

# Use of Animation for Improvement of Student Understanding of Energy Conversion

George G. Karady, Daniel Tylavsky  
Arizona State University  
Tempe, AZ 85287, USA

## 1. Introduction

The typical American University offers a one-semester, three-credit-hour course on energy conversion. This basic course, often mandatory for all electrical engineering students, deals with transformers, motors, generators and basic parameters of transmission lines. In addition, AC circuit theory is reviewed and phasors are regularly used for problem solving.

The difficulty observed in the undergraduate program, namely low student interest, is the result of several interacting factors. Most of these factors are beyond the control of the students and instructors. One factor that affects student interest and that we, as faculty, can control, is the way we present material in the classroom. Students get bored when they do not understand what we teach and they do not understand what we teach when we offer material in a mode that is different from their natural learning mode. Research has shown that about 75% of undergraduate engineering students are visual learners while (typically) in excess of 90% of our instruction is oral and written verbal communication [1]. Further, most students (60%) learn inductively, gathering sensory data about a process then synthesizing that into an understanding (mathematical or otherwise) about the process generating the data [1]. We tend to teach to deductively, providing a general engineering principal as (usually) a mathematical equation, then ask students to deductively generate the data such a system would produce.

Our goal was to provide a tool that would appeal to the inductive and visual learners while at the same time tying this understanding to the mathematics and physics of electric machine theory. To understand the fundamentals of electromechanical energy conversion, students must be able to envision how three magnetic fields (120-degrees phase-displaced in time and space) that pulsate in time can create a magnetic field that is of constant amplitude but rotates in space. Through an understanding of the laws of electromagnetic induction the student must visualize (for induction machines) how the first rotating magnetic field creates a second rotating field. Then, students must envision how the coupling between both fields leads to mechanical rotation. From 30 years of experience teaching this subject, we know how difficult it is for the students in the course.

Ideally, once students understand the concepts of electric machine operation, they can then conceptually connect this understanding with the use of the equivalent electrical circuit. The circuit schematic is the tool used for arriving at quantitative answers. Few students arrive at a solid understanding of theory of electric machines; consequently, fewer students can connect this theory with the electrical schematic.

This paper reports on the use of animation to improve understanding of the physics of machine operation and multimedia methods to present the technological aspects of machine construction and manufacturing.

## 2. Animation Techniques

Animation as a teaching tool has gained popularity in the last five years [2]. Recently we introduced into our energy conversion class, a learning module centered on the animation of electric motors and generators to improve student understanding of the physics of motor/generator operation. This module, consisting of four animation programs, was developed with the assistance of an undergraduate student under the supervision of Dr. Tylavsky. The animations were programmed using LABVIEW. The animation programs demonstrate:

- Generator operation concepts, a loop rotating in magnetic field
- Synchronous generator operation
- Rotating magnetic field generation
- Induction motor operation.

These programs are used two ways. In class they are used to visually demonstrate operation principles. After the in-class demo, these programs are downloaded by the students from the home WEB page of the professor and used to complete homework assignments.

Each animation has two parts:

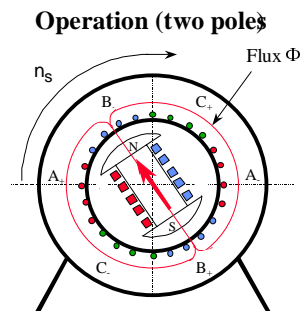
- Part 1: Animation model.
- Part 2: Setup and equivalent circuit

Part 1 contains the animation that helps students visualize the motor operation concept. Students experiment with the animation by changing parameters (load, impedance, and speed) and observing the effect of parameter change. Part 2 shows the equivalent circuit for the subject of the animation along with the currents and voltages that would be measured in the lab for a machine with the load, impedance and speed selected by the student. As homework, students are asked to calculate these currents and voltages and compare the results with those given by the model data.

## SYNCHRONOUS MACHINES

### Operation concept

- The rotor is supplied by DC current that generates a DC flux  $\Phi_r$
- The rotor is driven by a turbine with a constant speed of  $n_s$
- The rotating field flux induces voltages in the stator windings.
- The frequency of the induced voltage depends upon the speed.



11/22/97

360 Topic 6. Synchr. Machine

Figure 1. Concept of synchronous generator operation

The animations are used to introduce the concepts of device operation. As an example, the teaching of the principals of three-phase salient-pole generators starts with a brief description of the generator has shown in Figure 1.

Subsequently, the animation program is used to depict rotor-generated flux and induced voltage and current in the three phase stator winding. As an example Figure 2 shows Part 1 of the MMF and Current Simulation in a Salient Pole Generator.

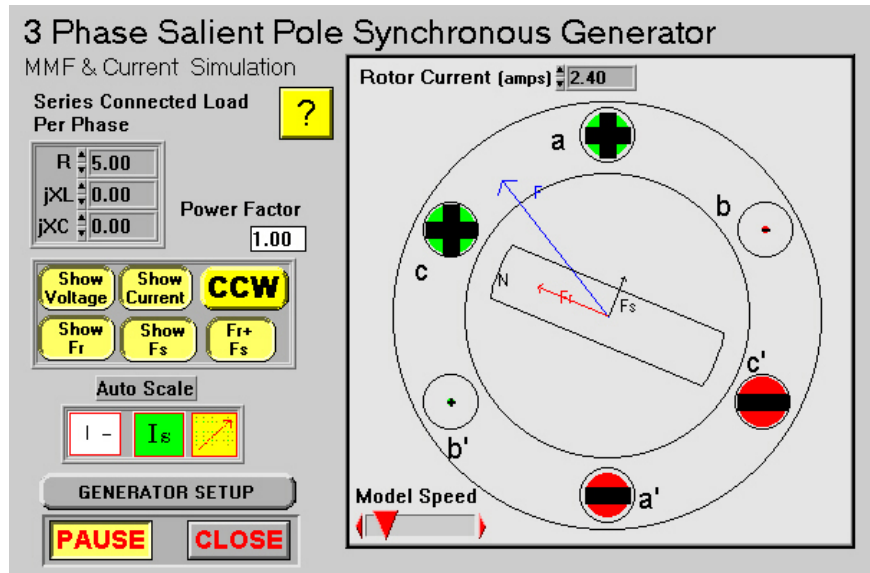


Figure 2. Part 1. MMF and Current simulation in a Salient Pole Generator

First the students select rotor dc current, speed and load impedance. The activation of the "Show Fs" button shows the rotor generated magnetomotive force (mmf) vector. The activation of the "Show Voltage" button shows the three-phase induced voltage in a form of colored dots with changing size. This is a colorful demonstration of the three-phase voltage generation. The students that are visual learners will remember this simulation.

The next step is the activation of the "Show Current" button. The model shows the load current in the form of variable size + and - signs. The phase shift between the voltage and current can be observed easily. The activation of Fs and Fr + Fs produces the load current generated mmf and the total mmf vector.

The load impedance and rotor current are varied and the animation shows the change in load current, voltage and phase angle. The students are requested to work with the animation and determine the effect of different parameters.

After this exercise the students switch to the second part of the model. Figure 3 shows the second part of the model, which gives the generator data (length, diameter air gap, magnetizing and synchronous reactance, etc.). Using this input screen, students get experience conceptually

connecting the theory of electric machine operation with the use of the electrical circuit schematic.

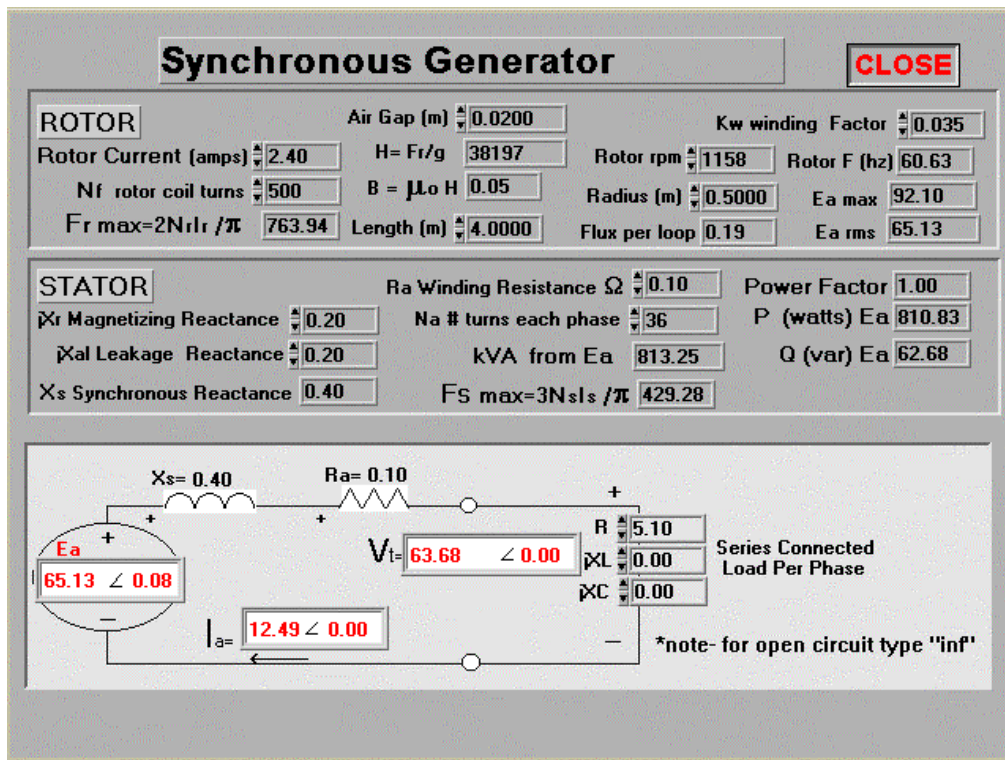


Figure 3. Generator setup (Equivalent circuit)

Using this model, the students calculate the operation parameters at different loads and different parameter values and compare the results with the values given by the animation Part 2 screen. This exercise connects the understanding of operation principles with the numerical analyses of generator performance. This is a simplified approach, which concentrates on basic knowledge and omits details.

Animation also offers a novel approach to homework problems. The students are assigned to solve selected homework problems and simulate them with the animation program. As an example, in the case of rotating loop (Figure 4), the student changes the magnetic field (B), the width and length of the loop and the speed of rotation, and then determines the effects of the changes on the induced voltage. These exercises force the students to play with the model, which in turn improves understanding of the physics of operation. In addition, the exercise is entertaining.

We found that the animation significantly increases the students' understanding, and because they have seen pictorially how operation occurs, they seem to recall the material better. The feedback from the students indicates that they also like the animation exercises and believe the animation exercises are good tools for improving understanding.

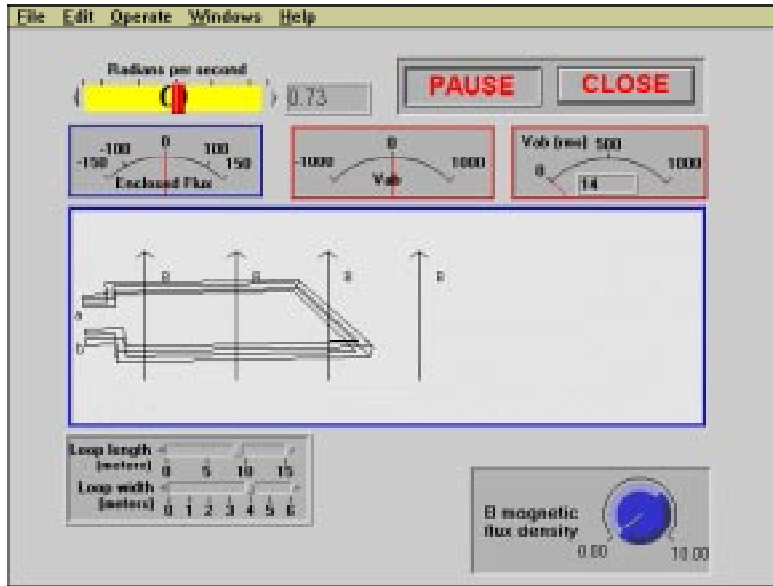


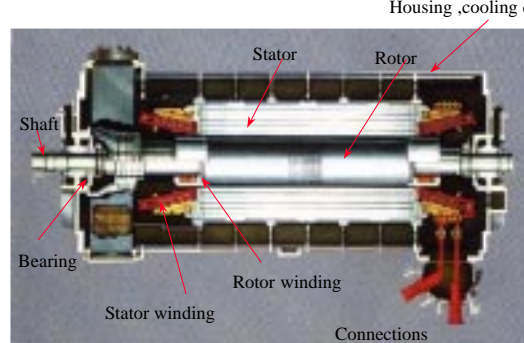
Figure 4. Loop rotating in a homogeneous magnetic field

### 3. Multimedia Approach to Technology Teaching

Discussions with students revealed that, with the use of this animation they learn to solve problems with more proficiency and attain a more in-depth understanding of the theory of electric machine operation; however, they still often lack a clear picture of how the machine is mechanically put together. Time pressure prevents complete description of hardware. Also the students find the descriptive method boring. A new multimedia based method has been introduced to teach technology efficiently.

The first step is the selection of one or two typical examples, which shows the major components. If the students know a typical generator or circuit breaker they can learn the other types easily.

## SYNCHRONOUS MACHINES



11/22/97

360 Topic 6. Synchr. Machine

Figure 5. Construction of a Westinghouse synchronous generator

We are using three methods to describe the typical equipment.

### 1. Digitized Color Slides

The digitized colored slides, obtained from industry, present technological aspects and describe hardware used in the electric power industry. The zoom feature of a digital projector permits study of construction details. Figures 5 and 6 illustrate this method. First the general arrangement shown in Figure 6 is discussed. The teacher identifies the major components and briefly describes their use.

After using the zoom feature of the digital projector, the details are studied by zooming in on a selected detail as shown in Figure 6. This presentation is quick. However, the students are requested to revisit the picture at home and answer questions. This work should be a team effort, where groups of students work together. The digitized slides are downloaded from the home page of the professor.

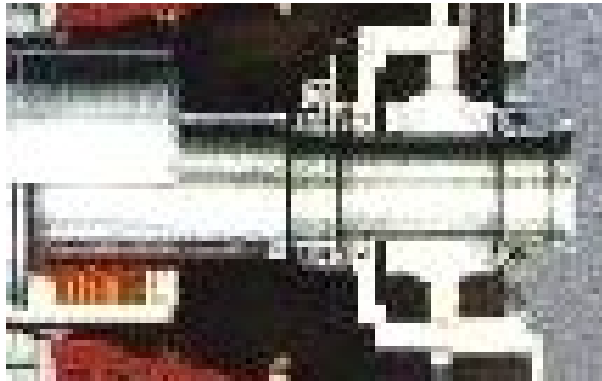


Figure 6. Enlarged bearing of a Westinghouse generator

### 2. Short Videos

We also have obtained short videos from industry. These 20-25 minute presentations show the real life environment and give an impression of the size of the power apparatus. These videos are unlike manufacturer-supplied videos that describe the equipment and its operation in detail. Such detail students find boring and tedious. The videos we are using are supplied mostly by the electric power utility industry and describe how of the equipment is used and functions in a real life environment.

The following videos are used at ASU:

- Generator and large motor coil manufacturing.
- Transformer maintenance.
- Circuit breakers. Power Plants
- Transmission system
- Kenatta substation.

### 3. Laboratory exercises and site visit

To appeal to active learners, we add a laboratory component to our course. This allows active learners to experience the material in their natural leaning mode. In the first technological exercise the students are required to disassemble and reassemble a motor and to identify and describe the function of each part. The students work in teams. Each group has a digital camera. They have to prepare pictures of the relevant parts, such as the commutator, to illustrate the description of the part. The students using CAD have to prepare a simple scaled engineering drawing for one selected part, such as the rotor of a squirrel cage motor.

Each group gets a different motor: single phase induction motor from a refrigerator or fan, three phase induction motor for a pump, hard drive motor, Dc motor for a battery powered tape recorder.

It is important that the motors are selected from the everyday life or in the high tech area (computers). This shows the importance of the subject and generates student interest.

The second technological exercise is transformer building. Each student group receives an iron core, insulating tape, a coil holder and a reel of insulated wire. Using their understanding of transformer design, they calculate the maximum rating of the transformer they can built with the materials at hand. They then select a voltage (5 Volt), calculate the number of turns and build the transformer. The transformer is tested in an open circuit mode. After this the transformer is disassembled and reused by the next group.

Both technological exercises require about 3 hours. Students like these technological exercises. They feel that they learn practical engineering. Particularly popular is the disassembly of the hard drive motor. We find that the students' understanding of motors improves significantly because they are able to connect the theory to the construction of the motors.

In addition, the students visit a power plant and a 500 kV substation on a Saturday morning. The visit duration is 3 hours and concentrates only on the major components. It is aimed at giving an impression of how the energy is produced and transported. The details are not required in this level. We found that the students get bored if the visit lasts longer.

### **4. Conclusion**

We believe that the use of animation significantly improves student understanding of motor operation. The multimedia approach and the technological exercises, together with a short site visit, improves student knowledge because they are able to connect the theory to the construction of the motors.

Further, the broadening and modernization of the subject matter makes the students better prepared for modern industry. The application of animation and multimedia to technology has improved the image of the power area at the undergraduate level. Selecting of motors used in everyday life, especially from high technology applications, such as CD ROM drives, increases student interest and improves knowledge.

## References

- [1] Richard M. Felder and Rebecca Brent, "Effective Teaching: A Workshop," Conducted at Arizona State University, January 1998.
- [2] Y. Liu: Animations of a) Pulse bounce phenomena in transmission lines, b) Breakdown in transformers due to lightning, c) RLC circuit response to AC signals. Iowa State University, Private communication, 1997.
- [3] George G. Karady and G.T. Heydt: Increasing Student Interest and Comprehension in Power Engineering Education at the Graduate and Undergraduate Levels. (submitted IEEE Transaction on Education).
- [4] George G. Karady and G.T. Heydt: Role of Computers and Multimedia in Teaching Basic Energy Conversion. Accepted for publication: International Conference on Large Electric High Tension Systems (C.I.G.R.E.), Paris, August 1998 .

## Biography

George G. Karady received his BSEE and Doctor of Engineering degrees in electrical engineering from Technical University of Budapest in 1952 and 1960 respectively. Dr. Karady was appointed to Salt River Chair Professor at Arizona State University in 1986. Previously he was with EBASCO Services where he served as Chief Consulting Electrical Engineer. He is the author of more than 100 technical papers.

Daniel Tylavsky received his B.S. degree in Engineering Science in 1974, his M.S.E.E. in 1978 and the Ph.D. degree in Electrical Engineering in 1982 from the Pennsylvania State University. In 1982 he joined the faculty of the Electrical Engineering department at Arizona State University and is currently an Associate Professor. He is a senior member of the IEEE PES and IAS societies, an RCA Fellow, NASA Fellow and member of Phi Eta Sigma, Eta Kappa Nu, Tau Beta Pi and Phi Kappa Phi.