EXPERIENCE TEACHING ELECTRICAL ENERGY SYSTEMS TO NON-ELECTRICAL ENGINEERING STUDENTS

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Abstract

This paper describes the author's experience in teaching modules on electrical energy systems to Civil and Mechanical Engineering students at University of Castilla-La Mancha, Spain, and University College Dublin, Ireland, respectively. Teaching electrical energy systems to non-electrical engineering students presents several didactic and methodological challenges. These are originated mainly due to the lack of knowledge of circuit theory and electrical machines as well as to the little motivation of the students to learn and understand concepts apparently not related to their programmes. The paper describes the teaching approach adopted by the author through several practical examples.

Keywords: Electrical energy systems; mechanical engineering; civil engineering; impedance analogy.

1 INTRODUCTION

Teaching electrical energy systems to non-electrical engineering students presents several didactic and methodological challenges. First, when they attend such modules, the students have only a very basic knowledge of circuit theory and lack fundamental concepts of electrical machine modelling and control theory. Then, since the students are not going to specialize in electrical energy systems, they often have little motivation to learn and understand concepts related to power systems. It is thus crucial that the matter of the module is delivered in an appealing way. Including examples where the students can see the similarities and differences with respect to other disciplines that are better known or more interesting to them appears a sensible way to deliver the module.

This paper describes the author's experience in teaching modules on electrical energy systems to two different groups of non-electrical engineering students, as follows.

- Stage 4 Civil Engineering (CEng) students at University of Castilla-La Mancha (UCLM), Spain. The module is an option and the students deliberately choose it to complement their programme with some notions of electrical machines and power systems. The number of students is low (about ten). The author has taught this module along with other colleagues from 2009 to 2011.
- Stage 3 Mechanical Engineering (MEng) students at University College Dublin (UCD), Ireland. This is a core module that all MEng students are expected to attend and is part of the required basic knowledge to obtain the degree. The number of students is high (about sixty). The author has taught this module in the academic year 2016/17.

The different features of the two modules and, more importantly, the diverse motivations of the students, make them relevant benchmarks to compare the proposed didactic approach.

The paper provides the following contributions.

- A discussion on the key features that a module on electrical energy systems should provide to non-electrical engineering students.
- A proposal of a didactic approach aimed at making power system topics interesting to students that are not majoring in power systems, and appealing for students that can choose Electrical Energy Systems as an option module. The discussion also presents a variety of examples discussed in the modules considered in the paper.
- Relevant students’ feedback on the effects of the adopted didactic approach for the modules taught by the author at UCLM and UCD.

The remainder of the paper is organized as follows. Section 2 outlines the structure of the CEng and MEng undergraduate programmes at UCLM and UCD, and describes the content of the modules that have been taught by the author in these two institutions. Section 3 discusses the challenges encountered by the author while teaching the modules and illustrates through examples the didactic
solutions through some examples. Finally, Section 4 draws conclusions and discusses relevant student feedback.

2 OUTLINES OF CIVIL AND MECHANICAL ENGINEERING PROGRAMMES AT UCLM AND UCD

This section briefly describes of the modules on electrical energy systems that was offered by the group of Electrical Engineering to the students of CEng at UCLM and by the author to the students of CEng at UCD. The section also describes the programmes within which such modules are offered.

2.1 Electrical Energy Systems for Civil Engineering Students at UCLM

The module (called Electrotecnia in Spanish) was an option module at stage 4 of the Civil Engineering programme. Except for basic electromagnetisms, this was the only module on circuit theory, electrical machines and power systems of the whole programme. The old programme has been recently discontinued and currently does no longer include any specific module on electric energy systems. These are briefly discussed along with other energy carriers and networks (such as water and traffic systems). The experience of the author refers to the old programme, where the module was offered by the group of Electrical Engineering at UCLM. Since it was an option module, only a very few students were selecting it for completing their degree.

“Electrotecnia” was intended to be a high-level module on circuit theory, electrical machines and power systems – in particular, distribution systems. The matter was selected to cover the topics that would more likely be encountered by civil engineering in their jobs. The focus was thus on distribution systems and motors, i.e., the consumer side of the electrical grid. The module included 45 hours of theoretical lectures and 15 hours of lab activities, for a total of 6 ECTS credits. Since the students did not have any previous knowledge of electrical circuits, half of the module was dedicated to circuit theory and a substantial part to the design of distribution systems. Remaining time was dedicated to provide an overview of power systems and electrical machines, namely, transformers, induction motors and synchronous generators. Basic bibliography included references on power system analysis [1], circuit theory [2], distribution systems [3], and electrical machines [4]. All these reference were in Spanish to help the students prepare the exam. Lab activities were following theoretical lectures discussing the topics of the labs. The author was involved in the teaching of the parts related to inductions machines and synchronous machines.

2.2 Electrical Energy Systems for Mechanical Engineering Students at UCD

“Electrical Energy Systems” is a core module for three engineering programmes at UCD, namely, Mechanical, Electrical and Electronic Engineering. Moreover, the three programmes share stage 1, where students are expected to learn a variety of very basic concepts, such as calculus, linear algebra, physics and chemistry. During stage 1, very introductory modules on mechanics and electrical and electronic engineering are provided to the students. During stage 2, the three programmes include the mandatory module “Electrical and Electronic Circuits”, which is offered in semester 1 and provides basic circuit theory concepts, such as Kirchhoff laws and Thevenin theorem. At this point, the path of MEng students and E&E ones start to differ. MEng students focus for the rest of stage 2 and for the first half of stage 3 on matters mostly related to mechanics. It is only in semester 2 of stage 3 that they encounter the module “Electrical Energy Systems”.

MEng students might not take any other electrical power modules until the end of their undergraduate studies. Students that choose to pursue the ME in Energy Systems Engineering, which is offered by the School of Mechanical Engineering, can take as options some modules from the ME in Electrical Engineering, such as “Power Systems Dynamics and Control”, and in the past also “Power Systems Stability Analysis” (currently discontinued). However, in the last 4 years, only one student actually did so.

“Electrical Energy Systems” is intended to be an introductory module on ac circuits, magnetic circuits and energy conversion, electrical machines and power systems. It includes 30 hours of theoretical lectures, 6 hours of tutorials, and lab activities, for a total of 5 ECTS credits. Due to time limitations,

1 The interested reader can refer to [5] and [6] for further details on these two modules.
each topic is necessarily just outlined and only very basic definitions and concepts are presented. All
topics are explained both theoretically and with problem worked on the blackboard.

The module is divided into six parts, namely, ac circuit theory including three-phase systems;
magnetic circuits and energy conversion; transformers, induction motors; synchronous machines; and
power flow analysis. Basic suggested bibliography includes references on electrical machines [7, 8],
and power systems [9, 10]. Learning outcomes of the module are: basic concepts of steady-state ac
circuits, main electrical machines (transformers, induction motors and synchronous generators) and
power system analysis. Theoretical lectures are accompanied by lab activities. These are divided into
two parts: (i) open-circuit and short-circuit test of a 3 kVA transformer; and (ii) power flow analysis with
PowerWorld software tool [11]. Labs on the transformer are organized similarly to what described in
[12], whereas a discussion on the didactic value of computer-based labs for power system analysis is
discussed in [13-15].

3 DIDACTICAL APPROACH TO TEACH ELECTRICAL ENERGY SYSTEMS TO
NON-ELECTRICAL STUDENTS

This section describes the main challenges encountered in teaching the module “Electrical Energy
Systems” to non-electrical students and proposes a didactical approach based on several examples
that illustrate similarities and dissimilarities between electrical and mechanical systems. A variety of
these examples is discussed in the second part of this section.

3.1 Didactic Challenges

The content of the modules taught at UCLM and UCD were and are challenging for the students for
several reasons, as follows.

- **Weak knowledge of circuit theory.** The basis of circuit theory were virtually null for the CEng
  students at UCLM and relatively weak (mostly for lack of interest) for MEng students at UCD.
The knowledge of complex numbers and trigonometry is also often quite weak.

- **Several different methodologies.** A module that has to cover circuit theory, energy conversion,
electrical machines and power systems has to introduce to the students at least three different
methodologies. **Methodology**, in this context, refers to a “way of thinking” along with a set of
physical laws and principles. Typical engineering modules only introduce one methodology. For
this reason, a module on electrical energy systems can be hard for the students.

- **Language and notation.** The scientific language and notation used by electrical engineers is
clearly different than that utilized by civil or mechanical engineers. This can be a barrier that
complicates understanding concepts that per se are not necessarily complex. This fact is
particularly relevant for students that are at stage 4, which got used to the language specific of
their degree. Moreover the different methodologies introduced in the module require different
languages and notations.

The didactic challenges described above clearly require an ad hoc didactic strategy. A possible
approach is presented in the next section. The interested reader can find an in-depth discussion on
the didactic challenges of teaching a module on electrical energy systems in [16].

3.2 Proposed Didactic Approach

This subsection presents a tentative solution to the challenges illustrated above. Whether such
solutions are actually also successful is discussed in the concluding remarks of the paper.

3.2.1 Analogies and similarities of electrical and mechanical systems

To utilise concepts and examples known to the students to illustrate and clarify new concepts related
to electrical engineering appears a sensible approach. In this way, in fact, the lecturer can take
advantage of the effort spent by the students to understand difficult concepts in previous modules or,
simply, exploit common sense. The following are relevant examples.

3.2.1.1 Spring-mass-damper model (impedance analogy)

Every basic module on physics and mechanics discusses the spring-mass-damper model. This is
indeed a very common example to illustrates Newton’s second law of motion and lead to the well-
known second order differential equation linking position, velocity and acceleration and external forces (see left panel of Figure 1). The so-called **impedance analogy** shows that the basic electric elements, namely, capacitances, inductances, resistances and generators, leads to the very same differential equation, at least formally, to the motion equations of the mass-spring-damper mechanical system (see right panel of Figure 1). This analogy is so general that has been largely exploited and many other analogies of physicals systems can be described (assuming linearity) with an electrical circuit. To cite just a couple of examples, water networks, acoustic systems, and magnetic circuits can be easily studied through an electrical analogy. This is clearly due to the fact that most physical systems consist of a source of energy (generator), a dissipative element (resistance), a storage element (capacity) and an inertial element (inductance). The interested reader can find a monograph on impedance analogy in [17].

![Figure 1: Impedance analogy.](image)

The main goal of presenting the impedance analogy to the students, and in particular to MEng ones, is to introduce electrical concepts in such a way that they do not appear too far away from their experience and to show that actually even mechanical systems can be treated using circuit theory concepts.

### 3.2.1.2 AC circuits and Galilean relativity example

The example above applies to any kind of motion imposed by the external force (generator). In power systems, however, the vast majority of applications utilise steady-state ac circuits and **phasors** (which in turns are vectorial quantities that can be expressed using complex numbers).

Explaining the physical meaning of phasors to students is hard. The idea of having a permanent oscillation and thus studying the circuit with a reference that is also oscillating at the same frequency is just not intuitive. Moreover, this approach has no direct equivalence in other engineering fields, except maybe the study vibrations, which, however, are generally an undesirable effect of motion.

In the experience of the author, the best way is to discuss phasors through an analogy with the classical Galilean relativity example and discuss ac circuits using two reference frames, one steady, which observes the wave changing in time, and one on top of the wave, and thus steady with respect to the wave. This analogy, if not totally intuitive, suggests at least that phasors can be thought as a change of reference frame or coordinates, a concept that is common in many engineering field.

### 3.2.1.3 Reactive power and cyclist analogy

One of the harder concepts that descend from the definition of phasors is that the power and, hence, the energy, of a steady-state ac system is a complex quantity. While it is straightforward to understand the meaning of active (real) power, which is the energy per unit time either delivered to loads or dissipated in the resistances, the imaginary component of the complex power looks like having appeared out of the blue.

The very first issue is its name: the imaginary component of the complex power is actually very real. Such an imaginary part is called **reactive power** and is the energy that is transferred at every cycle.

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2 The typical impedance analogy that is presented to the student is the one defined by Maxwell, which preserves the physical meaning of the elements of the circuits but not the topology. Observe, in fact, that, in Figure 1, the elements of the mechanical scheme are not connected as in the electrical circuit. There is also a topology-preserving analogy, known as **mobility analogy**, but this is seldom used for didactic purposes.

3 In [18], the author argues that “the main problem with imaginary numbers is their name. If \( \sqrt{-1} \) had been called “extended” instead of imaginary, perhaps it would not have given as many qualms to generations of students.”
from capacitances to inductances and vice versa. This energy is required to magnetise the magnetic circuits of transformers and rotating electrical machines and to energise the capacitors (physical ones or due to parasitic effects) of the grid. Inductances and capacitances do not dissipate such energy and, for this reason, the reactive power is conceptually different from the active one. Still, the reactive power flowing in transmission lines and transformers dissipate energy (as it contributes to the magnitude of the current flowing in the circuits) and is thus a crucial part of the operation and the design of electrical power systems.

Unfortunately, the reactive power has no direct analogy with any mechanical or non-electrical system. It is a direct consequence of the utilization of phasors to study steady-state ac circuits, which, as said above, is peculiar of power system analysis. It is also interesting to note that reactive power is actually hard to define in transient conditions and have been object of intense theoretical studies. It is still not clear, in fact, how to define the reactive power during a transient in such a way that the definition is both practical and fulfilling the energy conservation principle. The interested reader can find in [19-21] different definitions of the instantaneous reactive power and in Appendix B of [22] an excellent introduction to this topic.

The problem to clarify the concept of reactive power to the students is thus a tricky one. In recent years, the cyclist analogy has become popular on some websites (see Figure 2). Riders at the back are passengers (equivalent to electric loads), while riders at front are drivers (equivalent to generators). If some passengers lean out on a side (reactive load), the effort required to drive bike (active power) is unaffected, but the bike might fall over. The riders at front must compensate (reactive generation), pedalling becomes more difficult (reduced capability) and bicycle drag increases (more losses). This analogy has many flaws, the most important being that reactive power is actually necessary for the electric system to work, while riders could just refrain to lean out. So there is still the risk that the students interpret the reactive power as an unnecessary issue of some loads, which is not correct. However, the analogy is good enough, especially for students that are not majoring in electrical engineering.

![Figure 2: Cyclist analogy to illustrate the meaning of reactive power in electrical systems.](image)

### 3.2.1.4 Pendulum clocks, synchronous machines and synchronism

Power system dynamics is a matter of advanced modules of Electrical Engineering. Actually Electrical Engineering programmes often do not even include a module on the dynamic model of synchronous machines. However, any module on power systems will sooner or later state that “the frequency in a power system is the same everywhere”. This information is clearly an oversimplification and is actually incorrect. The frequency slightly fluctuates from bus to bus due to local load variations. Then, after a contingency such fluctuations can become large and, in some cases, lead to the loss of synchronism of some generator and to the collapse of the whole system.

The study of the loss of synchronism (transient stability analysis) is actually one of the most important dynamic analyses carried out hundreds of times per minute, every minute, by system operators all around the world. So, the statement above is just a trivialization of a complex subject. The fundamental concept, however, i.e., that the frequency of an electrical energy system is basically a common property of the system itself, at least in an ideal steady-state condition, is an important message that the students should assimilate.

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4 Note that the reactive power should not be confused with the imaginary power, which was proposed in [19] and refers to transient conditions and instantaneous power theory.

5 This was the case, for example, of the Electrical Engineering programme at UCD before the author joined the institution in 2013. The interested reader can refer to [5], [6], and [15] for further detail on the modules introduced at UCD by the author.
Probably the best way to communicate the fact that power systems are “synchronous” is to use the analogy with the synchronization of pendulum clocks as discovered by Huygens in 1665. First, it is useful to remember the simplified electro-mechanical equations of a synchronous generator [23]:

\[
\begin{align*}
\delta &= \omega \\
M \dot{\omega} &= p_m - p_e - D \omega \\
p_e &= \frac{e v}{x_d} \sin \delta
\end{align*}
\]

where \(\delta\) is the rotor angle position, \(\omega\) is the rotor speed deviation, \(e\) is the internal emf, \(v\) is the voltage at the terminal bus of the machine, \(x_d\) is the transient reactance, \(M\) is the inertia constant, \(D\) is the damping, \(p_m\) is the mechanical power, \(p_e\) is the electrical power, which is a nonlinear function of the rotor angle position of the machine.

When more than one machine is connected to the grid, the expression of the electrical power \(p_{e,i}\) of each machine \(i\) depends on the physical connections among the machines and their relative rotor angle positions:

\[
p_{e,i} = \sum_{j=1}^{m} b_{ij} \sin(\delta_i - \delta_j)
\]

where \(m\) is the total number of machines, and coefficients \(b_{ij}\) depends on the topology of the grid and on machine and network parameters. It is relatively easy to show that the only condition for which all machines are in steady-state is when they are synchronous (see [23] for more details).

The set of equations (1)-(3) are structurally the same as those of a mechanical pendulum and, as a matter of fact, synchronous machines oscillate around the equilibrium point. The main difference with a pendulum is that the steady-state condition of the synchronous machine is to rotate at the synchronous angular speed, whereas the pendulum is in steady-state when it does not move. But, recalling the definitions of phasors and rotating reference frame, the similarity between synchronous machines and pendulum clocks matches fairly well. Still, the maths that explains the synchronization cannot compete with the visual impact of the synchronization of pendulum clocks. Reference [24] discusses an interesting example of synchronization of metronomes (see Figure 3), which is quite successful in visually illustrate the phenomenon.6 In this analogy, each metronome is a synchronous machine and the shelf leaning on the tin cans represents the electric grid connecting the machines.

![Figure 3: Synchronization of metronomes [24, 25].](image)

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6 Several videos showing the synchronization of metronomes similar to the example given in [24] are freely available in the internet.
As in the case of the cyclists, while the principle of the synchronization is the same, the analogy of synchronous machines and metronomes is not a perfect match. Synchronous machines produce power and a failure in the synchronization, following for example a fault, can lead to catastrophic consequences. Then, in the example of the metronomes there are no loads nor there would be a simple way to include them. The visual impact, however, is the key point as it gives the clear message that the machines will naturally tend to the synchronism. Implicitly, it is also clear that the machines synchronize without the help of controllers. In actual power systems, controllers are actually always present, e.g., turbine governors, automatic voltage regulators, and power system stabilisers, but it is important to note that the behaviour of synchronous machines is intrinsically stable even without such controllers. This, in turn, is one of the main reasons why electric power systems work properly for the vast majority of the time.

3.2.2 Unintuitive facts on electrical systems

The previous section focuses on the effectiveness of analogy to clarify concepts that can otherwise appear obscure to the students. This section illustrates the utilization of the opposite approach, i.e., it shows unexpected or unintuitive aspects of electrical systems and their peculiarities with respect to mechanical ones. The following are relevant examples.

3.2.2.1 Transmission of power

Most people assume that “power systems” must necessarily be “electrical”. This is a given nowadays, but it has not been always the case. Before electrical machines become popular, mechanical power systems were common. They could be powered by running water or steam turbines (see left panel of Figure 4). These systems could be quite efficient but had several drawbacks: small distances; costly maintenance; difficult regulation; and limited flexibility. All these issues can be easily solved using electric power systems and that is the reason why these are the standard nowadays. However, there still exist mechanical power systems, e.g., the San Francisco cable cars (see right panel of Figure 4). The main message is that the choice of implementing power systems using electricity is just an option, among other possible engineering viable solutions. It is interesting to note that most students appear often very surprised by this fact.

![Figure 4: Mechanical power systems: (right panel) industry at the end of the XIX century; and (left panel) motors of the San Francisco cable car system.](image)

3.2.2.2 Electromagnet

Everybody has seen at least one American movie where a car is lifted by an electromagnet. These devices are actually quite common in industry and are used whenever it is necessary to lift and move heavy objects made in steel (see Figure 5). The force produced by the electromagnet is:

\[ f = -\frac{1}{2}\frac{\partial L}{\partial x}I^2 + \frac{1}{2}\frac{\partial L}{\partial x}I^2(\cos(2\omega t))^2 \]  

(5)

where \( I \) is the RMS value of the current, \( \omega \) is the angular speed of the current and \( \frac{\partial L}{\partial x} \) is the partial derivative of the inductance of the combined system composed of the electromagnet and the junks with respect to the distance between the electromagnet and the junks.

From observing equation (5) is appears that the force is composed of a constant component and a periodic one, whose amplitude makes the resulting force zero every half a period of the frequency of the ac system that feeds the electromagnet. In other words, the attractive force generated by the
electromagnet is zero every 10 ms if the fundamental frequency is 50 Hz. This is clearly in contrast with experience: in the American movies, we never see the car falling to the ground and then being attracted again by the electromagnet. Why is that so? The fact is that the inertia of the junks prevents the junk to fall down. The only effect that we see is the one of the constant (average) part of the force generated by the electromagnet.

![Figure 5: Electromagnets utilized to lift steel objects](image)

The electromagnet is just one the many examples that can be done regarding the concept of time scales, which is of fundamental importance in engineering. The time scales of electromagnetic dynamics are generally a few orders of magnitude faster than those of mechanical parts. For this reason the two dynamics are fully decoupled. The vast majority of engineering applications take advantage explicitly or implicitly of the difference of the time scales between different processes or phenomena.

3.2.2.3 Electric bell

The electric bell (see Figure 6) is another interesting example that the author generally utilizes to test the understanding of the students of the time scale concept. The circuit is composed of an electromagnet that, when energised, pulls a hammer that hits a gong. When the hammer is pulled, the electrical circuit opens and thus the electromagnet releases the hammer. The question posed to the students is the following: is it necessary that the current feeding the electromagnet is ac to make the device work? In other words, is it the alternate behaviour of the current that leads to the cyclic movement of the hammer?

The current, in fact, can be any and as a matter of fact, electric bells often come with a battery. Only students that have not properly assimilated the concept of the different time scales between mechanical and electromagnetic circuits -- and that have not fully understood the mechanism of the energy conversion in magnetic circuits -- answer that the current needs to be alternate.

![Figure 6: Electric bell](image)

3.2.2.4 Behind the scenes of nominal current

The final example given in this section describes another very important concept of electrical systems: the nominal current. The nominal (or rated) current can be defined as that current that can flow in a given part of a circuit for a given time without consistently reducing the estimated useful life of the device itself.
While the definition can appear a bit technical, everybody has experienced the concept of nominal current in daily life. It is well known, in fact, that one cannot switch on all electric devices at home. If one does so, the protection relay or the fuse of the general breaker will open and disconnect all appliances. This happens because the current flowing in the breaker is higher than the nominal current and thus the circuit cannot be operated safely.

Now, not everybody knows that the actual problem with a current exceeding the rated one is not only the current per se, but also the time such a current lasts in the circuit. To understand this, one needs some basic knowledge of thermodynamics and the Ohm’s law. Ohm’s law states the every current flowing in a circuit dissipates energy in form of heat, which is proportional to the resistance of the circuit and the square of the RMS current. The heat so generated is partly exchanged with the environment (typically due to convection or radiation) and partly contributes to increase the temperature of the conductor where the current is flowing. Clearly, the temperature does not increase instantaneously, but roughly follows an exponential law, which, under several approximations, can be deduced as the solution of a linear first order differential equation describing the heat transfer process. In turn, how fast the conductor is warmed up depends not only on the RMS value of the current but also on the thermal time constant of the heat transfer equation. It is then possible to determine, at least approximately, how long each value of the current takes to raise the temperature of the conductor up to a temperature dangerous for the circuit (e.g., the temperature at which the insulation of the cables melts). A protection has thus to simply measure the current of the circuit and keep track of how long such current lasts. Clearly the higher the current the less the protection can delay opening the circuit.

The concept above is relatively simple but may have unexpected consequences. For example, if we know that a given electrical machine is going to be utilized cyclically with a duty cycle shorter than the thermal time constant of the machine itself, one can safely overload the machine (this, in turn, means that one can utilize a cheaper machine). An extreme case is the torpedo. Since the useful life of a torpedo is few tens of minutes, the electric motor needed to drive it can be consistently overloaded, thus consistently reducing the weight of the motor and leaving more room for the explosive.

In conclusion, the key part of the definition of the nominal current is “for a given time”. The implications of the definition result often quite unexpected to the students.

4 CONCLUDING REMARKS

The paper discusses the experience of the author teaching electric energy modules to students in Mechanical and Civil Engineering. The didactic approach proposed in the paper is to utilize, whenever possible, analogies between electrical circuits and mechanical phenomena to clarify concepts of electric energy systems that often result obscure to the students. Since such analogies are based on examples that the students should know from previous modules in physics or mechanics, the learning process is expected to be faster and simpler. Along with analogies, the author also utilizes the very opposite approach, namely, presenting examples where the relationship between electrical systems and mechanical or thermal ones apparently contrast with experience. The surprise following the discussion of such examples help the students to better assimilate key concepts of electrical engineering.

The feedback of the students differs depending on the stage and their motivations. CEng students, which have deliberately chosen to attend a module on electrical energy systems, responded quite positively to the teaching approach utilized by the author. On the other hand, MEng students, for whom the module is core, has mixed feelings. Generally, the whole module itself is considered not interesting. This is actually more a prejudice than a consequence of the teaching approach. Still, some students appear to appreciate the effort of the author to adapt the matter of the module to the previous knowledge and interests of the audience.

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