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Photovoltaic system in education

Michaela Juráčková , Jan Krotký , Daniel Aichinger

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Juráčková Michaela[1], Krotký Jan[2], Aichinger Daniel[2]
jurackom@students.zcu.cz, conor@kmt.zcu.cz, dann@kmt.zcu.cz
[1,2,3] University of West Bohemia, Faculty of Education, Czech Republic

Summary

For my thesis, I chose the topic Photovoltaic system, its parameters and measurements. I have chosen this topic because of its topicality, since nowadays the attention is turning mainly to renewable energy sources, which have the task of less burden on the environment. Renewable energy sources represent comparatively less dependence and more saving for the environment. There are several alternative sources on the market now, one of them is the photovoltaic system. With photovoltaics, the sun's radiation is converted into electricity.

Keywords: Solar panel, photovoltaic power plant, solar cell, electricity, solar radiation, recycling

Introduction

The thesis is focused on photovoltaic systems. I have chosen this topic because of its topicality since recently more demands have been placed on the form of electricity generation in terms of environmental impact. The first part, it's focused on the generational development of photovoltaic cells and their production. The environmental impact and subsequent recycling. There is also a comparison of photovoltaic energy in the Czech Republic and the world and the current subsidy programme for the Czech Republic. In the practical part, I take measurements on a photovoltaic panel, where are investigate the current and voltage values when the panel is tilted behind the sun at a certain angle.

Photovoltaic panel

The panel needs a stable and durable support that supports the PV modules and tilts the panels towards the sun. Such a structure is forced to protect the panels from external influences such as wind, rain or humidity. The systems are usually made of aluminum. An essential component of a photovoltaic system is the inverter, which converts DC electricity into AC electricity.

Storage systems are batteries that are essential for energy storage, especially for PV plant owners who do not have easy access to the electricity grid due to poor geographic location or high grid connection costs.

Other components are cables, connectors and supports. The combiner is an essential part of the system that allows us to connect multiple solar modules in parallel. (altestore.com, 2022)

Recycling

Solar panel recycling is mandatory for solar power plant owners and panel importers. Panels can be recycled; they are mainly made of silicon modules (98%).

In the case of crystalline modules, the largest weight is glass (70%) and the aluminum frame (20%). Processing technologies can recover up to 100% of the weight for aluminum and 95% of the weight for glass. In addition, silver, indium, copper is found in the panel; these

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elements are not a problem for recycling. The rest of the panel is plastic, which can be recycled without major problems. The other two percent of solar power plants in the Czech Republic are made up of thin-film panels, which may contain cadmium, a dangerous element. This element is in the panel in the form of a compound, but even if the module is damaged, it cannot enter the biological chain. The manufacturers of thin-film panels guarantee free take-back and subsequent recycling. No hazardous waste remains that we are unable to process.

Finance for recycling

A CTU study confirms the benefits of recycling end-of-life panels. The cost of recycling is paid when silver or copper is recovered. Rare elements are thus an advantage. From PV panels, glass or plastic can be used for building materials.

Recycling obligation

There are currently power plants in the Czech Republic that are in the first third of their useful life. There is no need to replace them yet. Manufacturers guarantee a lifetime of 25 years, but experts estimate 40 to 50 years. The key motivation for recycling is that the recycling process is economically worthwhile. Manufacturers or importers are legally obliged to ensure recycling. But if someone already has a solar power plant at home that was commissioned by the end of 2012, the owner is obliged to pay for recycling.

Recycling companies

In the Czech Republic there are collective systems for the take-back of electrical equipment, which are authorized by the Ministry of the Environment. There are approximately ten of them on the market exclusively for solar panels. For example, REsolar, which was founded by the Solar Association, the latter ensures compliance with legal obligations for more than 2,500 operators. The number of discarded panels will increase and so will the interest of processing facilities in this business. So far, due to the long lifetime of the panels, there is not such an interest yet in this type of business. (solarniasociace.cz, 2021).

Manufacturers

Canadian Solar

A company that was founded in Canada in 2001. In the last 18 years, it has shipped over 38 GW of modules worldwide. It now supplies to over 150 countries worldwide. It offers very efficient solar energy solutions to its customers.

LONGI

LONGi has bet on monocrystalline technology. It has been on the market since 2000. It supplies more than 30 GW of efficient modules worldwide. This represents a quarter of the global demand. The company's core values are sustainable development and innovation. The company is considered the most valuable company in solar technology and has the highest market value.

Ja Solar

The company was founded in 2005 and it produces not only complete photovoltaic systems but also silicon wafers, cells, or modules. The products are distributed to 135 countries

worldwide. Due to a very well-established sales and service network, the company is recognized as a global manufacturer of high-performance photovoltaic products.

Trina Solar

Gao Jifan founded Trina Solar in 1997. As the company was one of the first contributors to solar energy systems it helped a lot to global research and improvement in the field of solar energy. The world leader from China reached its milestone in 2020 when the products were listed on the Shanghai Stock Exchange. (nanosun.com, 2022)

Experimental setup

The measurements were carried out at an outdoor temperature of 30° Celsius at 15:00. The panel temperature was 50° Celsius. A skewer was used for the measurement which was attached to the panel using a hot melt gun. It was then inserted into a small auxiliary prism. This skewer was used as a shield to show us the angle at which the sun's rays were hitting the panel and therefore the angle at which the panel was tilted. In the picture we can also see the shadow cast by this skewer on the panel. See the attached photograph.

Figure 1. Panel with a wood skewer, own source

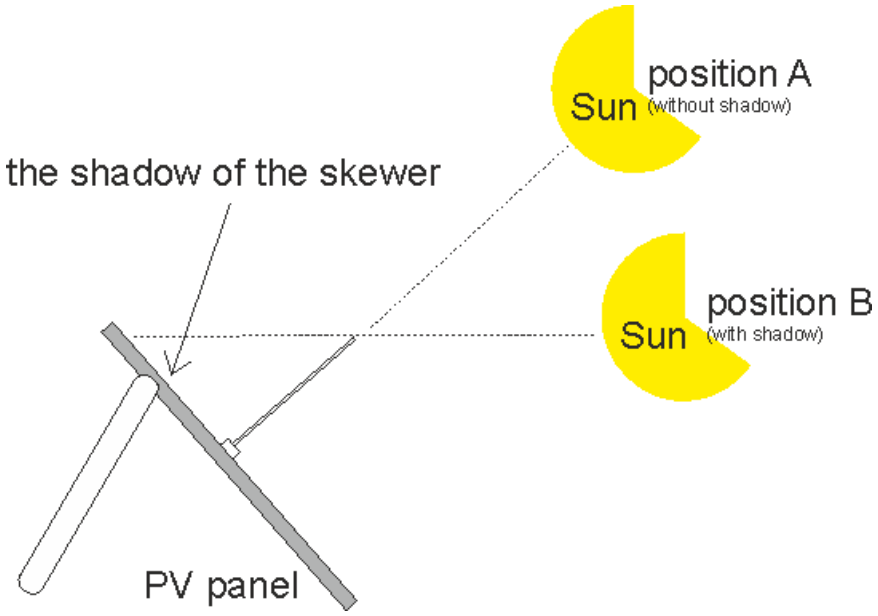

Figure 2. Angle of incidence, own source

Table 1. Measurements for panel width, own processing according to measured values

Voltage U / V	Current I / A	Angle φ / °
37,7	10,4	90°
37,3	10,33	78° 45'
37,2	10,17	72° 20'
37,18	9,8	66° 20'
37,1	9,45	60° 50'
36,97	9	55° 53'
36,7	8,6	51° 27'
36,65	8,17	47° 30'
36,61	7,7	43° 59'
36,6	7,37	40° 52'
36,58	7	38° 6'
36,5	6,5	35° 38'
36,4	6	33° 26'
36,2	5,8	31° 21'
35,8	5,3	29° 42'
35,7	4	28° 5'

Table 2. Measurement for panel in portrait, own processing according to measured values

Voltage U / V	Current I / A	Angle φ / °
37,15	10,42	90°
37,06	10,08	71° 16'
36,9	9,07	56° 40'
36,5	7,77	45° 41'
36,3	6,8	37° 40'
36,1	5,6	31° 46'

It can be said that the position of the panel in the horizontal position is optimal for both voltage and current. The measurement results show that the vertical position results in lower measurement values. If the panel is in a position perpendicular to the sun, which can be in relation with the fixed mounting angle of the panels around one hour per day, we achieve the highest values. In the horizontal position, this is 37.7 V and 10.4 A. Compared to the vertical position, it is 37.15 V and 10.42 A.

The measurements can be likewise used in the educational process. Using a skewer, a solar panel and other elements which were already mentioned, this measurement can be performed on a test panel and in technical education classes. There is no need to wait the whole day for the Sun to move in the sky (change of the angle of incidence), but you can speed up the measurement by tilting the panel and get the results faster. This experiment does not take more than an hour of direct measurements with the students. Another lesson can be devoted to analyzing and processing the results and drawing conclusions.

Apart from comparing the parameters obtained with panels of different manufacturers, different technologies (monocrystalline versus polycrystalline), the photovoltaic topic does not give us many other possibilities for further measurements realizable in a school (amateur) environment.

An interesting possibility may be to compare the energy gain between a PV system and a hot water system, under comparable outdoor conditions. This would show the characteristics of the two systems, including a decrease in the performance of the PV system as the panel temperature increases (demonstrated by our measurements) and conversely an increase in the performance of the hot water system under the same conditions.

The advantage of measurements on real PV panels is the authenticity of the electrical phenomena. For example, disconnecting the circuit of the panel measured briefly produces an intense electrical arc, which is an ideal stimulus for the topic of occupational safety, switching of DC and AC electrical circuits and regulation.

An interesting alternative to demonstrate the functions of PV panels and the efficiency of PV systems is to use some of the didactic aids sold that are tailored specifically for working with children. They usually have a very weak PV panel and a consumer of the energy produced in the form of a motor, electronic circuit or light element.

Didactic aids

Fishertechnik

It is a German manufacturer of kits that can also serve as teaching aids. An example is the Solar: beginner kit. This kit is an ideal demonstration of the use of solar energy. With the help of solar panel power generation, we can power solar-powered cars and boats.

The solar module that is used for this kit consists of four solar cells that are connected in series. The voltage supplied is 2 V and the maximum current is 200 mA.

A detailed manual is included which contains tutorials, problems and their solutions. Instructions for conducting the experiments are also included. For example, I was intrigued by the experiment to find out what type of light energy will make the motor run and how much of that light is needed. Also included is a table with the light sources we are to test such as: incandescent bulb, led bulb, energy saving bulb, halogen spotlight, sun. (fishertechnik.de, 2022)

The experiment I tried on a solar-powered boat is based on the principle of how long it takes to travel a distance of 1 meter in sunlight with a solar panel partially shaded. The boat covered the measured distance of 6 metres in 54 seconds in full sunlight at 2pm. In partial shading, it then covered that distance in 1 minute and 15 seconds.

If we want to find out what speed the ship is moving in kilometres per hour, we proceed as follows.

6 metres/54 seconds = 0.1111 m/s

0.1111 * 3.6 = 0.399 km/h

To check the result we can perform a test. The finding is as follows, the ship is moving at 0.4 km/h.

Horizont science education

This is a scientific kit for renewable energy that was developed in the United States of America. This didactic tool demonstrates how energy technology works on a small scale. For example, we can generate electricity for a circuit using a solar panel or a wind turbine. The kit is a comprehensive introduction to the principles of micro grids. This kit also includes material for up to 10 lessons focusing on renewable energy. You will find experiments such as using a solar panel to power an LED module or powering a wheel motor using solar energy.

Boffin 750

The Boffin 750 electronic building set is a creative building set that develops students' technical thinking. According to the included instructions, it is possible to build several hundred projects or invent your own project. The colour-coded parts can be combined with each other. Everything is compatible with other Boffin kits. The basic building block of each project is the board, on which the individual components are attached. In the instructions there are instructions for assembling the project and then evaluating whether the project works and what can be expected from it. It can also serve as a check that everything is working correctly. It is possible to build, for example, a compass, a lighthouse, a lie detector and various solar panel projects. The kit can also be connected to a computer. (iqhracky.cz, 2022)

There are several solar cell projects available. A project called "Types of Output" shows us different types of output from an electrical circuit. The value of the meter must be set to a very low value - LOW. Such a circuit uses all the forms of output of the building block, which are speaker (sound), bulb (light), LED (light), motor (motion), seven-segment display (light), and meter (movement of the needle).

Conclusions

In my work I dealt with the principle of conversion of light radiation into electrical energy. In the practical part, I was allowed to measure on a photovoltaic panel, which was available from Mgr. Jan Krotký Ph.D. The measurements were made with the panel in the landscape as well as portrait position. By the usage of a skewer attached to the panel and using a hot melt gun, the shadow of the incident sun rays was measured and then the tilt angle of the PV panel concerning the sun was calculated. The findings of this measurement show us that a panel built in landscape, as is already the case on the house in question, is more efficient than a panel built in portrait.

References

Elearning. fischertechnik. (n.d.). Retrieved from https://www.fischertechnik.de/en/service/elearning

Janouch, J. (2021). Porovnání a vyhodnocení multifunkčních didaktických stavebnic vhodných k výuce technických předmětů na základní škole. Retrieved from https://theses.cz/id/o61pmz/STAG94194.pdf

Libra, M., & Poulek, V. (2010). Fotovoltaika: Teorie I Praxe využití Solární Energie. Ilsa.

Murtinger, K., Beranovský Jiří, & Tomeš Milan. (2008). Fotovoltaika: Elektřina Ze Slunce. EkoWATT.

Nanosun: Solární Střídače a panely: Fotovoltaické Střídače. nanosun.cz. (n.d.). Retrieved from https://nanosun.cz/cs/index.html#our-products

Portadesign.cz. (n.d.). Cirkulární solární energetika: Co potřebujete vědět O recyklaci solárních panelů. Aktuality - Cirkulární solární energetika: Co potřebujete vědět o recyklaci solárních panelů - Solární asociace. Retrieved from https://www.solarniasociace.cz/cs/aktualne/21557-cirkularni-solarni-energetika--co-potrebujete-vedet-o-recyklaci-solarnich-panelu

Solar Panels, solar power systems, off-grid & DIY solar. altE. (n.d.). Retrieved from https://www.altestore.com/