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Animated e-learning Material for Solar Powered Electric Vehicles

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***Abstract*—The paper concentrates on the topic given in the title by using the e-learning technique, utilizing new possibilities of the electronic multimedia, widening the borders of communication in the elaboration, delivery and dissemination of knowledge. 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 one of the modules titled Solar Powered Electric Vehicles are described in some detail.**

I. 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 six Universities from six member countries is aimed at modernizing Sustainable electric energy vocational training by enhancing existing or establishing new training methods for enterprises and education [1]-[17].

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 Vehicle
8) Power Control and Energy Management in DC microgrids
9) Luminous efficacy of modern light sources

The different modules with remote experiments and/or interactive animation materials will be offered in an up today web based learning portal, which available at the address: 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.

II. Overview of the Module "Solar Powered Electric Vehicles"

Brief description of one of the e-learning modules titled Solar Powered Electric Vehicle provides the frame of the current paper. To help looking into the main features of the whole module some animated screen we have designed and worked out are presented. As no animation is possible on paper here only its operation is described in addition to the content of the screen.

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 photovoltaics, 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 car industry has resulted in hybrid and full electric driven vehicles [19], [20], [21], [22]. They require large quantity electric power in future. In the module, some problems and solutions are introduced for solar powered electric vehicles (EV).

One of the theoretical possibilities for utilizing solar energy could be to install PV panels on-board for the vehicle together with batteries to store electric energy. 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.

The solar energy is utilized for supplying auxiliary equipment (like fan or air-conditioning drives [23]) in many commercially available vehicles. The overall power demand of the auxiliary equipment is not significant, but it is remarkable that the PV cells can charge the energy storage device even if the vehicle is parking. A possible example to illustrate the utilization of the solar energy in EVs used by commuters, when the car covers relatively short distances daily and stays 8-9 hours in the open parking lot. 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.

In summary none of the authors of this module think that in the near future hybrid or electric vehicles will be in mass production supplied exclusively by on-board solar cells. Of course the energy supplied for some auxiliary parts (air conditioner etc.) can be drawn from on-board solar cells and in this way it can increase the cruising range of the car. On the other hand, significant amount of the energy required by hybrid or electric cars could be produced by renewable energy sources and collected by the vehicles off-board from grids or micro-grids. This second utilization of solar energy gives the practical significance of the module entitled Solar powered electric vehicles.

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 chapter the required background to understand the 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. After the differences between internal combustion engine (ICE) vehicles, hybrid and EV will be treated briefly. This first chapter presents also the history of solar powered EVs from the beginning of 20th century to nowadays. Many facts, figures and the current trends concerning EV will be also given. Finally a detailed SWOT analysis of the solar powered EV is presented to show why the utilization of solar energy in automobile industry can be a cost-effective solution.

The second chapter discusses the concept and the technical background of mounting PV panels on the chassis body 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 in 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) microgrids and the architecture of a solar powered charging station with practical examples. This chapter deals briefly with fuel-cell vehicles also. 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. Later on a more detailed explanation of the operation of one of the simulators will be given.

The animated module was made with the help of Adobe Flash Professional CS6 computer software.

III. Operation and the Layout of the Modules

As it was mentioned the multimedia material will be offered in an up today web based learning portal. A screen shot of the portal explaining the operation of the modules 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 lead the user to the desired accumulation of knowledge, the fastest possible way. The user can also just 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, notes for additional annotations and question for the mentor to ask random questions. 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 [18] in more details.

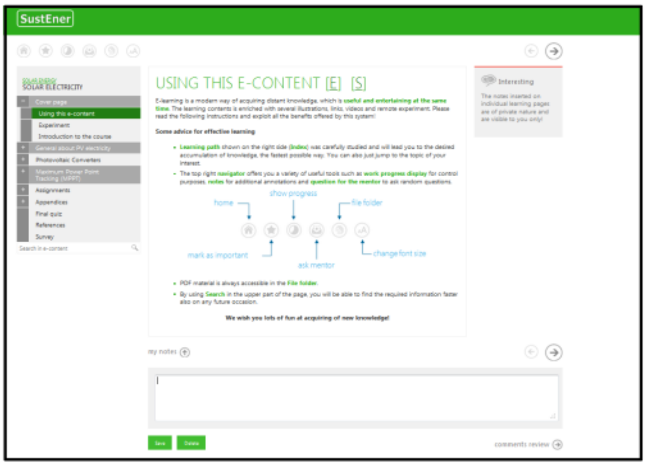


Fig. 1. Screenshot of learning portal

Layout of each page is the same: after the title the detailed description of the given subtopic is described. It can be used similarly to a Text book. The animated screens (see later) to help the better understanding are embedded in the text. These screens include relatively few information helping fast comprehension. They apply big capital letters and plenty of animations. In some cases for better comprehension interactive simulators are also included. They are mathematical and drawing engines by solving the equations and drawing the results on-line. In the case of the learning module with virtual experiment, the page transfer and connect the reader to the remote laboratories.

IV. Animated Slides

In this section a few animated slides are presented briefly.

The solar energy can be used in current commercial vehicles as an auxiliary power source or as the main power source it it is collected on ground and not on board. Generally these vehicles are hybrid vehicles, so they have internal combustion engine beside the electric motor. In the case of the hybrid cars four different groups can be distinguished, like the micro, mild, serial and parallel hybrid. The animated slide presented in Fig.2 explains the main difference between the different types of hybrid cars. The different constructions can be obtained by clicking on the button in the upper side of the page. The drive and the electric power flow in the different construction are indicated by blinking arrows and blocks.

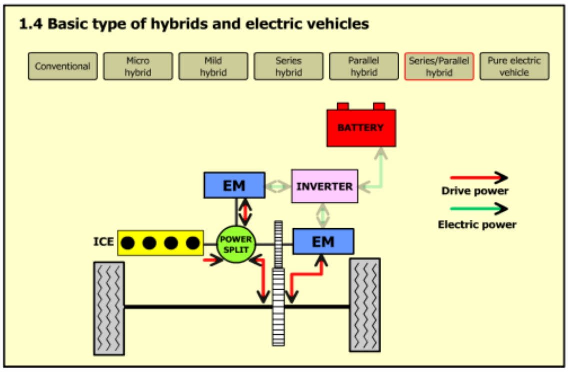


Fig. 2. Screenshot of the animated page explaining the main difference between the different types of hybrid cars

The solar radiation that reaches the upper atmosphere is approximated 174 petawatts average power yearly. The amount and intensity of solar radiation reaching the Earths surface depends on the geometric relationship of the Earth with respect to the Sun. Thus location plays a key role in the utilization of solar energy. The interactive slide presented in Fig.3 calculates the theoretic daily solar radiation which reach the surface of the photovoltaic (PV) panel. The inputs are the day of the year and the latitude angle. For simplicity the latitude angle of few cities are predefined, which can be selected from a drop-down list. 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.

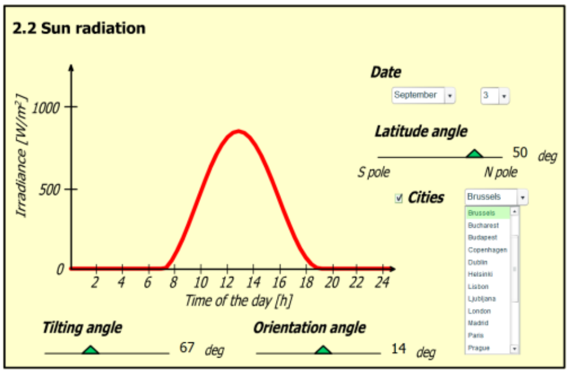
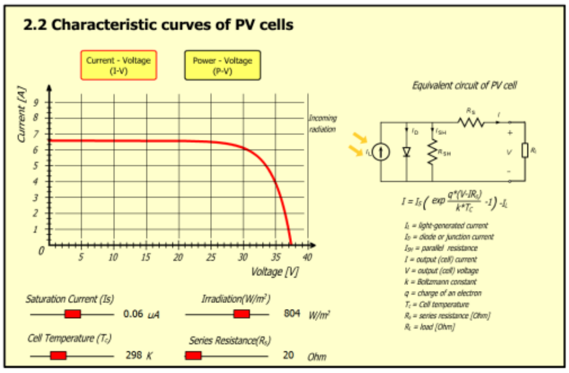
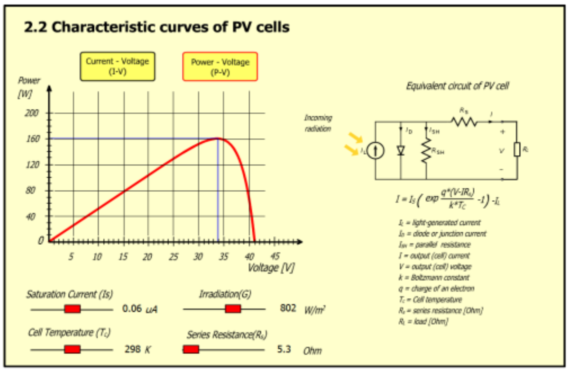


Fig. 3. Screenshot of the interactive screen calcualtion the daily solar radiation

In photovoltaic power generation the PV 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 from silicon even though other materials can also be used. The basic operating principle of PV cells is quite similar to diodes but here, the electron-hole pairs are generated externally. The PV cells can be characterized by the Voltage Current (V-I) characteristic curves and represented by an electrical one diode model. The interactive slide presented in Fig.4(a) and 4(b) plots the Current-Voltage or Power-Voltage characteristic curves, respectively. The user may change many parameters, like irradiation or cell temperature, which influences the characteristics.



(a) Current-Voltage

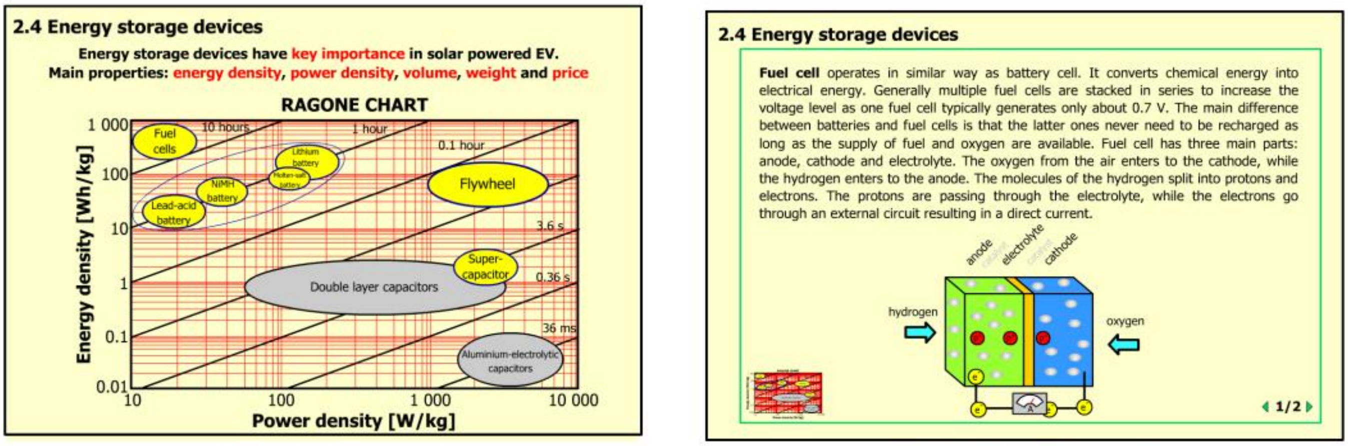


(b) Power-Voltage

Fig. 4. Screenshot of the interactive screen which calculates the characteristic curve of a PV cell

Energy storage devices have a role of paramount importance in a solar powered EV since they store the energy received from the PV cells via DC/DC converters or from external power sources (like charging station) utilizing the energy harvested at least partially from the sun. The energy density, power density, volume and weight are the most important characteristics of a storage device, not to mention the price. In most cases batteries are used to store energy in EV, but the animated screen introduces other promising storage devices, like the supercapacitor, the fuel cell and the flywheel. Figure 5(a) shows the animated screen. By clicking on the different energy storage devices shown on the Ragone chart, the detailed animated description and the theoretical background pop-up for the given device (e.g. fuel cell see Fig.5(b))

Wind energy is a form of solar energy as the winds are caused by unequal heating of the atmosphere by the sun. The wind energy is proportional to the cubic of the wind speed, which means that, the integration of the wind energy into the electricity is efficient only at greater wind speeds. Another drawback of the wind energy comparing to the solar energy is that, it is not easy to install wind turbine at any location (e.g. in big cities). However, the wind energy has a bright future, the installed wind power capacity, like the solar power capacity, increases exponentially. In 2011 this value was around 250 GW according to the Global Wind Energy Council. In August of 2012 the first fully wind source powered electric vehicle charging station is installed in Barcelona. The interactive slide



(a) Interactive Ragone chart

(b) Description of Fuel cell

Fig. 5. Screenshot of the animated slide explaining the different energy storage devices used for EV

presented in Fig.6 calculates the output power of a wind turbine under different circumstances. The user may change many parameters, like the geometric data of the wind turbine (height, radius, pitch angle), the wind speed and the rotation speed of the turbine.

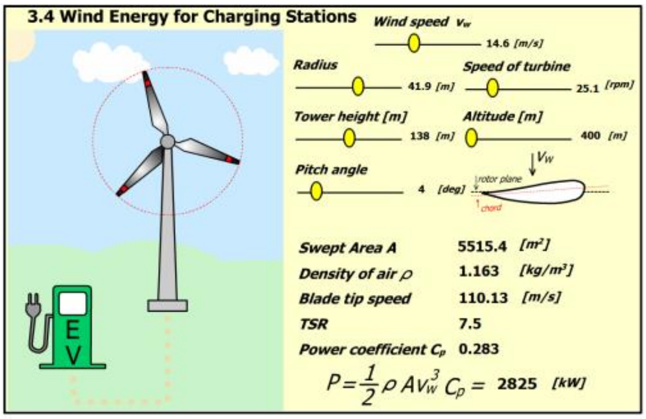


Fig. 6. Screenshot of the interactive screen explaining the utilization of wind energy for charging station

V. Simulators

As it was mentioned previously complex equation solver simulators are developed for helping the better understanding the operation of solar powered EVs. For example interactive simulator is developed to analyze the behaviour of a DC charging station supplied by renewables by investigating the time functions of the generated electric power of the given units (Fig.7(a)). The charging station is supplied by wind park, PV cells and it is connected to the utility network as well. Two kinds of charging methods can be simulated, normal and fast charging. The normal charging approximately takes 6-8 hours to charge up the batteries of the electric vehicle, while the fast charging takes only 10 minutes.

Large number of parameters of the charging station can be varied by the user clicking on the Settings buttons. In the case of the wind park the reader can enter the main parameters of the wind turbine (like blade diameter, wind velocity etc.) and the number of turbines. The reader can select different daily wind profiles. The efficiency of the power electronic converter can be also 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 time generation single-crystal silicon to the third generation Multi-junction type) and the number and dimensions of the PV cells (Fig.7(b)). 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.

As it was mentioned the charging system can provide both fast and normal charging. For simplicity 5 cars can be simulated daily for the fast charging, and 10 cars for the normal charging. By clicking on the "Settings" button, the user can adjust the starting time of the charging for each car, the initial State of Charge (SOC) of the batteries and the nominal electrical power of the vehicles.

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.7(c)). In Fig.7(c) the charging power is constant.

VI. Conclusion

The final paper will give a brief account on the e-learning module developed in the field of Solar Powered Electric Vehicles within the framework of the Leonardo da Vinci program of the European Union. It will discuss the programming tools used during the implementation and will present more animated screens and simulators as well as their concise descriptions. Separate papers will discuss the other e-learning modules within the obligation of the dissemination requirement of the EU project.

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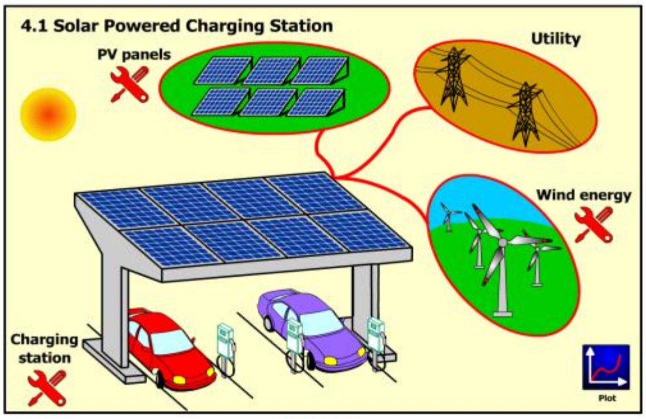
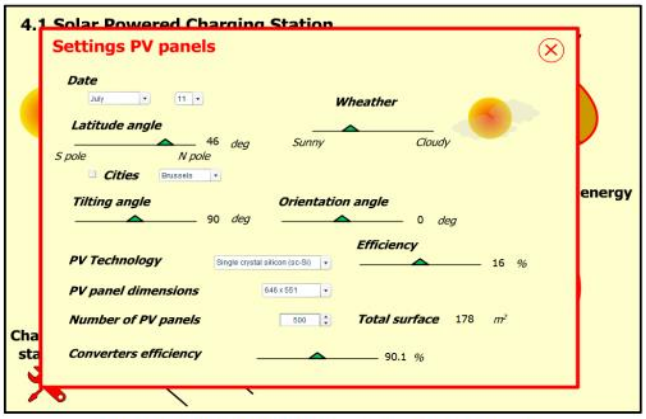
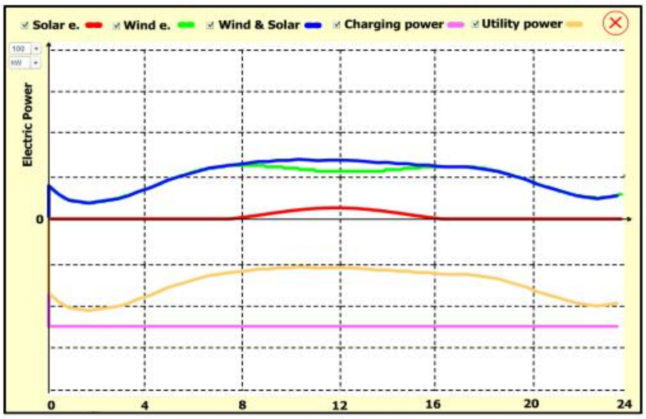


(a) Main screen



(b) Pop-up window for the setting of the PV panel



(c) Time functions of the power distribution between the sources and the load

Fig. 7. Screenshot of the interactive simulator of a solar powered charging station

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