Effective Visualizations for an Electric Machines and Power Systems Course

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Abstract

This paper presents the visualization examples developed to accompany an Electrical Machines and Power System course. Several of the examples that were developed are currently utilized in the electric machine courseware for the NSF-funded Greenfield Coalition for new Manufacturing Education. The course introduces essential types of electric power and electric machines in industrial applications. Traditional teaching methods find it extremely difficult to relay the concepts of electromagnetic phenomena on which the operation of the entire class of static and rotating machinery lie. The simulation and visualization components and the interactive drag and drop type of examples developed in order to enhance student learning of electric machines are discussed. The visualizations accompany the computer-based courseware developed that presents itself as a self-learning and self-assessing tool for the students. Adaptation of the developed materials into an electric machines course in the EET curriculum are discussed.

I. Introduction

Though the traditional 'Energy conversion course' had remained almost unchanged for several decades, a redesigned structure has been proposed by several references over the last decade [1-2]. Types of motor drives worthy of addressing in undergraduate curricula are discussed [3]. Recently, LabView has been utilized in developing some animation for an EE course [4]. Multimedia projects funded by the NSF and the Department of Education suggest that visualization, animation and interactive simulation effectively help learners understand abstract concepts. However, there have been no major instances of a multimedia approach to *EET* electric machine courses except those that utilized NIDAQ tools, *Authorware*/*Flash and Pspice* as part of the NSF-Greenfield Coalition (NSF-GC) CBI development [5-7] for manufacturing curriculum.

Due to current structure and old technology, it is not possible for students to gain industry relevant experience at several institutions. They are also not exposed to the advances in data acquisition, simulation, control and visualization that every modern industry currently employs for immediate data observation, analysis, and presentation. Hence simple methods that enhance understanding of electric machine concepts and insure student learning and increase appreciation of electric machines area are required. Another strong reason why student selection of machine drives, power and power electronics as fields of advanced study is more essential today than ever, is because of the introduction of electric power deregulation and prominence of fuel cell and battery driven electric/hybrid vehicles [8, 9].

II. Methodology

The ‘*Electric Machines and Power Systems’* course has been revised by adding dc/ac drives, real time data acquisition, and visualization components of both simulation and interactive kind. The inclusion of these components into the course involved a structured attempt. The projects that utilized NIDAQ tools, *Authorware*/*Flash and Pspice* as part of the NSF-GC CBI development serve as background work. While some of these examples are under development, this paper will focus on their *enhancement, adaptation and implementation*.

III. Simulation and Visualization examples

Three-dimensional representation of machine structures, understanding of number of poles in ac machines, revolving field, slip and synchronous speed, flux distributions, stepper motor full and half-step movements, power factor correction, etc., are some of the visualizations developed.

The visualizations are interactive in that they allow the students to interact and input their entries to certain level, such as, create the type of fault on a motor or a generator, insert varying amounts of capacitors into a motor circuit to observe the power factor correction process, observe flux patterns due to change in the number of poles, reverse direction of rotation, etc. These visualization examples are concept based and the courseware also contains other interactive components of the drag and drop type to enhance learning. Some examples of this kind enable the student to correctly identify different parts of an ac or dc machine, an positioning system, etc.

Thus the implementation embeds threads of traditional teaching methods into instructional material woven around elements from modern computer capabilities, together with the hands-on experience derived from practical systems. The visualizations were mostly developed using Macromedia’s authoring tools *Authorware* and *Flash*. The development aims to finally make this material available on CD-ROM and utilize it to supplement the course instruction. Embedded pictorial illustrations and these visualizations in the CBI material are expected to provide the students better understanding and learning of the material.

An *electric machines* course must discuss fault analysis of ac induction motors (IM), due to their wide use. Also current and voltage information on schematics after an interactive fault creation will provide better information. Animations are being developed to observe induction motor behavior on any of the open and short circuits, or under unbalance:

Whereas the simulation type of visualizations is based on *Pspice*, the flux distribution type is being tried using *Flux2D* installation on evaluation basis. While *Pspice* is much suited for circuit simulation, *Saber* enables system simulations, for example, study of drive system with a dc/IM/brushless motor as a component. This course will employ *saber* in future for simulation.

The animations illustrate the different parts of the physical structure of a dc, synchronous and induction motor. They also help illustrate the meaning of phase sequence and direction of rotation. They help students understand meaning of poles and rotating MMF. They also help students observe flux distributions due to changed number of poles. They also enable student start and actuate motor operation. The stepper motor visualizations illustrate half, full and microstep modes of operations by utilizing a cross sectional view of the motor stator and rotors. All animations are developed using *Authorware* and *Flash*.

Videotaped demonstrations of some Hampden controllers for ac and dc motors, evaluated as part of the NSF-GC project serve as laboratory illustrations for the manufacturing curriculum. The in-depth analysis and comparison of flux distributions and mmf studies not essential for the manufacturing course, are developed for the *EET* senior level course. For this electric machines and power system course, drives are part of the regular laboratory as basic power electronics is a course topic. The flux distribution, animation and data acquisition tools are currently loaded on one single computer and are demonstrated to students. Funds are sought for future expansion.

IV. Course Structure

The course content has been carefully structured to cover major concepts while providing opportunities for the enhancements. The new components have not required any course time changes. The following interactive visualizations and laboratory experiments are conducted after covering relevant theory in lecture.

- The essential features and use of LabView, NIDAQ and *Flux2D* tools will be made known. S*tudents run the animations made which explains the effect of power factor on the total power drawn and its improvement.* **Fig. 1** illustrates Authorware screen captures of an example development.
- Students will *interactively visualize the flux and mmf distributions in inductors. Fringing flux due air gap and flux distributions due to change in geometry/material/airgap length will be observable*. **Fig. 2** illustrates a flux plot solved from geometry of an actuator.
- A*nimation examples demonstrate Voltage –Current relationships in Delta-Wye configurations.* **Fig. 3** shows the current relationships in a delta-connected source. Students have freedom to choose the length and reference of the phasors to observe consistency of the relationships. A similar animation illustrates voltages in a wye connection.
- V*isualization examples enable observation of internal machine structure and also flux distributions within. The interaction allows them to observe effect of changed number of poles.*
- *Students acquire motor speed, torque and generated voltage signal for the DAQ board, from which they witness the performance characteristics of the machine in real time on LabView screens*. They also observe impact of load *power factor on regulation* and efficiency of alternators. *Visualization examples also enable comparison of dc and synchronous machine structures.*
- *In the visualization examples, students compare dc, synchronous and ac machine inside structures, understand synchronous speed, observe meaning of number of poles, revolving field, slip and slip speed of induction machines. They also observe the flux distributions and compare with the dc machine fluxes*. They examine the *effect* of phase sequence using the animations.

Fig. 4 is a screen capture of the mmf and flux distribution that are made for student selection and interactive use. The student selects the particular stator in order to view that mmf.

The LabView front panel and block diagrams, *Flux2D* examples, and *Authorware*/*Flash* animations as well as the signal conditioning circuitry are designed and loaded on computer before hand. In the laboratory, students will devise the configuration using instructions of instructor.

Conclusion

This paper presents the types of visualization components developed to accompany an Electrical Machines and Power System course, one for an electric machine course for the NSF-funded Greenfield Coalition for new Manufacturing Education, another in the EET curriculum at Wayne State University. The courses introduce electric machines and their specific applications. Enhancing student learning of electric power, machines and drives using modern multimedia computer capabilities is the main goal in this approach. The interactive simulation and visualization components developed to accompany the computer-based courseware present themselves as self-learning and self-assessing tools for the students. Several examples developed are summarized. The components of the course, due to their general structure, can be adapted as supplements to any undergraduate level electrical engineering course. Such a course structure is certain to enhance student learning. The courses are being tested currently and results therefrom will be made available to the technical community in the next year.

References

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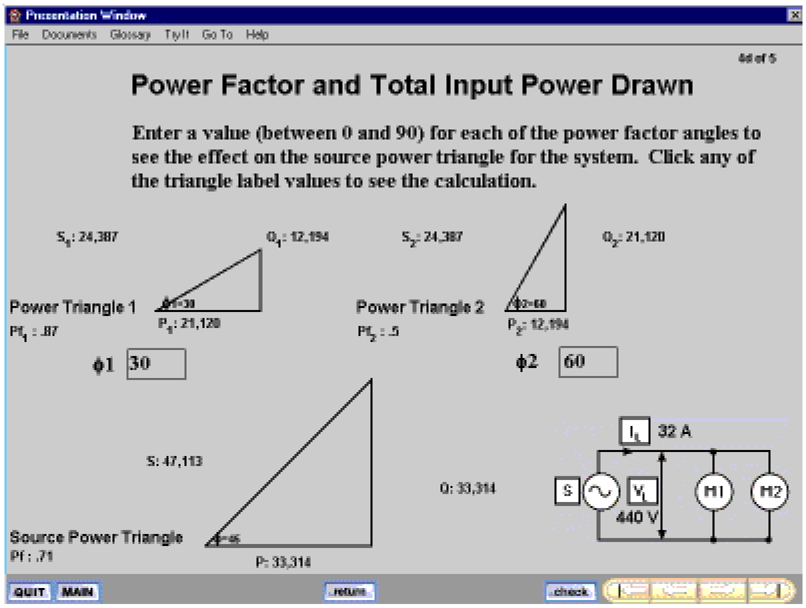

Fig. 1. Power factor triangles for individual motors and the complete system.

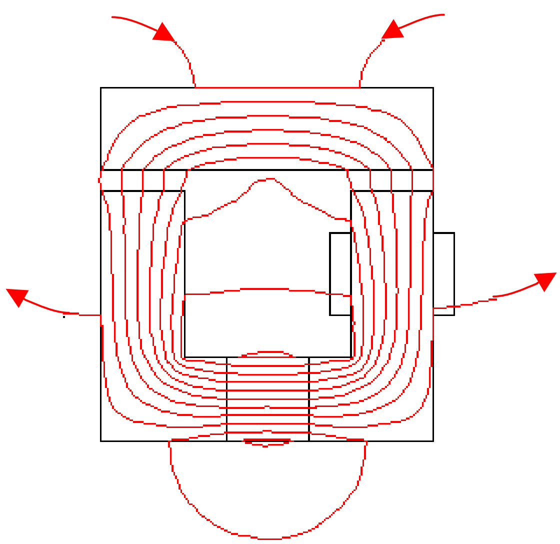
Fig. 2. Flux distribution in an electromagnetic actuator, solved using Flux2D finite element method.

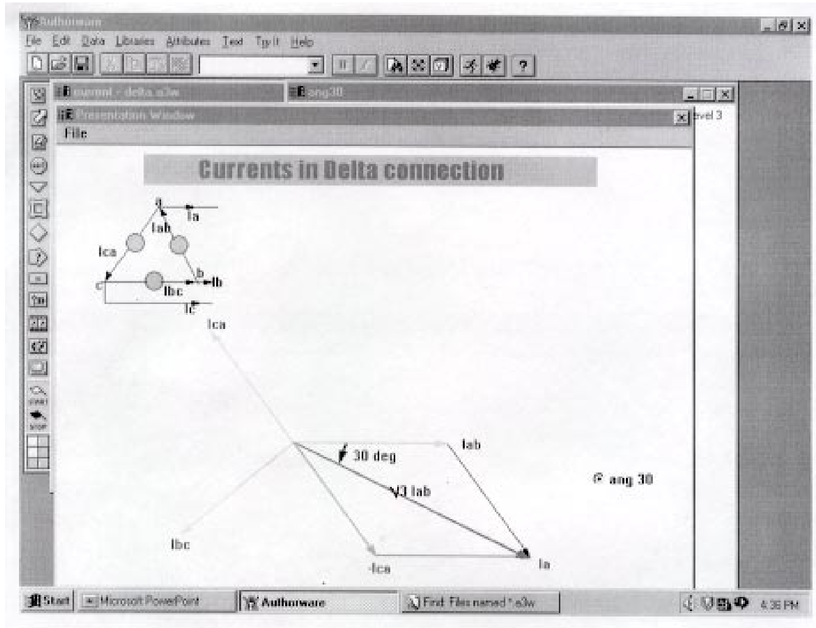

Fig. 3. Illustrations of current relationships in Delta connection.

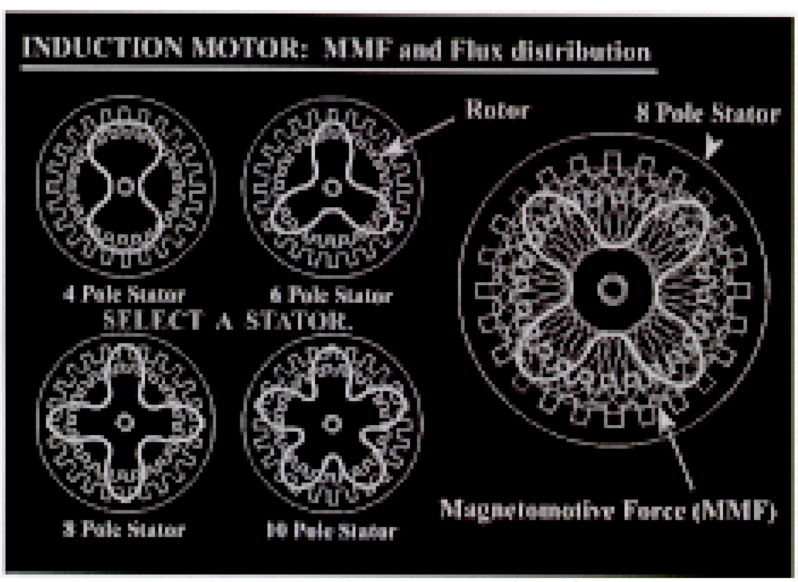

Fig. 4. Authorware screen of Induction mmf and flux distributions.