Abstract.

Traditionally, the education in electrical engineering is roughly divided in two areas viz. electronics and telecommunication at the one hand and electrical energy at the other. Though the borders between these two areas have become vague, still this division is clearly observable, in particular, when it comes down to the student’s perception of these areas as potential fields of study. Electrical energy has an old fashioned image. Furthermore, over the last decades there has been a shift from laboratory experiments to computer simulations. In this paper a new approach is introduced, that is aimed at raising first year students awareness of the potential attractiveness of electrical energy as an area of study. The approach is project oriented and based on teamwork. Projects are carried out that are aimed at the design, implementation and verification of small total energy systems. The problems involved are related to energy production, system design, energy storage and consumption.
1. Introduction
Over the last decades the image of electrical engineering as a field of study has changed quite
dramatically. In the fifties and sixties Electrical Engineering was associated on one hand with
a radio, TV, audio and on the other hand with the electrical power systems such as machines
and high voltage. The first field has developed into communication systems, computers and
micro-electronics whereas the latter field evolved to sophisticated control of energy
distribution and conversion. At the same time the latter field attracts less students. Some
possible reasons are the rather old fashioned image and the low visibility of the field. Also,
many students believe that the area of electrical energy isn’t very challenging. Another
phenomenon is, that due to the tremendous increase of cheaply available computer power,
there has been a shift from laboratory experiments to computer simulations, which detracts
the students attention from real hand-on experience. In the Department of Electrical
Engineering we tried to raise the awareness of the area of electrical energy by introducing a
module that would be highly motivating for students.

2. General, educational objectives and framework
Traditionally, first year (electrical) engineering curricula are highly mathematics and physics
oriented. A minority of courses are more field specific such as circuit theory, basic electronics
and computer science. The courses are often presented in the form of lectures and/or small
group exercise courses. In this type of education the students often show, that:
- They don’t understand the mutual relations between the different course contents
- They don’t see the relevance of the courses for
  - the future study programme
  - the engineering practice
Furthermore, the education is often more analysis oriented rather than synthesis (i.e. design)
oriented. As a consequence of these problems, students start to show a lack of motivation,
which may lead to poor results and sometimes even to giving up the study at all. Finally, in
traditional curricula there is a lack of development of general engineering skills such as the
ability of working in a team, communication skills and creativity. In general the first year
curriculum is aimed at developing basic subject specific competences and hardly at
developing generic competences.
Some years ago, we developed a module that was aimed at solving, at least some of the above
mentioned problems, however, without creating a complete new curriculum [1]. The key
issues of the educational objectives of this module are:
- Learning to think in alternatives
- Learning that in real life there are always more solutions to problem than just one
- Learning to evaluate alternative solutions by first formulating criteria
- Learning to think in terms of functions, rather than implementations
- Learning to use knowledge and skills as a means rather than a goal
- Learning to perceive technology in a context

The course has the format of small working groups of ten students, which run throughout the
first year. The study load of the course is equivalent to 11 ECTS credit points. The groups
carry out small projects and a tutor (a member of the academic staff) with an advisory role
supervises them. The pedagogic philosophy can be best described as the traditional
Montessori-approach (though not explicitly applied): ‘teach me how to do it myself’ [2],[3]. It
was decided, that, within the framework of this course a project had to be incorporated, that,
apart from the general problems mentioned above, might help to solve the problem as
discussed in the introduction, viz. the ignorance of the field of electrical energy [4]. This
paper encounters the project aimed to propagate Power Electronics and Electrical Drives study specialization.

3. **Specific objectives for the Electrical Energy project.**

Electrical Power engineering and Power Electronics and Electrical Drives in particular do not belong to the subjects known by a fresh electrical engineering student. The image of power engineering is of one traditional, not developing and old fashioned field. Power Electronics in particular is not known at all. Many students can not even give any answer to the question what power electronics is and what it studies.

The selection for a direction of the study is however made after second year. The tendency today is that students select subjects they are familiar with such as computer technique, telecommunication and information technology. This choice has little to do with the actual market situation and to the needs of a society. Therefore the project can positively contribute to that selection in benefit of power electronics. The first specific objective is to propagate energy technique a specifically power electronics and to positively influence the direction and choice of the study for this subject.

The renewable energy and wind and solar energy on the other side in the last years attract attention. The relation and link to a Power Electronics is by the students often missing. The second objective is thus to propagate the renewable energy sources and to place them in context of the Power Electronics.

The young generation can nowadays think in terms of bites and bytes but not in the terms of energy and most important in terms of amount of energy. The physical understanding of amount of energy needed for a simple task such as the one described next in the project is beyond the expertise of most of the students. The third objective is to learn to think in terms of energy and also to effectively deal with the energy.

4. **The Electrical Energy project**

To meet the general and specific objectives of the project the assignment were defined. The project assignment likes to be in a first place very simple: There is a need to get water from the drain, which is 1 meter deep. The drain is located in a remote place, in area where no source of electricity is available. As a tool there is a crane with basket or a water pump available. On the other side present sources of energy are sun or wind energy that is both available for a limited time interval. The designed system could use any of the two available energy sources with any of the two loads, viz. the crane and the pump (Fig.1).

![Fig. 1: Available sources and loads](image-url)
There are thus four different combinations. Taking into consideration the rest of the building blocs the number of possible combinations of connection of components (building blocs) is even larger.

4.1 Selection of the building blocks.
The available basic building blocks (Fig.2) are:
  - Solar cells
  - Windmill
  - Up/down chopper
  - Super caps energy storage
  - Pump
  - Crane

Fig. 2: Solar cells, windmill, dc-dc up/down converter and super caps, crane

The building blocks are selected with respect to the specific objectives. Renewable energy sources wind mill and solar cell are selected with the aim to propagate the renewable energy sources and also with the aim to think in terms of amount of energy. A fan drives windmill and it delivers peak power of 4.1W. The wind is available for a limited time of four minutes. Similarly the two solar cells deliver a power of 2.1W for a time interval of six minutes. Solar cells are illuminated with the set of lamps (see Fig.2). Purely taking in consideration this fact the amount of energy per available source can be calculated. The result is 972 Joules obtained from windmill generator compare to 757 Joules from solar cells. Another effect taken into consideration is that the solar cells deliver the energy immediately after lamps are switched on while the windmill has a starting up effect and it takes some time to obtain the maximum power. The start up takes also longer if the windmill is loaded.

The crane and pump are selected to show the importance of effectiveness of components in an Electric Drive. Good understanding of the component but also creativity in selecting the optimal working point in the complex system is here the key points. As seen from Fig.3 the voltage of a crane is limited to 6V (parameter of the used machine) which must not be exceeded. To connect the crane to a windmill the chopper has to set up the working point. The power converters (up/down chopper which performs a dc-dc conversion) places power electronics in the context of a larger energy system. Straightforward linking of any of the two energy sources to any of the loads does not lead to satisfactory results because of the
mismatch between these sources and the loads. This latter fact is essential. Therefore, the need of energy conversion becomes apparent. The application of power electronics conversion is consequently introduced in a natural way. The up/down chopper can change voltage from 3-25 V to a voltage of 3-50 V. The detailed understanding of the power converter operation is beyond the expertise and expectation of this project and its function is explained by a simple imagination of a ‘dc-dc transformer’ able to change voltage and current.

Fig. 3: Electrical characteristics (power) of the available components: crane, pump, windmill and solar cells

4.2 Organisation of the project
The project is simultaneously and independently performed by several groups of students. Each group consists of 10 students. The time available for this project is limited to a four half days. The amount of work and limited time forces the group to divide into subgroups with different tasks. Usually it was one subgroup of two students per available component. By the design the results of each subgroup is of the same importance. This means that students have to accept results not only of several subgroups but also critically evaluate work of their colleagues. Work in teams and communication skills by the interaction between the subgroups are the important and necessary abilities. By this they also learn to perceive technology in context as one of the educational objectives.

4.3 Evaluation of the educational objectives
Let us evaluate the other educational objectives. The students learn to think in alternatives and learn that in real life there are always more solutions to problem than just one as the system can be connected by numerous ways. Every group obtained a different solution with a different result. This results in a different amount of water obtained from the drain. The students learn to evaluate alternative solutions by first formulating criteria such as power, energy, time, and voltage or current. Without this many measurements prove to be at the end unusable for the ultimate system design. The students learn to use knowledge and skills as a means rather than as a goal. The goal is to get water from the drain the knowledge about the components is only a means of obtaining it. Specific knowledge about power and energy as
well as knowledge about the components e.g. converter (up/down chopper) is required. To obtain this knowledge certain skills such as experience with measurement and measurement technique is necessary. Evaluation of alternative solutions based on formulated criteria is the essential part of the process. As already mentioned the students learn to perceive technology in a context of a larger project.

4.4 Project Implementation
The essence of the project and final objectives comprise:
- Finding the optimal working point of each element (source, load) with the use of a power electronics converter and learn to manipulate energy in an efficient way
- The proper use of energy storage elements (super caps)
- Matching voltages and currents and maximal allowable parameters of the components
- Implementation of a complete system

There are numerous possible solutions and it is not the objective of this paper to describe the best solution since such a solution would be based on dynamical models and deep analysis of the components and the use of a control theory. Surely there is a scientific solution to the project assignment, but it is impossible to expect it from the first year students. Still it is interesting to follow how some students intuitively approach the so called scientific solution. Each element has an optimal working point. For example, the used solar cell output power is optimal at a certain value of the load as can be seen in Fig.3. Similarly, there are optimal working points for other components too (Fig 3). The ‘optimal’ point requires to define the criteria before finding one. With the help of dc-dc converter (up/down chopper) source characteristics can be made different to suit better the load. In Fig.4 the characteristics of the windmill is ‘shifted’ by the use of a dc-dc converter to match the characteristics of crane. In the real system this is changing dynamically by loading the windmill generator. The winner group discovered this fact and changed the duty ratio of the converter during the operation achieving a simple regulation effect. By creating a simple hand controlled power point trekker the better use of energy is achieved.

Since the energy sources are available for a limited time, the students learn to think in terms of available amount of energy and efficient energy conversion respectively energy storage. The use of the energy storage allows using the crane or the pump for a longer time than the availability of sources. At the same time use of energy storage allows utilization of energy by start up or shut down of the source.

The used components have their electrical parameters defined. However tempting and advantageous it can be these parameters cannot be exceeded. As it appears during the evaluation it is not always clear to the students. Although every team obtains the same tools and means the results prove to be quite different. The group that learns to manipulate the energy in a most effective way achieves the best result.

The students obtain experience with the power electronic component (dc-dc converter up/down chopper) and they learn that the use of energy conversion leads to more effective energy transfer. At the same time they learn to develop alternative solutions and select an optimal solution by a given particular criterion.

5. Assessment
The key issue of the final assessment is a real working system. Furthermore, we introduced a competitive element. After completion of the project by all teams, the teams come together in a final session where all teams have to show their results in a short presentation. A panel of three assessors assesses each group. The assessment of the teams concentrates not only in terms of the transported amount of water but also in terms of the quality of the presentation. Although it is not realistic to expect a scientific results from the first year students, the criteria
such us good study and understanding of components, and creativity are assessed too. Creative solutions are especially rewarded. From the electrical point of view it is very important that students take electrical parameters in consideration too. These are e.g. maximal allowed voltage of the super caps, of the crane etc. Exceeding these parameters for a short time does not have to lead to a disastrous effect on a short term but on the long term affects the system reliability and lifetime. Therefore exceeding some of this parameters lower the assessment results. The team that obtained the best result get a small prize.

6. Conclusions
The project is highly appreciated by the students. The main objective (to get familiar with power engineering in general and power electronics in particular) is hereby fulfilled. The students not only get acquainted with power electronics but as a result of the project they recognise that without the power converter and conversion the aimed goal cannot be achieved. (As mentioned before, straightforward connection does not give satisfactory result). Moreover the better understanding of the power conversion leads to a better result. The practical results are not always the same. As an example, the amount of water transported varied between 9 and 12 litre of water. This is dependent on the choice of the sources, the loads and their interconnection through the energy converters. Interestingly, the choice of the renewable energy sources leads to the required results, which demonstrates the potential value of these sources.

Besides the mentioned educational objectives it gives the freshmen students the feeling of doing the real research. Obtaining functioning results is an important issue here. Different groups with different solutions obtain different results as well. The competition between the groups enhances the motivation of the students.

References

