Teaching Engineering Students Energy Conservation

Hassan A. Kalhor and Mohammad R. Zunoubi
Electrical and Computer Engineering Department
State University of New York
New Paltz, NY 12561
kalhorh@engr.newpaltz.edu

I. INTRODUCTION

Conservation of our energy resources and protection of our environment is the duty of everyone especially the engineers, and engineering students must be made aware of this responsibility. Many engineers have been engaged in developing alternate sources of energy preferably renewable sources. Despite all the research effort and expenditure of large sums of research money no practical source has yet been put into practical use. But, we should not lose hope and continue our endeavor.

In the interim, we need to educate engineering students to become more energy conscious. An increasing number of our students now take two elective courses in energy conversion and electric power. The ones that don't choose these courses can be taught the material in this presentation in seminar form. In this talk, I will concentrate on conservation of electrical energy, as it is the most common form of energy used in residential, commercial, and industrial premises. Loss is waste of energy that adds to the infrastructure and running costs of power equipment. It also depletes our energy resources and increases the environmental pollutants.
Many government agencies have stepped in and set minimum efficiency standards for electrical equipment. Legislatures now require the manufacturers of electrical equipment to design, manufacture, and sell only the equipment that meet these minimum standards. They cannot go by the minimum cost criteria of old times. Many national laboratories and research institutions are experimenting with new techniques to make conventional equipment such as generators, transformers, transmission and distribution lines, electric motors, and electric lights more efficient. Many states now subsidize the purchase of high efficiency equipment

There are many ways by which loss can be controlled and the efficiency of electrical equipment can be raised. The objective of this talk is to introduce the engineering students to how electrical equipment work, where the losses occur, and how they can be reduced. Thus, in this presentation, the determinants of equipment efficiency will be identified and a number of energy-enhancing methods will be evaluated. Use of low loss magnetic cores and high temperature superconductors in electric generators, transformers, and motors will be considered. Compact fluorescents and LED's with much higher illumination efficiency compared to common incandescent bulbs will be discussed.

II. PARTICIPATING AGENCIES IN EFFICIENCY ENHANCING PROGRAMS

Awareness about energy conservation is relatively new. In the past, engineers and designers saw as their main duty to design equipment and apparatus with minimum cost. Equipment low purchase prices were very important to managers and decision makers who often did not question the running costs, losses and adverse effects of such losses on the environment. Depletion of natural resources and adverse effects such as global warming has come to the forefront only in the past decades. Many national, state and local agencies are now participants in energy conservation programs. Some are trying to find and put to use alternative forms of energy and some others are attempting to conserve electrical energy that is generated by conventional means. Some of the participating agencies are:

US Department of Energy (DOE)
National Electric Manufacturing Association (NEM)
American Council for Energy Efficient Economy (ACEEE)
Consortium for Energy Efficiency (CEE)
New York State Energy Research and Development Authority (NYSERDA)
Oakridge National Laboratory (ORNL)
Brookhaven national Laboratory (BNL)
Naval Research Laboratory (NRL)

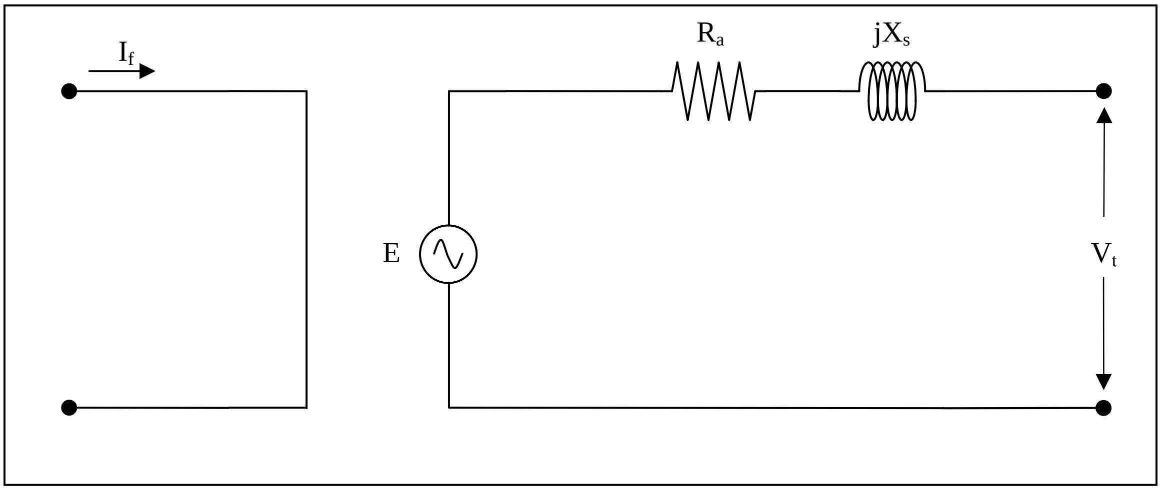
III. CANDIDATES FOR EFFICIENCY ENHANCEMENT

Almost all power system components and apparatus are candidates for frequency improvement. In the following sections we consider electric generators, transformers, transmission and distribution lines, electrical wiring and cabling, lighting and office equipment. For each of these components we briefly explain the principle of operation, novel design and construction. We then localize and evaluate their loss mechanisms and give proposals to reduce them.

IV. ELECTRIC GENERATORS

Almost all electrical power is generated by AC synchronous generators. These machines have a rotor that is supplied with direct current to produce the needed magnetic field and a stator that houses a three phase winding in which AC power is induced. The shaft of the machine is driven by some prime mover that could be a steam turbine or a hydro turbine. Mechanical power is converted to electric power in the process. Two pole, three phase, 3600 RPM, 60 HZ units of about 1000 MVA, generating a voltage of 20 KV are industry standard.

Losses of generators are relatively small, but any fractional enhancement of their efficiency leads to considerable savings as they convert large amounts of power. Losses of generators are comprised of rotor copper loss, stator copper loss, stator core loss, friction, windage and bearing loss. Rotor core loss is small because the rotor is rotating in synchronism with the revolving field. Stator core, which is stationary, is subjected to a magnetic field rotating at synchronous speed that causes both eddy current and hysteresis loss. A simple electrical circuit diagram of one phase of a synchronous generator is shown in Fig. 1. Mechanical losses are not shown in this circuit.



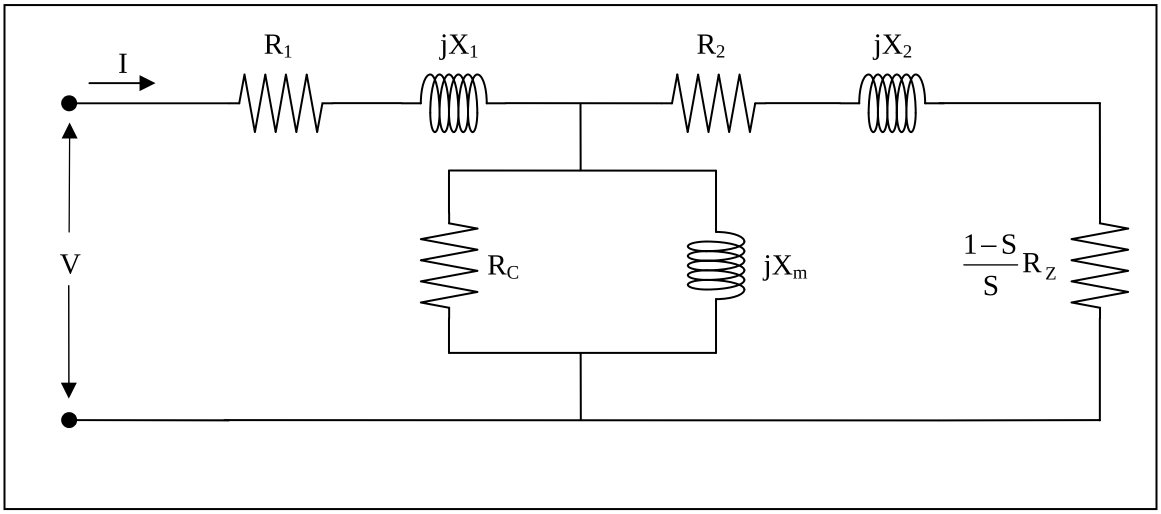
Error!

Fig. 1- Equivalent circuit of one phase of a synchronous generator

Rotor copper losses can be reduced considerably by using High Temperature Superconducting (HTS) coils. Stator core loss comprised of eddy current and hysteresis losses can be lowered by using low- loss grades of steel, using thinner laminations, and making sure that stator laminates are not making electric contact. Stator copper loss can be reduced by employing more copper or by using HTS coils. Before the discovery of HTS, low temperature superconductors had been used in generators and had led to increased efficiency as well as smaller volume and weight. Discovery of HTS increased the interest.

V. ELECTRIC MOTORS

Electric motors use about 60% of all the electrical energy that is produced and, therefore, any small increase in their efficiency leads to considerable savings, preservation of our natural resources as well as keeping our environment cleaner. Three phase induction motors constitute 90% of motor capacity and the remaining 10% are single-phase induction motors, DC motors, and synchronous motors. Growth rate for motors is about 1.5% annually. Three-phase induction motors known as the workhorse of industry and are popular because they are robust and need little maintenance. These motors were first built around 1890 and were gradually improved. These motors have a stator that carries a three phase copper winding and a rotor that is wound of copper in larger motors or die-cast aluminum is smaller size motors. Both stator and rotor cores are made of laminated steel to give high permeability and low loss. The equivalent circuit of an induction motor is shown in Fig. 2.



Error!

Fig. 2- Equivalent circuit of one phase of an induction motor

Losses in induction motors consist of stator copper loss, rotor copper loss, core loss, friction and windage loss and stray loss. Using better and thinner and effectively insulated silicon-steel laminations for higher magnetic permeability and lower iron loss per unit weight can reduce these losses. Motors should also be sized correctly and run near full load. Speed should be adjusted as load is varied for optimum operation. Changing die-cast Aluminum rotors to copper is difficult and costly but improves the efficiency.
Legislative action has been taken to improve induction motor efficiency. Energy Policy Act of 1992 eliminated least efficient motors by setting minimum efficiency limits. This act became effective in 1997. Later NEMA raised efficiencies further by introducing premium motors. EPAct and NEMA motors are more expensive but have short payback times. Some of the recent methods used to increase the efficiencies of induction motors have been using intelligent adjustable speed drives, LTS and HTS motors. A 1000 hp synchronous motor was tested in 2000 by Reliance Electric/Rockwell Automation and a 5000 hp motor is under development. Such synchronous motors have efficiencies of about 98.6% versus 96.8% in conventional and a volume of about 47% of the conventional motors.

VI. ELECTRIC TRANSFORMERS

Power transformers make efficient transmission of large blocks of power possible. Despite their high efficiency of about 98%, 60-80 billion KWh of energy is lost annually in transformers. There are about 40 million distribution transformers in the USA, and about 1 million are sold annually. The equivalent circuit for one phase of a transformer is shown in Fig 3.

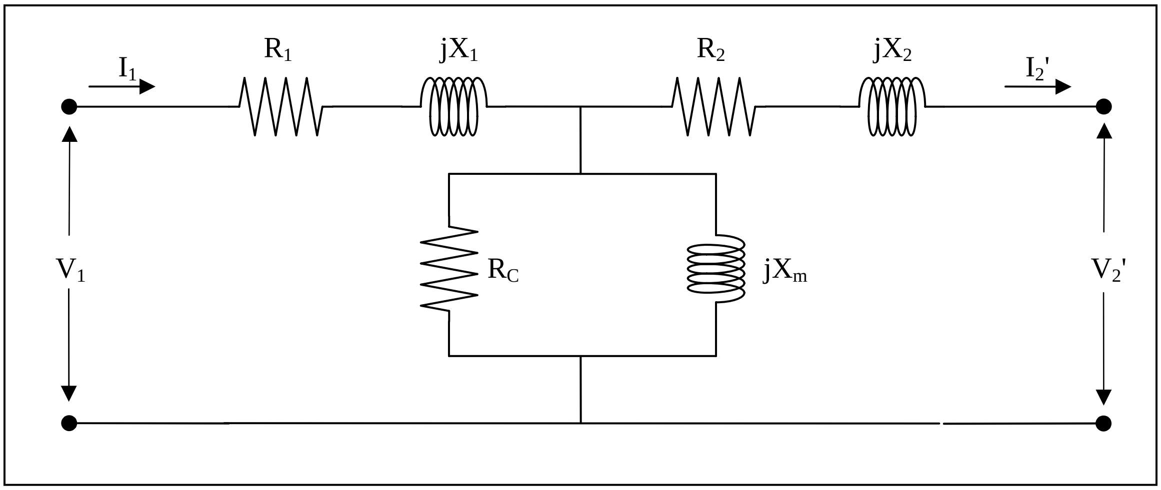


Fig.3- Equivalent circuit of one phase of a transformer

Losses in transformers are core losses that are fixed and copper losses that vary with load. Employing low loss core material and more copper in the windings reduce losses. Also, since transformers are static devices, they are easy to cool by cryogenic means. The first HTS transformer rated at 630 KVA, 18.7 kv/420v HTS distribution transformer was used in the Swiss system in 1997.

VII. ELECTRIC LIGHTING

About 10% of all generated electricity is used in lighting. Incandescent lights have been standard since the time of Edison. Recently, compact fluorescent lights that are 4 times more efficient with 10 times longer life have entered the market. New trends are toward using LED's, which have much longer life and much higher efficiencies.

VIII. CONCLUSION

We have presented some energy saving measures in electrical equipment that need to be taught to engineering students especially to those majoring in electrical engineering. They should be made aware that the best design is not the cheapest design but one with lower running cost and least impact on our energy resources and environment.