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DEVELOPMENT OF E-LEARNING MODULES FOR TEACHING ENERGY FOR SUSTAINABLE WORLD

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Abstract: *Within the project "Teaching Energy for Sustainable World" (SustEner) financed by the European Union nine practically oriented modules with remote experiments or interactive animation materials will be offered in a web based learning portal. Here the development and the operation of two modules titled "Solar Powered Electric Vehicles" and "Luminous Efficacy of Modern Light Sources" are described in some detail.*

Key Words: ***Education, e-Learning, Solar Power, Luminous efficacy***

1. INTRODUCTION

The ***SustEner*** project originates from the recognition of the enormous social, economic and technological potential of a European sustainable, low-carbon economy, and from the range of scientific and non-technical challenges preventing the realization of this vision. Within the framework of the Leonardo da Vinci program of the European Union, the SustEner project incorporating seven Universities from seven member countries is aimed at modernizing Sustainable electric energy vocational training by enhancing existing or establishing new training methods for enterprises and education [1]-[7],[11].

As a first step a survey was performed, to find out what specialized knowledge and skills in Sustainable energy-engineering are required by industry. As a result of the survey 9 topics out of 16 have been selected by industrial and educational institutions in the six countries. Each selected topic has been assigned to an e-learning module. By this way the development of 9 e-learning modules fulfill the requirements of the end-users. The list of modules:

1. Solar Electricity - From Solar cell to system
2. Photovoltaic Systems
3. Wind Energy Conversion and Control
4. Drivetrain and Combined Energy Storage System for Electric Hybrid Vehicle
5. Power Management Techniques for Hybrid Electric Cars
6. Power Electronics for Electric Cars
7. Solar Powered Electric Vehicles
8. Power Control and Energy Management in DC microgrids
9. Luminous efficacy of modern light sources

The different modules with remote or virtual experiments and interactive animation materials will be offered in an up to date web based learning portal, that are available at the addresses: http://learning.sustener.eu or also directly over the project web page: http://sustener.eu. Provided contents and learning functionalities will enable employees, high school and university students or trainees to acquire new professional skills and enhance their job performance. Brief descriptions of two e-learning modules will provide the frame of the current paper. The first one is an interactive animated material with virtual experiment in the field of "Solar Powered Electric Vehicles". To help looking into the main features of the modules some animated screens designed and realized are presented. As no animation is possible on paper here only their operation is described in addition to the content of the screen. The second part of the paper introduces a module titled "Luminous Efficacy of Modern Ligh Sources" with remote laboratory experiment. The background of the experiment and the layout of the test are presented.

2. OPERATION AND THE LAYOUT OF THE MODULES

The learning modules will be offered in an up to date web based learning portal. A screen shot of the portal presenting a general guide for the users can be seen in Fig.1. The interaction with the portal is very simple. It contains a number of functions: the learning path shown on the left side (Index) which leads the user to the desired acquisition of knowledge, in the fastest possible way. The user can also simply jump to the topic of his interest. The top left navigator offers a variety of useful tools such as work progress display for control purposes or notes for additional annotations. In the bottom of the page the reader can enter his comments and save them.

The development of a similar learning portal is presented in [4] in more details.

Layout of each page is the same: following the title the detailed description of the given subtopic is described. It can be used used like a textbook. The animated screens (see later) to help better understanding are embedded in the text. These screens include relatively few information helping fast comprehension. Here large capital letters are applied and plenty of animations. In some cases interactive simulators are also included for better comprehension. They are mathematical and drawing engines solving the equations and drawing the results on-line. In the case of the learning module designed for remote laboratory experiment, the page transfers and connects the reader to the remote laboratories.

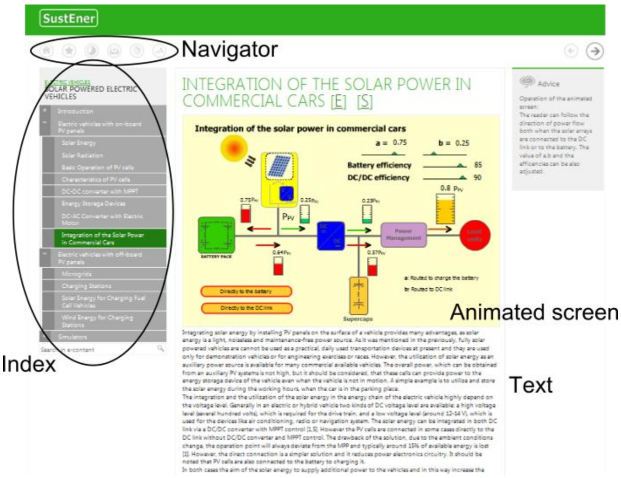


Fig. 1. Screenshot of the learning portal

3. OVERVIEW OF THE MODULE SOLAR POWERED ELECTRIC VEHICLES

3.1. Introduction

Solar energy, irradiation and heat from the sun, has been harnessed by humans since ancient times using a range of ever evolving technologies. Solar energy technologies including solar heating, solar photovoltaic, solar thermal electricity and solar architecture offer promising solutions to solving some of the current problems of power generation the world now faces.

The recent development in the car industry has resulted in vehicles with hybrid and full electric drives. It can be expected that in the future when their application will be wide spread, they will require high level of electric power. In the module, some problems and solutions are introduced for solar powered electric vehicles (EV).

One of the possibilities for utilizing solar energy could be to install PV panels on-board of the vehicle together with batteries for storing electric energy [8,9]. Applying PV panels for harvesting solar energy offers some benefits, as the production of solar energy is noiseless, the panels have low weight and they are ”maintenance-free”. Disadvantage of the solution is that the solar energy is not available continuously therefore energy storage devices are necessary and as both the PV panels and the batteries are expensive, the cost of the solar powered EVs is high. Fully solar powered vehicles cannot be used as practical, every day transportation devices. At present they are used only for demonstration vehicles or for engineering exercises or races. A much more practical approach for the utilization of solar energy in EVs is when the energy is produced off-board by renewable energy systems and this energy is collected by the vehicles via grids or micro-grids and stored on-board.

3.2. Structure of the module

The module has four main chapters. In the first three chapters the theoretical background is described briefly, while in the last part interactive simulators (see later) help better understanding of the theoretical part.

In the Introduction the required background to understand other parts of the module is given. It embraces an overview with up-to-date statistic data about possible renewable energy resources focusing mainly on the solar power. Next the differences between internal combustion engine (ICE) vehicles, hybrid and EV are treated briefly. The chapter presents also the history of solar powered EVs from the beginning of 20th century to date. Many facts, figures and the current trends concerning EV will also be given. Finally, a detailed SWOT analysis of the solar powered EV is presented to show that the utilization of solar energy in automobiles can be a viable, cost-effective solution.

The second chapter discusses the concept and the technical background of mounting PV panels on the chassis of an EV. In the first part of the chapter the basic principles of the solar powered EV, namely the solar electric energy generation, the solution of the energy storage and the drive system are summarized. In the second part the state of the art is given about the current trends in the solar energy utilization and integration into commercially available cars.

In the third chapter the charging stations for EV utilizing solar and renewable energy are presented. It explains the concept of the local (stand alone and grid-connected) micrograds and the architecture of a solar powered charging stations with practical examples. This chapter deals also briefly with vehicles applying fuel-cells. Here the solar energy can be used to produce hydrogen utilized as fuel in fuel cell vehicles. As the winds are caused by unequal heating of the atmosphere by the sun, wind energy is a form of solar energy. In this sense the last part of the chapter discusses the usage and the integration of wind energy in charging stations.

The fourth part of the module has interactive complex simulators for better comprehension.

The learning module was developed using Adobe Flash software.

3.3. Example for animated screen and simulator

The solar radiation that reaches the upper atmosphere is approximately 174 petawatts average power yearly. The way of how the incoming solar radiation is distributed is shown by an animated drawing in Fig. 2, where the ratio of absorbed, reflected and transmitted energy is visualised.

The amount and intensity of solar radiation reaching the Earth’s surface depends on the geometric relationship of the Earth with respect to the Sun. Thus the location plays a key role in the utilization of solar energy. The interactive slide presented in Fig.3 calculates the amount of daily solar radiation that can be harvested by the photovoltaic (PV) panel depending on the calendar date of the year, the latitude angle of the place and the tilting angle of the panel. For simplicity the latitude angle of few cities are predefined, which can be selected from a drop-down list.

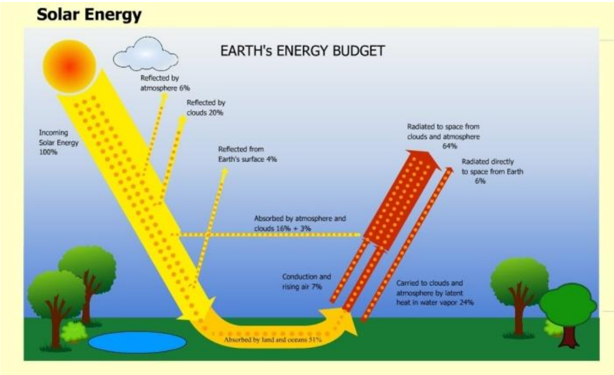


Fig. 2. Screenshot of the animation of Earth's energy budget

The maximum solar energy collection is achieved when the Sun rays are perpendicular to the collecting area. The user can also set the tilting and orientation angle of the photovoltaic (PV) panel to study their effects.

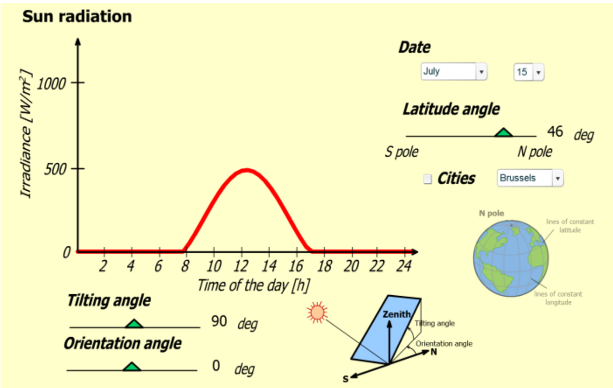


Fig. 3. Screenshot of the interactive screen calculation the daily solar radiation

In photovoltaic power generation the photovoltaic cells are the basic components. They are usually connected both in series and in parallel to get reasonable power level for consumers. Generally, most of them are made of silicon even though other materials can also be used. The PV cell is basically a p-n junction which is made from two different layers of silicon doped with a small quantity of impurity atoms. If the two layers are joined together p-n junction is resulted. The screenshot of the animated screen explaining the operation of the PV cell is shown in Fig.4.

In case of EVs that are equipped with on-board PV panels the maximum power should be extracted to gain as much power as it possible for the drive system. Since the solar cells have non-linear characteristics and their characteristics vary with radiation and temperature, the generated power depends strongly on the working point (WP). By changing OP, we can find an OP. where the maximum power is produced. Usually an intermittent element, DC/DC converter is inserted between the PV panels and the load ensuring that the PV panel is always operated at Maximum Power Point (MPP).

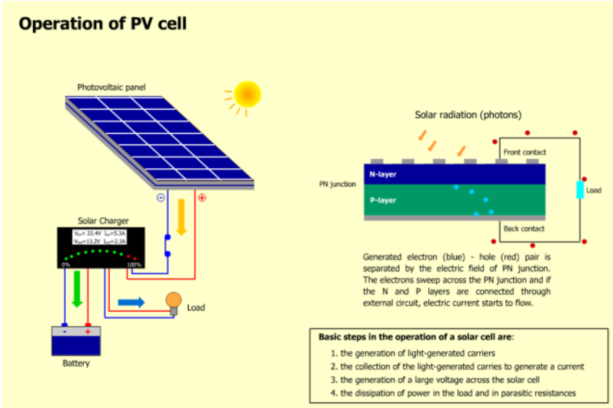


Fig. 4. Screenshot of the animated screen explaining the operation of the PV cells

A seeking algorithm is implemented in the control unit of the DC/DC converter to follow the MPP by controlling the DC/DC converter to find the appropriate voltage level of the solar panels.
Maximum Power Point Tracking (MPPT) algorithms are necessary in PV application because the MPP of a solar panel varies greatly with temperature, thus the use of MPPT algorithms is required in order to obtain the maximum power from a PV to be stored in batteries or other energy storage devices of EVs. In the last decades numerous methods of MPPT algorithms have been developed for many applications. The MPPT techniques differ in many aspects such as cost, effectiveness, complexity, hardware, required sensors, etc. Here the basic principle of operation of the MPPT is demonstrated using the animated drawing in Fig.5.

In the animation the Perturb and Observe algorithm (P&O) as one of the most widely used MPPT algorithm is demonstrated.

In Fig. 5 an on-board charging system of EVs is also shown utilizing the power of PV cells mounted on the EV. The power flow between the elements is shown by moving dots.

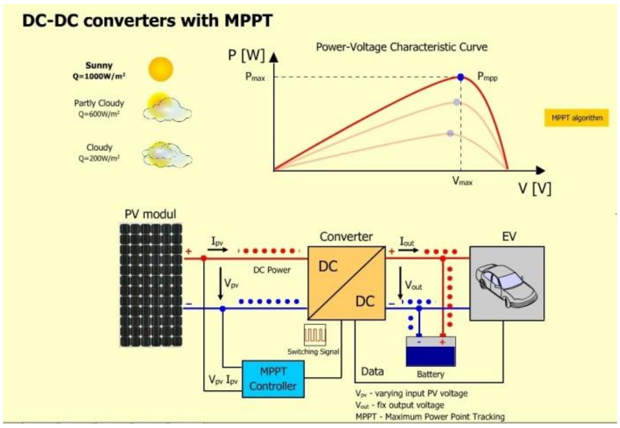
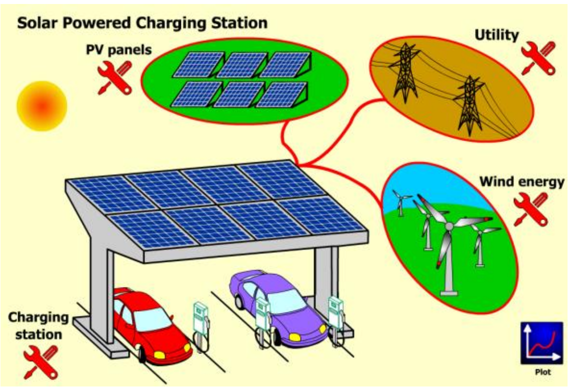


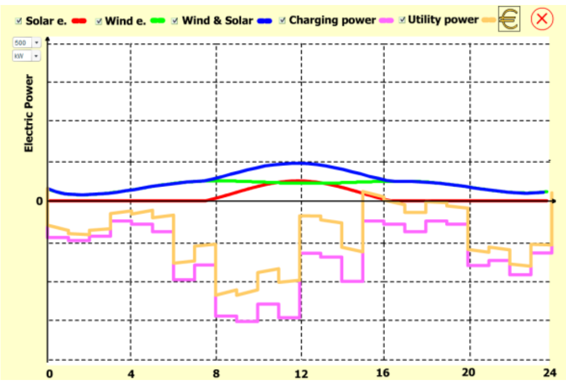
Fig. 5. Screenshot of the interactive animation of DC/DC converter and MPPT algorithm

An interactive simulator is developed for the analysis of the behaviour of a charging station by investigating the time functions of the generated electric power of the given units.

The charging station is supplied by wind park, PV panels and it is connected to the utility network as well. Large number of parameters of the charging station can be varied by the user clicking on the Settings buttons (Fig.6a). In the case of wind park the reader can enter the main parameters of the wind turbine (like blade diameter, wind velocity etc.) and the number of towers. The reader can select different daily wind profiles. The efficiency of the power electronic converter can also be adjusted. In the case of the PV cell the daily sun radiation curve are calculated from the location and the date. The weather condition can be also set. The reader can select the type of PV cell (from first generation single-crystal silicon to the third generation Multi-junction type) and the number and dimensions of the PV cells. In the Settings of the utility the reader can enter the price of the electric energy. This value will be used to analyse the effect of the additional renewable sources on the expenses. In the settings of the charging station the reader can adjust the number of EVs over a day, which should be charged at the station. The charging station can provide fast (AC and DC) and normal (AC level 1 and level 2) charging. By clicking on the ”Plot” button in the lower right side of the slide the simulation starts and the time functions of the power distribution between the sources and the load are plotted (Fig.6b). Their scale can also be adjusted. By rolling-over the € sign, the daily cost is calculated.



a) Main screen



b) Pop-up window for plotting the results

Fig. 6. Screenshot of the interactive simulator of a solar powered charging station

Fig. 7. Screenshot of the animation of a typical microgrid configuration

A typical microgrid configuration is shown in Fig. 7 consisting of electrical and micro sources connected through a LV/HV distribution network. In the last years a new type of load has appeared: the electric vehicles that require electric power as their prime mover is electric motor. The micro sources have plug-and-play features as far as control, metering as well as protection functions are concerned and furthermore they are mostly capable both for stand-alone and grid-connected modes of operation.

Different elements of a microgrid (energy storage elements, PV plants, micro turbines, photovoltaic EV charging stations…) are shown in the animation slide helping to understand and imagine the essence of microgrids. The power and communication flow between elements will be represented by moving arrows and dots. The elements can be highlighted by moving the arrow above them.

4. OVERVIEW OF THE MODULE LUMINOUS EFFICACY OF MODERN LIGHT SOURCES

4.1. Introduction

In the everyday life, lighting is one of the most energy intensive human activities. We use different light sources to illuminate our cities, buildings and homes, thus we use a lot of energy for this purpose. When there is no natural light source available, we need to make it up to create visually comfortable environment. The applications of energy-efficient, modern lighting technologies are becoming more important. In the case of a light source, there are two dominant economical characteristics: lifetime and efficacy. Efficacy shows that how many lumens (visible light or luminous flux) can be produced by 1 W of electric power. So it can directly characterise the rate of the energy saving.

The aim of the learning module is to acquire knowledge required to determine the luminous efficacy, and to make online measurements using an incandescent lamp and a LED light source. To introduce the energy efficiency of LED sources, compared to the traditional ones, we implement a comparative measurement between a modern LED and a classical incandescent lamp. During this measurement the luminous flux and the power input of both sources could be measured at the same time interactively, and the energy saving advantages of the LEDs could be shown easily.

4.2. Measurement Configuration

In our measurements, we implement a direct method to compare the luminous efficacy of an incandescent source against a modern LED emitting white light with the same colour temperature. To do so, we carefully selected two comparable sources from the mentioned types, and put them into two integrating spheres with appropriate size.

The formation of the spheres follows the most common measuring method. The sources take place at the centre of the spheres, and there is also one detector per sphere to measure the illumination value in a general point of the sphere wall.

The detectors are calibrated photo diodes covered with a baffle shield against direct illumination from the sources. The sphere walls are painted with diffuse white coating, to produce even illumination on the wall, independently from the illumination distribution of the LED and the incandescent bulb (Fig. 8). With this test configuration the calculation and comparison of the luminous efficacy of the measured illumination values became possible.

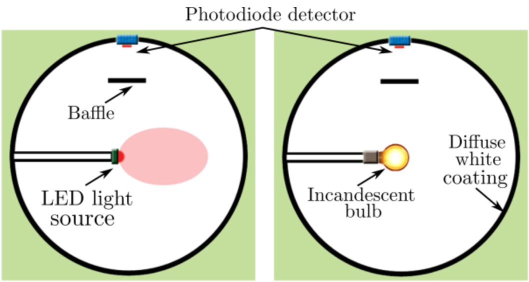


Fig. 8. Illuminance test of LED and incandescent lamp using integrating spheres

The aim of the remote laboratory is to provide comparative tests with luminous flux and electric power between the light sources. During the tests using a GUI, both of the luminous flux of the sources can be measured at the same time interactively and the energy saving advantages of the LEDs could be shown easily. Figure 9 shows the configuration of the test..

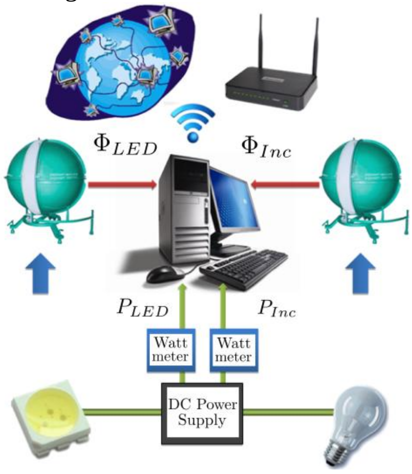


Fig. 9. Complete configuration of the test

5. CONCLUSIONS

Utilizing a wide range of advanced e-learning tools two e-learning modules are presented in the field of sustainable engineering within the framework of the Leonardo da Vinci program. The current paper gives a brief account on two e-learning modules developed in the field of Solar Powered Electric Vehicles and Modern Light Sources. We believe that both the animated e-learning material and the remote experiment presented are efficient tools in helping students and users to get acquainted with complex systems and ideas connected with the fields of Sustainable World..

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