Virtual Labs for learning Electrical Machines in Marine Engineering

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Abstract: - Studies within the EHEA framework include skills as independent learning, which requires the student will devote much of his time to personal and group work, to strengthen and supplement the information acquired in the different academic classroom activity. To consolidate the results of these activities is necessary for the faculty to develop tools that encourage the study and facilitate the process of autonomous learning. With this aim, this work presents the use of virtual laboratories, based on simulation by Ejs (Easy Java Simulations), covering electrical machine learning, facilitating the testing and understanding of them.

Key-Words: - Virtual Labs, Ejs (Easy Java Simulations), electrical machines

1 Introduction

The convergence and recognition of studies within the European Higher Education Area (EHEA), has created the necessary inclusion in the curricula of learning approaches based on generic and specific skills, that will enable the student a for the exercise of the profession.

One of these skills or abilities is to develop autonomous learning by solving exercises, problems and case studies. That is, the student has to devote much of their time (around 50% of the ECTS credits) at to personal and group work to reinforce and complement the information collected on the lectures, or participatory class, practical laboratory, problems sessions, projects supported by the teacher, etc.

Autonomous learning in Grades Marine Engineering and Naval, where the practical component of the learning process is important, requires innovative ways to motivate and help students consolidate the result of individual effort. This requires new tools that complement and strengthen study and research activities based on books, notes, queries in libraries or through Internet browsers. These tools facilitators of autonomous learning should include experimentation through virtual labs (simulators) or remote laboratories, web-based or PC-resident application.

With this purpose, this paper presents the use of simulation techniques and virtual labs, applied to the learning of Electric Machines and the initial evaluation results obtained of Naval Technical Engineering students, in a pilot program implemented in Nautical School of Barcelona, Spain, and whose basic objectives can be summarized in two:

1) Enhance use of simulation as a study tool.
2) Determine the type of e-lab can deliver better results to understand the theoretical class and complement practical laboratory.

1.1 Hands-on labs vs Simulated labs

This is an old controversy between proponents of one or another model, of which there are strong arguments to take account of both points of view [1-3]. Hands-on labs help the future engineers to make contact with the equipment and materials, which in future will have to use, allow you to deal with unforeseen problems and uncontrolled variables that offers real experiments, in return means are expensive, require space and have availability limited use. For their part, virtual labs offer the possibility of analyzing a wider variety of cases, the repetitive study of each situation, are economic, not limited by time of use, except for the user time. The development of ICT technologies (Information and Communication Technology) has stimulated a growing interest in virtual labs and its broad scope, as evidenced by the increasing number of applications and publications listed in [3,4].

1.2 Virtual Lab Platform

Currently there are a variety of platforms or software that allow developing virtual labs with a high power of simulation, a high degree of interactivity, multi-user capability and flexibility to online learning and to easily integrate in e-learning platforms.

For our application we have chosen the Java Ejs (Easy Java Simulations), since it is a free software tool designed for developing interactive virtual labs, has configurable and interactive visual elements that allow the rapid construction of models and views of the virtual labs [5]. Compilation in Java of independent execution code, commonly called applets, allows applications to reside in the Web of our university or can be downloaded and executed on the user's PC, using JVM (Java Virtual Machine software of free diffusion) [6]. Additionally there is the possibility of integrating Matlab/Simulink models in the Ejs models, through Jim (Java Internet Matlab) application [7], which allows you to extend the capabilities of Ejs.

2 Model: Parameters and operational interface

The virtual laboratory that this paper presents is based on the induction motor, has been developed in Java Ejs and has been generating an application for students, of direct execution by an applet. The model uses the exact equivalent circuit of asynchronous machine, figure 1, 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 2.

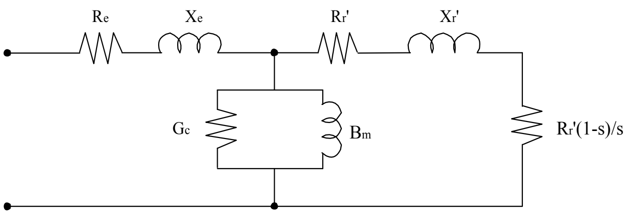


Fig. 1, Equivalent circuit per phase

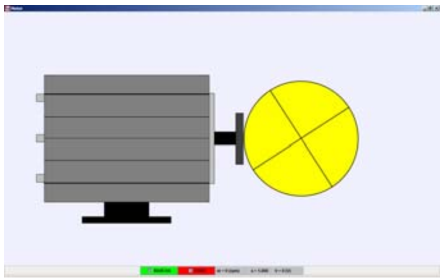
Circuit parameters, previously defined for the machine are:

- V: Rated voltage
- f: Frequency
- p: nº 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
- Pm: Mechanical losses

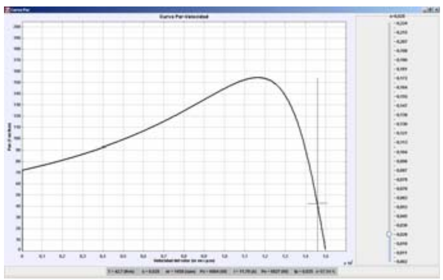
Fig. 2, Laboratory

The model builds three windows that let the user interface, figure 3:

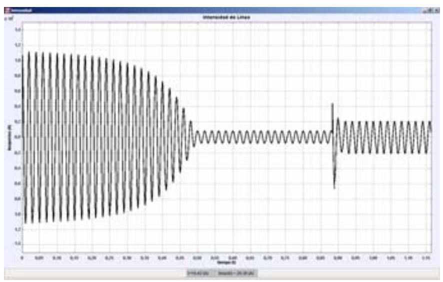
• Window ON/OFF
• Window graphics Torque-Speed curve
• Window graphic Current intensity



a. Window ON/OFF



b. Window graphics Torque-Speed cur



c. Window graphic Current intensity

Fig. 3, Windows virtual lab interface

Each provides the necessary information associated, that overall, allow to know at any given time the different values of the motor variables:

- T: Internal torque (N.m)
- I: Current intensity rms and peak (A)
- Pe: Electrical power input (W)
- fp: Power factor
- s: Slip
- nr: Rotor speed (rpm)
- Ps: Mechanical power output (W)
- η: Efficiency (%)

The graphic window of the torque-speed curve is the fundamental tool of analysis of the virtual lab model, is composed of three parts, which can clearly be seen in figures 4, 5, and 6:

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

The motor operating conditions, which can be analyzed with the model, are:

- Starting
- Regime at maximum torque
- Steady state under loads conditions
- Steady state no load (empty)

2.1 Starting the motor

The first window of the model, figures 4, starts the motor by pressing the "ON" green button ("Marcha") and enables indicators for voltage, speed and slip, in any load condition. As a first step of simulation and analysis, is generated torque-speed curve, figure 5, with the information on this window can know the different magnitudes of the motor at the starting point (s = 1).

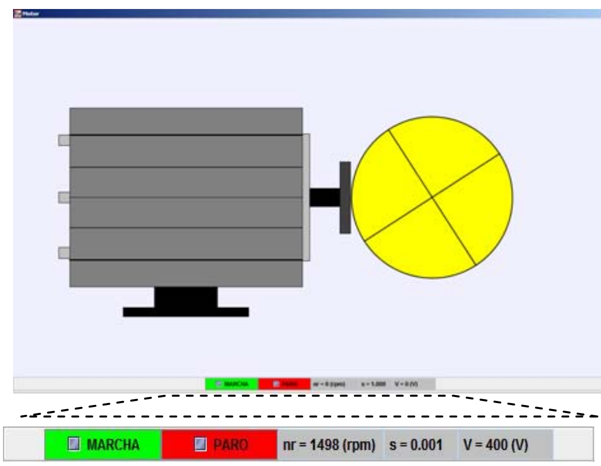


Fig. 4, Window buttons ON/OFF Motor running no load

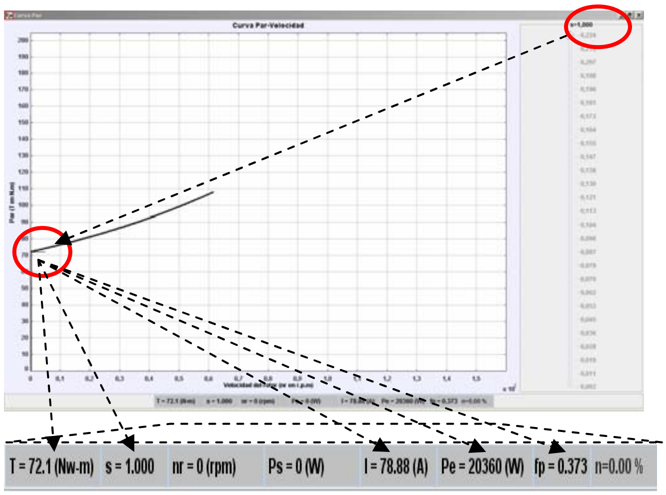
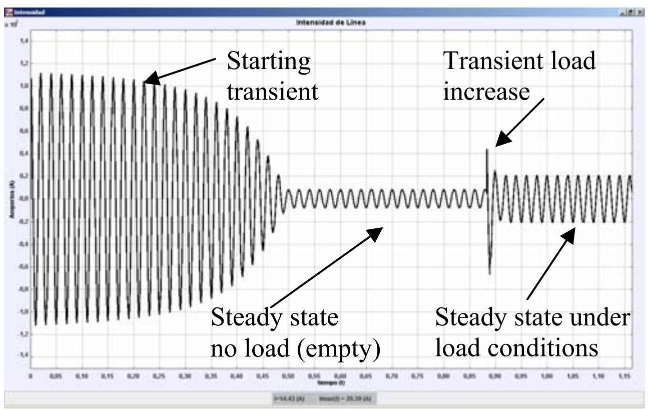
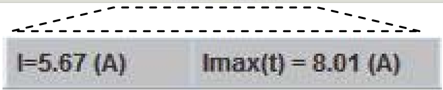


Fig. 5, Window graphics "Torque-Speed curve" – Starting point

The transient current during starting can be displayed in the window graphic of line current, figure 6, where they can read the instantaneous values of:

- Current intensity (rms)
- Current intensity (peak)





a. Motor running without load

b. Motor running with load

Fig. 6, Window graphic "Current intensity line"

2.2. Regime at maximum torque

Once past the transient starting and completed the generation of the curve, enables adjustment of cursor by clicking on the figure and represents the value of smax and Tmax, and the other values of the different variables, for these conditions of the motor.

This point of analysis is accompanied by the respective representation of the instantaneous values of current, in the window graphic of current.

2.3. Steady state under loads conditions

The slip cursor can be moved for simulate any load point between maximum torque and empty. In figure 7 has selected a particular point of load (s = 0.028), the rated value of the motor, and obtain again the values of the different variables of the machine. As in previous cases, this analysis is accompanied by the representation of the current intensity values in the window graphic of current, figure 6.

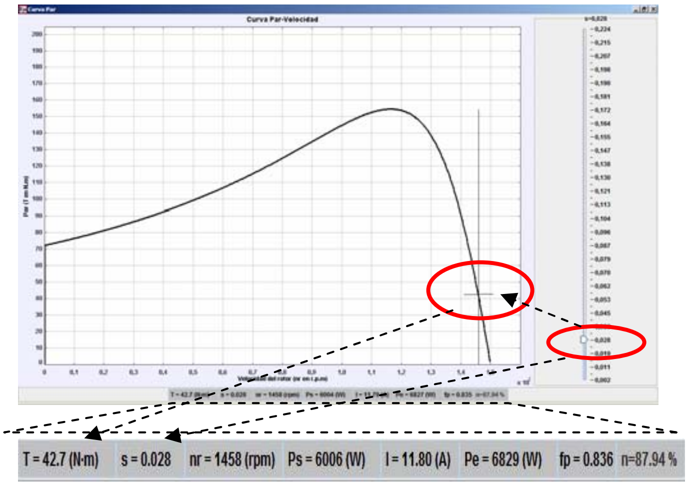


Fig. 7, Window graphics “Torque-Speed curve” – Rated slip point

2.4. Steady state no load (empty)

The slip cursor can scroll to the bottom to obtain the values of the different variables of the motor no load, figure 8. Once the motor reaches its operating in no load, this analysis is accompanied by the respective values of current intensity, in the window graphic of current, figure 6.

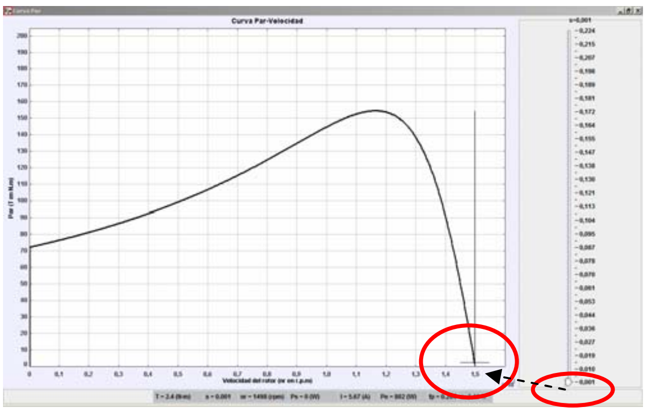


Fig. 8, Window graphics “Torque-Speed curve” – Motor no load (empty)

3 Evaluation and results

This section presents the evaluation and results.

The platform and virtual laboratory model presented have been used by students of subject "Electrical Machines and Installations", which provides the Department of Electrical Engineering, of the Polytechnic University of Catalonia (UPC), in the Nautical School of Barcelona, Spain. This subject is compulsory in the grades of Marine Engineering and Naval and the same have hands-on laboratory.

After the course, students were asked to anonymously and voluntarily participate by answering a survey, previously described, with a scale of five response levels (1: Not useful or appropriate, 2: Not helpful or appropriate, 3: Neutral, 4: Useful or appropriate, 5: Very useful or appropriate). The participation was of 52.2% (24 students from 46), the questionnaire and the results are shown in Table I.

Table I

Survey to students for assessment the induction motor practice, in virtual laboratory and hands-on laboratory

Virtual lab activity	1	2	3	4	5	Average	% >3
Accessibility	0	4	6	12	2	3,5	58,3
Doesn’t require special software	0	4	9	6	5	3,5	45,8
Ease of use	0	2	10	7	5	3,6	50,0
Clarity of command / windows	0	3	8	8	5	3,6	54,2
Support for learning	1	1	7	12	3	3,6	62,5
Hands-on labs activity							
Preparatory instructions	0	6	6	10	2	3,3	50,0
Web lessons and preliminary report	0	5	5	12	2	3,5	58,3
Physical presence in lab	0	0	4	9	11	4,3	83,3
Lab report	0	1	9	11	3	3,7	58,3
Team work	0	3	5	10	6	3,8	66,7
General opinion	0	1	5	16	2	3,8	75,0

According to the results obtained, the platform and the virtual model proposed has an average rating of 3.5/3.6 points over 5. In most valued aspects, consideration of useful or very useful is equal or higher than 50%, reaching 62.5% the opinion on the "aid for learning". The aspect of "does not require special software, with 45.8%, may be indicative of a

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minor importance over the type of software in use. It is a variable to be considered further amply in future assessments and in project development.
In the evaluation of aspects relating to the hands-on labs, the consideration of useful or very useful, is prevalent in all cases and is equal or higher than 50%. Interestingly and perhaps not surprisingly in these studies, the evaluation of "physical presence in lab," exceeds 83% and the valuation of "general opinion" over hands-on labs, reaches 75%.

4 Conclusion

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 in Web of school.

The context of these early reviews suggest that this type of action requires further exploitation, which encourages us to continue the effort to expand the range of virtual laboratories in our field, and evolve to remote labs can mean a major improvement.

The 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 can not set a general trend pro remote or virtual lab, in detriment of the real experimentation.

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