IMPLEMENTING A 15 kW ELECTRIC SOLAR POWER SYSTEM AS A STUDENT PROJECT

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ABSTRACT

Solar PV (photo voltaic) power is the fastest growing energy segment globally. In 2014 40 GW of solar PV power was connected to the grid globally. In ten years the growth has been outstanding: from 3.7 GW in 2004 to 177 GW in 2014. In Finland the installed solar PV power is only about 20 MW , so we could do much better.

In Lahti University of Applied Sciences (LUAS) the students of Energy and Environmental Technology can specialize in Renewable Energy Technologies. They have done a lot of research-based studies and projects, but the real hands-on projects were missing from the curriculum. On the other hand, in the Degree Programme of Mechatronics there was a long tradition of these types of projects starting from the first academic year. In the Niemi Campus the facility owner (Osaamiskiinteistöt Oy) expressed that the energy efficiency of the facilities should be improved. Due to these facts, we launched a project where an electric solar power system was installed in the Niemi Campus.

The main specifications for the system were:

- 10 kW nominal power (+ 5 kW reserve for wind mill)
- Grid inverter included (no batteries)
- Web-based data logging and remote control to customer’s server
- Mounting brackets and accessories for the panels
- Training and start-up (1 day)

The aim of this paper is to report how we managed this project with inexperienced students and share information about project learning in general and especially about this project (the process, learning outcomes and curriculum with CDIO community. The scope of this paper is in the process: to report why, what and how we ran this project. The project was successful: all stakeholders (the students, instructors, supplier and customer) gave us positive feedback. The next project, which we have just launched, was encouraged by this project: the windmill project.

KEYWORDS

project learning, active learning, renewable energy (solar), multidisciplinary projects, standards: 3, 5, 6, 7,

INTRODUCTION AND MOTIVATION

Solar PV (photo voltaic) power is the fastest growing energy segment globally. In 2014 40 GW of solar PV power was connected to the grid globally. In ten years the growth has in addition, been outstanding: from 3.7 GW in 2004 to 177 GW in 2014 (Renewable Energy Policy Network, 2015). In Finland the installed solar PV power is only about 20 MW, which is among the lowest figures in Europe (Motiva, 2015). So we could do much better. The European Union National Action Plans (Ministry of Employment and the Economy, 2009) point out that also Finland should substantially increase the production of renewable energies in general. Unfortunately the action plan target for solar PV power is far from ambitious: only 30 MW until 2020. It seems that Finland will fulfill this target, but the problem is that the original action plan target is far too low. On the other hand, Finnish enterprises are doing well globally. It was just announced that Fortum won a contract of a 70 MW solar PV power plant in India. Also ABB and Nocart have managed well in global markets (Motiva, 2015).

In Lahti University of Applied Sciences (LUAS) the students of Energy and Environmental Technology can specialize in Renewable Energy Technologies. The students have done some research-based projects, but the real hands-on projects were missing from the curriculum. There was also a strong demand from the students and other stakeholders, that real hands-on projects should be available in the curriculum. In the Niemi Campus the facility owner (Osaamiskiinteistöt Oy) expressed that the energy efficiency of the facilities should be improved: a solar power system would also improve the image of Niemi campus as a low energy facility. In the Degree Programme of Mechatronics there was a long tradition of these types of projects starting from the first academic year. Due to these facts, we launched a project where an electric solar power system was installed in the Niemi Campus.

PROJECT-BASED LEARNING AND CDIO

From the CDIO perspective project based learning is based on design thinking: design is the key activity in engineering. Design is also a very complex and extensive process, which embraces almost all subjects in engineering. That makes it extremely difficult to learn and teach (Dym & al., 2005). That is why experienced and skillful design engineers are very well paid.

Hands-on projects also have context-based (hardware), social (teamwork) and end-result driven aspects. Well-designed projects provide design experiences for the students. Margot Brereton studied how engineering students learn and develop engineering intuition by continuously shifting their thinking paradigm from engineering theory to interaction with hardware. She demonstrated that “engineering fundamentals are learned through activities at the border that involve continually translating between hardware and abstract representations. She is also suggesting the application of convergent-divergent thinking in a hands-on project context (Dym & al., 2005) and (Brereton, 1998). Project-based learning, which is implemented through numerous well designed hands-on projects, continuously challenge the students´ thinking: communication between engineering Theory and Praxis.

The theoretical basis of project-based learning also lies on the experiential learning theory by David Kolb (fig. 1): hands-on projects serve design and learning experiences, which excite the reflective thinking and knowledge creation of the students (Kolb, 1984). Engineering knowledge is contextualized: it emphasize the knowledge that is relevant to the engineer’s every-day life.

In the curriculum level the hands-on projects should drive the content of study courses rather than the other way around. In many cases the hands-on projects have a more or less weak link to the content of other study courses. It would be beneficial if hands-on projects direct the content of basic study courses: it emphasizes “real life” relevance and makes the course content more compact (Kaikkonen, Lahtinen, 2011).

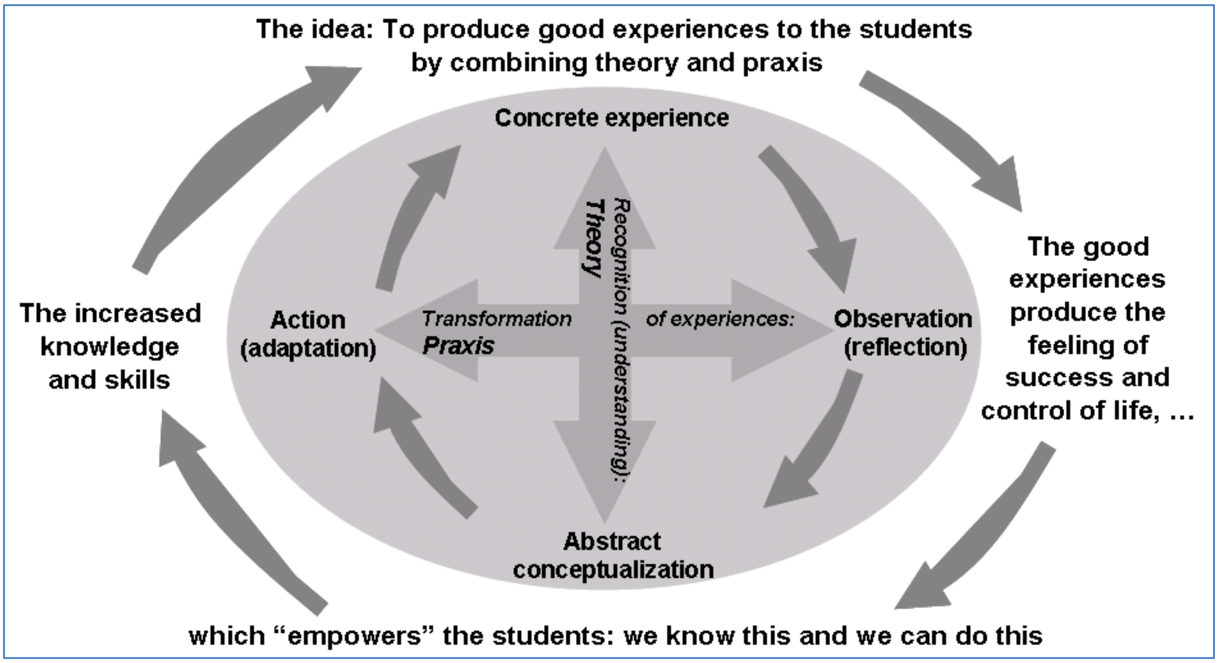

Figure 1: The Experiential Learning (Kolb; modified by Lahtinen)

The experiential learning model by Kolb has four phases: a) experience, b) observation (reflection), c) conceptualization and d) action. This is described in the inner circle of Figure 1. The action-observation pair forms the transformation of the experiences axis, which is very strongly related to the Praxis. On the other hand, the experiences-conceptualization pair forms the recognition (or understanding) axis, which is based on the Theory (Kolb, 1984 and Kaikkonen, Lahtinen, 2011).

Project-based learning can be formulated and defined in many ways, but when implemented trough well-designed hands-on projects, it serves a powerful learning and teaching tool for engineering education. From the CDIO Standards´ point of view it covers the following five standards: 3 (Integrated Curriculum), 5 (Design-implement experiences), 6 (Engineering workspaces), 7 (Integrated learning experiences) and 8 (Active learning) (Crawley & al., 2014). The challenges of project learning are usually related to the change process: the curriculum should be updated, the personnel should be trained as project managers and the workplaces should be equipped with proper hardware. This requires a strong motivation from the personnel and the ability of attitude transition (Kaikkonen, Lahtinen, 2011).

THE PROJECT AND PROCESS

This project is an optional project (6 cr) for the 3rd year students of Energy and Environmental Technology. The students should deepen their knowledge of renewable energy technologies. They should also be able “read” technical documents (wiring plans, mechanical plans etc.). The students should also develop their practical skills related to the implementation process: mechanical and electrical installations.

The project was launched in October 2014 by writing the all required documents for the invitation to tender. After that process Nocart Oy was selected as a provider of the system and they delivered the system in January 2015.The main specifications for the system were:

- 10 kW nominal power (+ 5 kW reserve for wind mill)
- Grid inverter included (no batteries)
- Web-based data logging and remote control to customer’s server
- Mounting brackets and accessories for the panels
- Training and start-up (1 day)

The system consists of 40 pcs of 250W solar panels, control cabinet (inverter, DC-DC converter, EMC filter, PLC and GSM unit). The panel frames were constructed from 40x40 mm aluminum profiles. 20 kg concrete bricks were used as counterweights.

In January also the project team was formed: 3 instructors, 7 students of environmental technology and 2 exchange students (electrical engineering) from UPC Barcelona Spain. Also ICT students of LUAS Faculty of Technology were involved in this project. The data logging server, which was connected both to the Solar Power System and the advanced weather station (big data) were their main tasks.

An experienced project manager (Mechatronics), who is also a licensed contractor of electrical installations, took the main role in project management. He was assisted by a project engineer and a lecturer from the department of Environmental Technology.

The project team had 4 hours/week of lectures in January and February. During the lectures following topics were discussed:

- The basics of electrical engineering related to the solar panels
- The basics of wiring
- Mechanical plans of panel frames and counterweights (together with an expert from Nocart Oy)
- Panel frame construction training (together with the expert from Nocart Oy)
- Safety issues: ground rules and regulations
- Safety issues: safety tool training (harnesses and ropes)
- The basics of DC-DC Converter and Inverter; EMC (exchange students)

In late January a team of four students was benchmarking a 10 kW solar power system in LEMKEM Oy. The system was documented and presented to the rest of the team as a reference. In February the components of the solar panel system were studied (panels, DC-DC Converter, Inverter and filters). The exchange students created study material (MultiSim simulation models) and presented it to the other students in English.

In March the installations started with counterweights and panel frames. In counterweights the bottom plates and through bolts were installed and panel frame aluminum profiles were cut and assembled as wishbones. This was the most time consuming part of the project. The panel frames, panels and wiring were installed in May. The wiring was finalized in August and final inspections were done in November. The system is connected in the grid and the production data will be collected later on.

Besides the lectures the students investigated the rules and regulations related to this scale of solar power plant. They also contacted the authorities and Lahti Energia Oy (power company) during the visit in March. Here is the list of required documents:

- planning permission (City of Lahti and facility owner)
- The connection of the micro power plant to the grid (Energiateollisuus ry; guidebook)
- A Technical appendix for the connection of micro power plant to the grid
- The basic data of the micro power plant (Lahti Energia; power company)
- The preconditions of electric power production and services (Energiateollisuus; TLE 2014 and TVPE11)
- Wiring layout
- Wiring diagrams of the facility control cabinet
- Wiring diagrams of the Inverter control cabinet
- Guide leaflet for safe power cut-off of the system

THE PARTIES INVOLVED IN THIS PROJECT

Nocart Ltd (the provider of power plant) was established in 2010. In 2015 the company is the leading provider of power generation solutions for small power plants in the renewable energy segment. Maximizing the advantages of renewable energy Nocart offers solutions for small power plants. The Nocart Power Generation Unit can be connected with multiple different types of power units, such as wind turbines and solar panels. The system is an economical and reliable choice for any conditions in the field of renewable energy. Installations can be found in farms, industrial estates and even in village communities of developing countries.

The main products of Lahti Energia (power company and grid holder) are electricity produced from combined power plant (Kymijärvi) and district heating. Lahti Energia sells electricity in Finland nationwide. The grid services are provided by the subsidiary LE Oy. The length of the power lines is 4580 km. Lahti Energia is also a provider of natural gas (167 kilometers of natural gas pipelines).

Osaamiskiinteistöt (customer) is focusing on facility services: renting and operating its own or leased real estates and maintenance services.

THE END RESULTS AND FEEDBACK

The end result was approved and all stakeholders (students, provider, customer and power company gave positive feedback for us. In the future the students have an excellent learning platform for the next projects, the provider use the system as one of their references, the customer is more than satisfied and also the power company have listed system as one of their references (fig. 2 and 3).

After the project a short questionnaire for the students was implemented to collect feedback and ideas for the next projects. The questionnaire had 5 questions or statements and open answers (table 1). In scale 1 (totally agree) to 5 (totally disagree) we got 1.4 as a total average. In open answers there were following comments and feedback.

Hits: “The best course/project ever”, “The project was very good and unique. Absolutely more like this”, “The project idea was great and interesting. It was very nice that the students could make the panel installations. More like this!”

Misses: “The schedule did not work too well”, “There were problems in communication between the lecturers and the students”, “The workload was not even between the students”, “It could be better if all students could join all phases of the project (wiring)”, “All students were not present every time”

Table 1. Questionnaire Results

Questions							**AVE**
Scale: 1=totally agree, 5=totally disagree	**a**	**b**	**c**	**d**	**e**	**f**	**Students**
Hands-on projects are useful.	1	1	2	1	1	1	**1,2**
There should be more hands-on projects in Energy and Environmental Technology Programme.	2	1	2	1	1	1	**1,3**
In Energy and Environmental Technology Programme there should be more training of various technical tools.	2	2	1	1	2	2	**1,7**
The training was sufficient before and during the installations.	1	1	2	2	1	1	**1,3**
The safety issues were taking care of during the installations.	2	1	3	1	1	1	**1,5**
Total average							**1,4**

Figure 2: The first panel string installed

Figure 3: The “bird’s eye” view of the location

CONCLUSIONS

According to the experience and feedback collected in this hands-on project, it seem obvious that when the students interact with hardware in well planned projects, transition of knowledge really happens: balancing between Theory and Praxis. Real life experiences strengthen the learning: the students can form a strong link between theoretical and practical knowledge and skills. The motivation aspect is also vital: by learning new practical skills the students will be “empowered”. By proper project management the students can achieve incredible performance even though they might have a weak level of prior knowledge.

From the implementation point of view the safety issues had the outmost importance when working with inexperienced students. The safety training and supervision should be in order. The policies and processes should follow the industrial standards as well as possible (simulation of the real life projects). For example the tools should be “state-of-the-art”-quality to avoid extra cuts and scratches and to make the assembly work more effective.

The trigger for this project was a feedback from the students: “we want hands-on projects”. By analyzing the feedback, it seems that we did quite well. The project is already a solid part of the curriculum. With the next projects especially the timetable and communication should be improved. The timetable issue is already partly organized: the project is now two period course instead of one. It has been a privilege to work with the students, who are so motivated and willing to learn.

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BIOGRAPHICAL INFORMATION

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