which can be selected and dragged into place on the screen by the mouse. The numbers of types of different functions which are needed for the present modeling project are surprisingly few. They include: addition/subtraction, multiplication, integration, inputting constants, graphing of output and a clock (to keep track of the model time). MATLAB and SIMULINK are available in three different versions: (i) student edition, (ii) standard edition and (iii) a classroom kit which is for use in PC laboratories. Hence there is potential for the students to purchase their own copies if desired, in much the same way as purchasing a textbook.

MATLAB is also capable of producing interactive simulations. This can enhance the quality of presentation with graphical simulations. With the help of interactive simulations instructors can effectively illustrate the change in system response due to parameter variations. This helps students gain a better understanding of the subject. Moreover, since there is no need for students to do any programming, this will allow students with limited or no knowledge of MATLAB programming to access features of MATLAB with little investments of time[42-50]. This feature is essential in an interactive courseware development.

4. Virtual Platform, Laboratory and Experimental for Electric Machines, Energy Conversion and Power System Courses

The Electrical Machines, Energy Conversion and Power System Analysis Virtual Laboratory integrates computers and industrial hardware expanding the range of instrumentation and control to virtually unlimited capabilities, offering for the students a pre-practice, a replacement or a post-analysis of the real laboratories. The methodology used in the Electrical Machines, Energy Conversion and Power System Analysis Virtual Laboratory is structured in a same manner as in the case of the real lab. It begins with an introduction containing a short discussion on the laboratory exercise to be performed (including details on data collection and data analysis), procedures (instructions on how to conduct the laboratory work), respectively a step-by-step guide through the virtual lab, analysis, report writing requirements and references. Virtual lab applications in engineering education are gaining very substantial place[32-46]. An integrated virtual learning system for the development of motor drive systems was developed in ref. 40, while ref. 41 and 42 proposed a virtual electric machine laboratory for synchronous machine application. A web based real time speed control experiment on ultrasonic motor for educational purposes was developed in 36 and 45. There are an increased number of virtual electrical machines laboratory tools and simulators in the last two decades. In this study, distance accessed virtual laboratory for an electrical machine was established.

A block diagram of developed educational tool based on internet is shown in Fig.1. In order to develop the educational program on a server computer, the devoted packed programs such as MATLAB/Simulink, LabVIEW, Simulation Interface Toolkit (SIT) and LabVIEW WEB Server

(LWS) were used altogether in this study. Simulation of models of the electric machines, energy conversion devices and power system components are designed, developed, implemented and coded in MATLAB/Simulink and Maple environments. An interface for users is developed using LabVIEW. Data transfer between user and the SRM simulation program is achieved with help of SIT. To access the educational tool through an internet LWS program is used. When all mentioned programs are appropriately operated on a server a user friendly powerful educational program can be gained. On clients or student's/user's computers only internet connection and internet explorer program are enough to access the educational tool. So they do not need any additional programs and expenses.

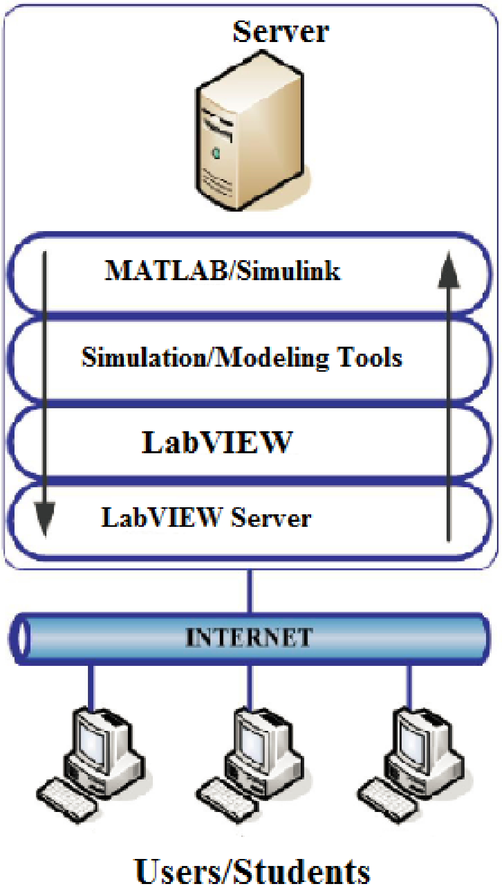


Figure 1: Block diagram of developed educational virtual platform

4.1 Development of Electric Machines E-learning & Virtual Platform

One of the first steps in using computers in education represented the mechanical conversion of the traditional study materials *into electronic form* and making them accessible to students, usually via the university network. New materials were produced and distributed on PCs, but nevertheless, they proved unsuitable for work in electronic form. Their predominantly textual shape directly predetermined them to the traditional form of study – to reading from printed materials. In the next paragraphs a development of E-learning is presented. It concerns the teaching material in electronic form available through the internet/intranet. Other issues focus on the style of teaching under the impression of extensive usage of multi-media like video-clips, audio or "slide shows" in the classroom or via internet.

The basis of a virtual laboratory consists in simulation of the measurement of a motor. The aim of this contribution is to describe creation of a complete model of a machine for such laboratory, an induction single-phase motor with external rotor. The model will be comprised of electrical, mechanical and thermal parts. All these parts will be finally assembled to make a single complete model which will be used within the virtual laboratory program. An e-learning platform is a set of tools, which manage the interaction between the training system users (students, tutors and administrators) and the central server. The two principal features of the e-learning platform are the delivery of information and data, in electronic format as didactical units e.g. courses, lessons and checking of the training results. With a server-client platform, the e-learning courses remain open systems for implementing new information in the future. The information – study area is adaptive to the user and the teaching contents are listed in a tree structure, which enables easier orientation of the student during the studying. The control and guidance of the students through the teaching contents has been realized using Perti Networks. Each project user is able to log on to the server by simply using any common browsers.

4.2 Virtual Platform Structure

In this project the complete laboratory session of the Electrical Machines, Energy Conversion and Power System Fundamentals courses has been simulated using LabVIEW, MATLAB/Simulink and Maple software packages. The fundamental equations and simulation models of Transformer, DC Machines, Induction Machine and Synchronous Machines using their equivalent circuits and standard input parameters have been developed, implemented into the LabVIEW and MATLAB for simulation purpose. The list of experiments for Electrical Machines course which has been simulated during this project include experiments such as: Load Characteristics of Separately Excited DC Motor, Shunt DC Motor, and Series DC Motor; Load Characteristics of DC Generators; Calculation of the Parameters of Transformer using Open Circuit & Short Circuit Tests; Voltage Regulation for a Single Phase Transformer; Equivalent circuit parameters of an Induction Motor; Load Test of a Three Phase Induction Motor; Load Test of a Single Phase Induction Motor; Torque vs. Speed Characteristics of an Induction Motor; Equivalent Circuit of an Induction Motor; Synchronous Generator Tests and Equivalent Circuit. While for Power System Fundamental course the simulation modules include: Power in Single-Phase AC Circuits; Star/Delta Connections; Transmission Line Models; Economic Dispatch Module; and Nodes Equations and Ybus. There several papers published in the last decades using LabVIEW and MATLAB simulators of various electric machines or power system components. However, the complete Laboratory Experiments of Electrical Machines and Power Systems courses, implemented in LabVIEW and MATLAB based upon the exact ratings and on-ground machines parameters as a pioneer and novel research endeavor. The front panel of the Electric Machines virtual platform is shown in Figure 2.

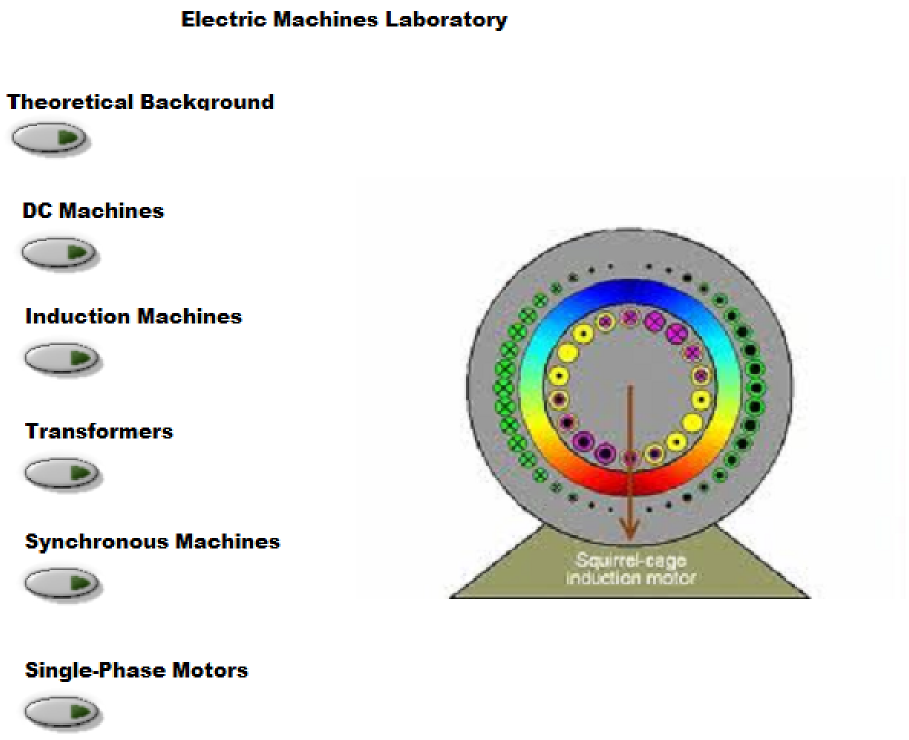


Figure 2 – Front Panel of the Electric Machines Virtual Lab

4.3 Example of Virtual Platform Module: The Induction Motor

The virtual laboratory experiments on Induction Machines are based on the induction motor equivalent circuit parameters and characteristics (see Figure 3), has been developed, implemented and coded in LabVIEW and MATLAB. It has been generating applications for students, of direct execution by an applet. The model uses the exact equivalent circuit of asynchronous electric machine (induction motor) Figure 3, and its function is to help analyze and understand the operation of this machine when works as motor, without having to use a real installation.

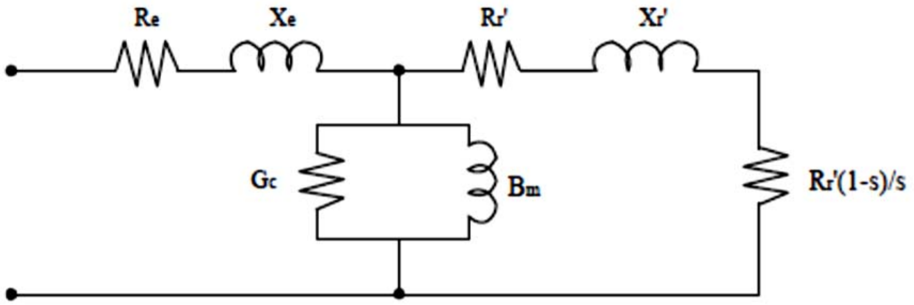


Figure 3, Equivalent circuit per phase of an induction motor

Circuit parameters of the induction machine are: V, rated voltage, f, Frequency, p: number of poles; Re: Stator winding resistance; Xe: Stator leakage reactance; Rr’: Rotor winding resistance referred to stator; s: Slip; Rr’(1-s)/s: Load resistance or effect of slip on the rotor; Xr’: Rotor leakage reactance referred to the stator; Gc: Conductance that represents iron losses; Bm: Magnetizing susceptance; and, Pm: Mechanical losses The graphic window of the torque-speed curve is the fundamental tool of analysis of the virtual lab model, is composed of three parts:

1) Torque-speed curve;
2) Cursor adjustment of slip, load adjustment, (s);
3) Values of the variables of interest.

The motor operating conditions, which can be analyzed with the model, are: a) Starting; b) Regime at maximum torque; c) Steady state under loads conditions; and d) Steady state no load (empty). The main menu of the induction machines module is presented in figure 4.

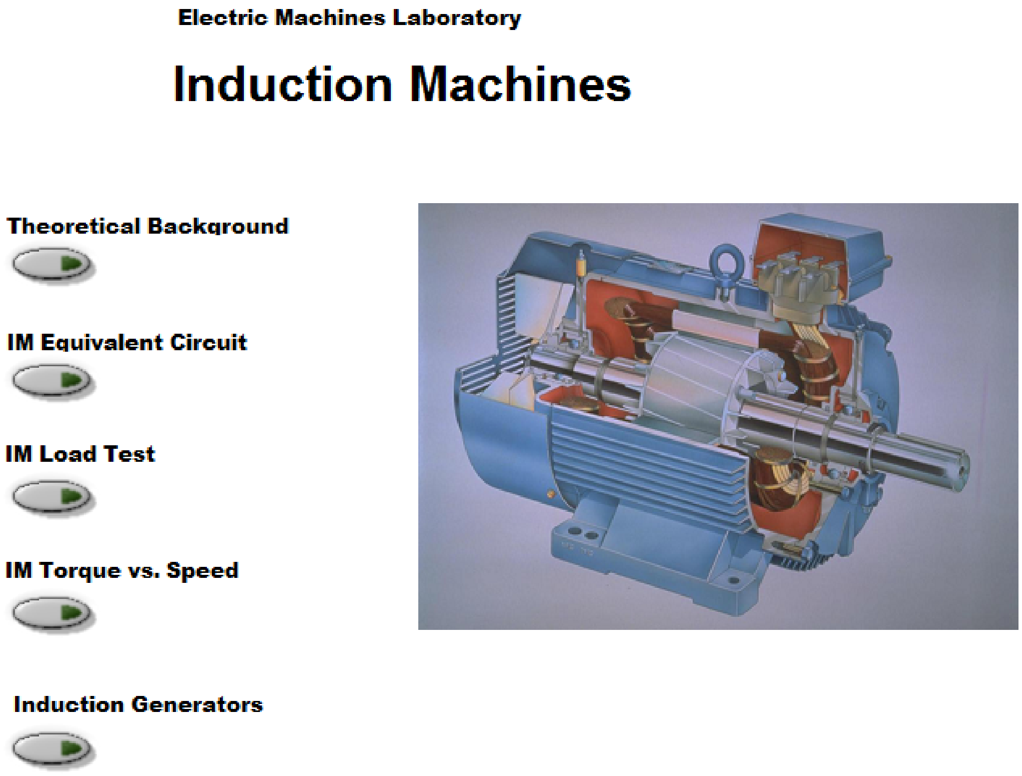


Figure 4 The Induction Machines Module Menu.

An induction motor is an AC motor in which power is supplied to rotor with electromagnetic induction. The fundamental relations associated with Induction motor are one found in the most of the electric machines textbooks. The induction machine block diagram was designed and assembled according to the requirements during modeling in LabVIEW and MATLAB. The block diagrams helped to make a general layout of an induction motor as shown in figure 5. While, figure 6 is showing results of the simulations. The overall module gives the students deep inside the operation, characteristics, efficiency, performances of the most common type of induction machines. Front Panel diagram for equivalent circuit model parameters of an Induction

Motor, not shown here, allows the students to include specific parameters taken after they learn and read the theoretical background section of the module.

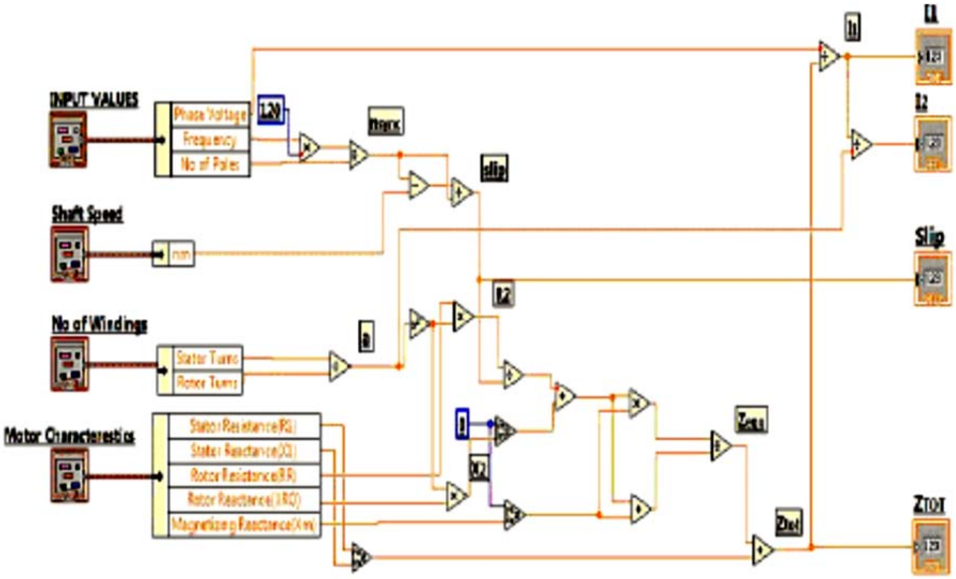


Figure 5. Block diagram of an induction motor

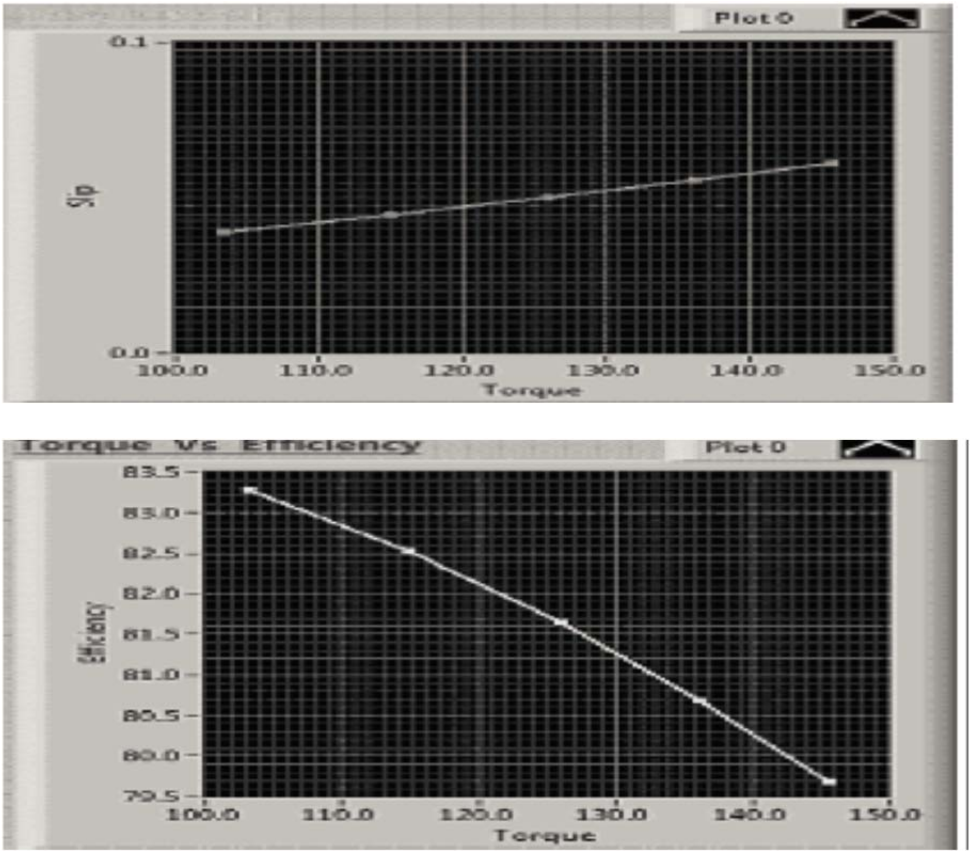
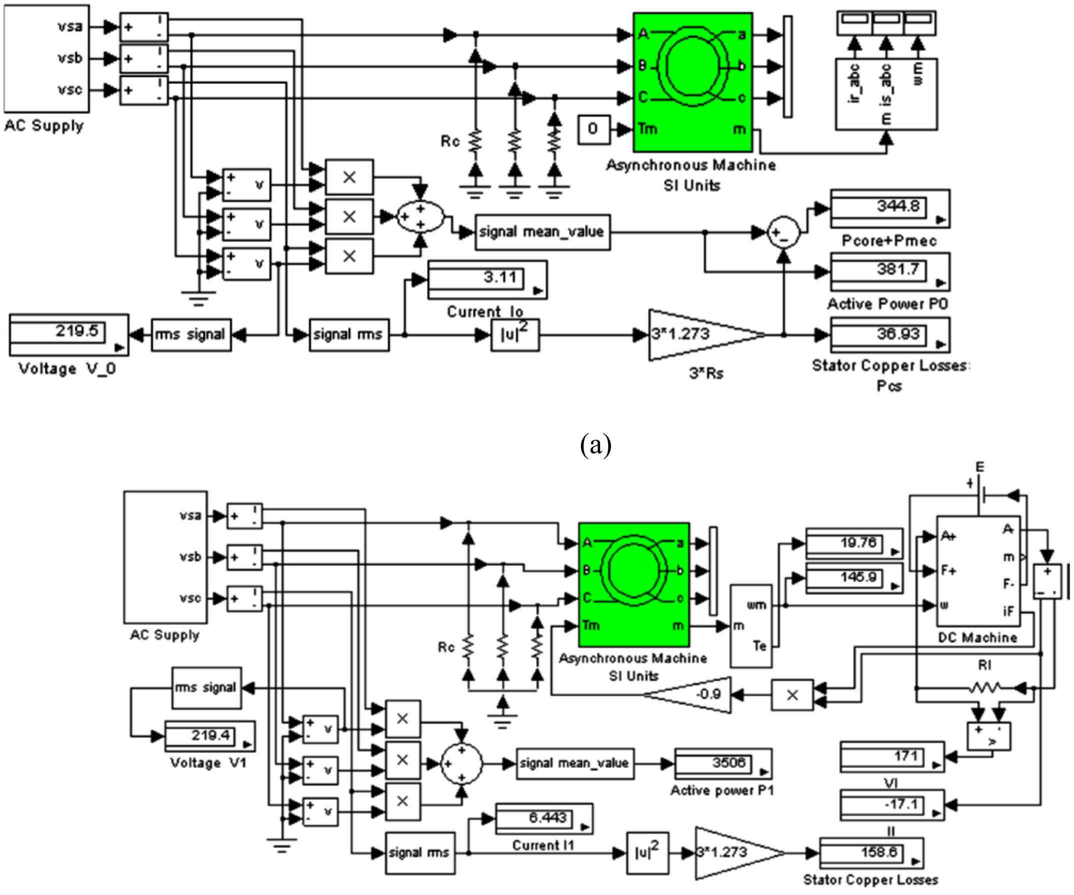


Figure 6 Torque vs. Slip (upper panel), and Torque vs. Efficiency (lower panel)

To validate the models, several standard machines were simulated and the results were compared with reported results. Similar structure and approach was implemented for each module of the virtual platform.

4.4 MATLAB/Simulink Simulation of Induction Motor



(a)

(b)

Figure 7 IM simulated tests (a) No-load model (b) Resistive load model.

The voltage and torque equations that describe the dynamic behavior of an induction motor (IM) are time-varying. It is successfully used to solve such differential equations and it may involve some complexity. A change of variables can be used to reduce the complexity of these equations by eliminating all time-varying inductances, due to electric circuits in relative motion, from the voltage equations of the machine. The classical theory permits the layout of the considered machine equivalent circuit. Then all parameters figuring in this equivalent circuit have to be identified experimentally or analytically starting from the real lab. Next, the identified parameters will serve in plotting the machine diagram automatically using MATLAB/Simulink program[42-50]. The usual characteristics of the machine are predetermined virtually using Simulink models. Subsequently, the virtual laboratory is presented to the student, via interactive course tools of the platform, as detailed above. The IM has two active elements (two three-phase balanced windings), the stator field circuit and the rotor armature, interacting via an air-gap where the energy exchanges take place. In normal operation, the stator is excited by alternating voltage of frequency *f*. This creates a rotating magnetic field inducing currents in the rotor winding. These currents, in turn, interact with the rotating field to produce torque. The stator and rotor fluxes can be computed and implemented in MATLAB/Simulink, as one shown in Figure 7. Because of the symmetry of the balanced three-phase IM stator and rotor windings, it is sufficient to take only one phase into account. Each phase has a resistance in series with a linkage inductance, and the windings are magnetically coupled through a mutual inductance (as shown in Figure 4) [40-50]. With this equivalent circuit, the operational performances of an IM can be completely described. At normal operation, this diagram is used with constant voltage and frequency, therefore with a constant flux linkage. The developed models of no-load then for load tests are depicted in Fig. 7 (a) and (b).

5. Assessment and Evaluation

The project objectives and a set of expected and measurable outcomes were used for the evaluation of the project. First, the completeness of the experimental units and e-Learning modules will be assessed. Testing and improvement of the laboratory components and of the emulators including beta-testing and pilot testing for online and remote operation was performed using focus student and instructors groups using seminar format. The developed teaching materials were evaluated by detailed surveys at the end of each quarter. The surveys will evaluate the experimental units and e-Learning modules in terms of the following items: 1) is the theory presented clearly? Are the methods and procedures well explained? 2) ***Emulator***: Is the emulator easy to use? Is the emulator performance satisfactory? 3) Is the theory presented helpful? Does the virtual model show all necessary features? 4) **Overall evaluation of the teaching material**: Does the teaching materials help you to understand renewable energy systems? ***Please include your suggestions for improvement***. The laboratory units and e-Learning platform modules will be evaluated by the instructors and TAs as well. The faculty members who participate in testing will be also asked to provide feedback about the developed materials. Their feedback and student surveys were carefully reviewed and proper modifications were made to the emulators and e-Learning modules to improve our e-Learning platform. On a scale from 1 to 5 the student feedback and evaluations on average for two years of using the virtual platform was about 4.40.

The e-learning instructional design is another essential component of learning. Questions addressed to this issue show a good general valuation. The learners/students are aware of learning objectives as they are using the virtual learning environment, and they felt actively involved in the learning process (based on the results of each survey feedback), which is in agreement with its decision to register in the course. The students feel very comfortable learning at its own pace but not so much deciding in what order to learn. It is very plausible that, while the course materials and virtual lab are available at any time, the sequential presentation of some of the scientific content of the modules limit in what order the modules could be completed. The tasks to complete each module are clearly stated and the perceived interactivity of the course and experiments reflects that the choices that students make are meaningful and not just not for the sake of making choices. However, in general, the responses amongst the surveyed groups (students, graduate students (TA) and instructors) showed little divergence. With respect to the graphics, the scores were more demanding, perhaps as a result of comparisons with the quality of graphics found in in many common electronic devices such as mobile phones. This is one of the areas for future improvements, because the graphics and user interface may strongly affect the motivation to use the program. Another area that requires improvement, but could increase the complexity of the calculations and therefore slow down the simulations, is the accuracy of the data obtained for certain models of complex systems such as power plants at high temperature. In addition to the continuous improvement of the application based on information collected from users, especially those aspects that can cause fatal errors and hinder the use of the application, a series of additional surveys will be conducted at the end of the school year to assess the degree of satisfaction with these tools. These additional surveys will be performed to obtain a broader perspective, collect all suggestions for improvements that may be incorporated in later versions and assess the impact of the Electric Machines and Power Systems virtual platform implementation on students' academic results. However of this high and positive assessment of the practical sessions, real, warns that virtual or remote laboratories can be a complementary tool, but not for replace hands-on labs, at least in the subjects and engineering's considered in this study. Showing that cannot set a general trend pro remote or virtual lab, in detriment of the real experimentation.

6. Conclusions and Future Work

In this study, an application of internet based distance learning to virtual lab is presented, which can be also used for traditional education. Virtual labs of conventional electric machines (single-phase transformer, synchronous machines, induction machines, and DC machines) including automated diagrams and simulated models using MATLAB/Simulink and LabVIEW have been developed in this paper. The implemented simulators cover most of the traditional electric machines and power systems experiments, such as DC machines, induction motors and generators, synchronous machines, transmission lines, power computation, etc. In this virtual lab as an example for the application, the operation characteristic of an induction machine is selected. The purpose is to enhance the electric machinery course and to increase both students understanding level and outcomes by adopting an interactive innovative pedagogy. By performing their practices first at the virtual laboratory, students can predetermine the usual characteristics of conventional electric machines and then handle safe tests in the real laboratory to validate their simulations. The virtual modules presented in this paper are tested with the input values from various examples in the most used textbooks for electric machines, energy conversion and power system analysis. The results are matched with the results of the examples. The modules and virtual platform presented in this paper are developed using simplified models. Although this is sufficient for introducing the concepts, elaborate models must be incorporated into the modules to address the complex real world situations. A number of software packages are currently being used in engineering, technology, and sciences curriculum. While some of them require a programming background, others are designed for specific course requirements. LabVIEW has features and built-in virtual instrument modules identical to most of the features found in all these software packages. MATLAB is extensively used for studying circuits and power systems, and a number of books and literature are available on this topic. On the other hand, MATLAB package requires writing codes. In contrast, LabVIEW provides a graphical environment to solve complex problems. No or minimal programming knowledge is necessary to design and develop the VI modules. LabVIEW has provision to transfer data between LabVIEW, Excel, and MATLAB and call MATLAB and Excel from the LabVIEW environment. Therefore, one can use LabVIEW to address the needs of various courses. This will be beneficial for students and faculty and introduce standardization across the curriculum. The feedback from students and other instructors was very positive and encouraging. The results obtained from point of view of students, offer a positive view on the potential of this pilot scheme to support the autonomous learning and facilitating the understanding of the theoretical concepts, from of e-learning. Additional modules, experiments, simulations and significant improvements in the user interfaces, front panels, simulation and lab manuals are planned in the near future.

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