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Photovoltaic Mobile Charging System Design (Solar Pole) - in Gümüşhanevi Campus of Gümüşhane University

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Abstract

The decrease in fossil-based resources, the pollution of the environment and the threat of sustainability constantly increase the interest in renewable energy sources. Solar energy is one of the leading renewable energy sources due to its large capacity. Today, solar energy appears in many applications. In this study, a photovoltaic-based solar pole design has been realized and a prototype that can be applied almost anywhere in open-air conditions has been produced. The prototype produced was tested and installed at Gümüşhane University's Gümüşhanevi Campus. The prototype mobile phones produced have a fast charging feature with 5V-2A. In future studies, it is planned to provide the solar tracking feature to the photovoltaic (PV) panel in the system, and it is aimed to bring such systems to the campus in general.

1. Introduction

Today, the use of solar energy has become possible in almost every area where energy is needed. Electricity generation from solar energy ranges from power levels of a few kW to hundreds of MW [1]. Apart from this, solar-powered bus stops, solar powered tents, solar-powered backpacks, solar-powered led lighting equipment, electric or hybrid vehicles equipped with solar panels and many similar small powerful applications are commercially applied today. Among these applications, solar-powered charging stations are very popular, solar charging stations, which usually only charge mobile phones, are very popular in the streets, city centers or bus stops, in non-closed environments where people wait and spend time.

There are many studies for solar energy applications. In [2], LED lighting and irrigation pumps, where electronic devices can be charged via USB, were supplied with a PV system isolated from the electricity grid. Different DC voltage levels were obtained from step-down and step-up converters in the system. Solar energy can be used for charging mobile phones in wearable applications such as arm bags. In such an application in [3], the efficiency problem arises because the solar cells on the bag are exposed to different radiations. In this study, five different converter configurations were tested according to the differential power processing strategy and the parallel DPP converters were determined as the most suitable converter. In another study, single-axis and double-axis solar tracking systems were proposed to make maximum use of the sun [4]. The solar panel can be used as an energy source in mobile robot applications. PV system design and implementation have been done for Mars rovers. The tracking of a 20W solar panel was provided with a single axis azimuth and elevation angle setting, and around 44% more power was obtained with this tracking [5]. For wireless sensor networks, PV systems can be a viable energy source solution. In [6], a system in which the current and voltage measurement of the battery and the load of the microcontroller-based PV system was

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proposed. PV energy can be used at charging stations for fast charging of electric vehicles. In [7], a model was developed in MATLAB Simulink for the design and sizing of solar charging stations. It is predicted that the proposed system acts as a mobile power system and electric vehicles can be charged at 80% capacity in 10.25 seconds. Three-wheeler vehicles are one of the most cost-effective options for short-distance transportation. In [8], an intelligent energy management system for PV-based charging station was proposed for such three-wheeled vehicles. Intelligent energy management performs energy management by using data such as PV data, user requirement and battery charge. A solution offering parking reservation via mobile application was proposed for these three wheeled taxi vehicles. In another study [9], a PV charging system that charges mobile phones with USB 3.0 technology with 5V - 2A values has been proposed. In a study [10], solar tree application was proposed for charging mobile phones in open urban areas. The solar tree consists of four leaves and a total solar panel power of 200W. Solar tree has six USB ports and two 110V-200W electrical outputs in total. In a different study [11], one-year data was examined to examine the performances of different types of solar panels. According to the results, it has been seen that Cd-Te type solar panels were less affected by temperature and perform better. The work on the prototype of the solar powered backpack was given in [12]. A study in which the performance analysis of solar power plants was examined and the performance data were analyzed over a sample power plant was presented in [13], and the performance ratio of the small power PV plant within Kocaeli University was 87.5% - 98.1%.

In this study, a single solar panel solar pole application for charging mobile phones was carried out at the Faculty of Engineering and Natural Sciences in Gümüşhane University Gümüşhanevi Campus. With the 42W solar panel and the energy stored in the 12V 9Ah lead acid battery, 5V-2A fast charging is provided thanks to two USB outputs. The number of USB outputs can be increased thanks to the modular structure. The study was carried out within the scope of the undergraduate thesis, and in the next section, the basis and general characteristics of solar energy are mentioned. Then, the solar energy potential for Gümüşhane province is given within the framework of basic information. In the fourth chapter, the mechanical and electrical details of the design are given and the results of the study are given in the last section.

2. Materials and Methods

Solar energy is one of the cleanest renewable energy sources on earth, without any gas emissions. Radiation energy is formed because of some chemical events that occur in the sun. Solar radiation can be converted into electrical energy with PV modules. Systems that use the energy from the sun to generate electricity are called PV systems. PV systems have many uses. Some of these are; roof-integrated systems, solar energy systems for lighting purposes, large-powered solar fields, auxiliary energy source in electric vehicles, mobile robots, mobile devices, calculators, backpacks and many wearable applications.

Among the listed PV applications, there are solar panels as a power source, a charge controller USB module for battery charging, a battery for storage, in the structure of systems where mobile devices can be charged. Examples of PV systems that allow charging mobile devices are given in Figure 1 and Figure 2. As can be seen in the examples, the solar panels are positioned at different angles in order to make the best use of the solar irradiation.

Figure 1. PV system example-1 [14].

Figure 2. PV system example-2 [14].

Solar energy systems are generally divided into two groups as grid-connected and off-grid systems. In grid-connected systems, the electricity produced is directly consumed or some of it is transferred to the grid. In systems that are not connected to the grid, the energy produced can be used instantly, or it can be stored in batteries and used for use when solar electricity is low.

2.1. Solar Energy Potential in Gümüşhane

Solar energy is one of the most common renewable energy sources on earth. Electrical energy and heat energy can be obtained from this type of energy. On the other hand, since the costs of PV panels are higher than fossil fuel-based production, only 0.04% of the solar energy coming to the earth is used by people.

Turkey is lucky compared to many countries in terms of its solar energy potential due to its geographical location and structure. According to the study made by using the data of sunshine duration and solar irradiation measured in 1966-1982 at the General Directorate of Meteorology Affairs, the average annual total sunshine duration of Turkey. It was determined that the duration of the study was 2.640 hours (7.2 hours in total per day), and the average total intensity of heating was 1.311 kWh/m² per year (total 3.6 kWh/m² per day). In Turkey, which has a high solar energy potential of 110 days, there is potential to produce an average of 1.100 kWh of solar energy per square meter per year if the necessary investments are made (Energy Sector Report, GEKA).

The sunshine duration (hour-year) of Gümüşhane province is 2.349. The radiation value (kWh/m^2-year) is between 1.400-1.600. The map in Figure 3 shows the solar energy potential of the Gümüşhane province as kWh/m^2-year. As can be seen on the map in Gümüşhane province, the highest solar energy potential is seen in Kelkit and the least in Kürtün region.

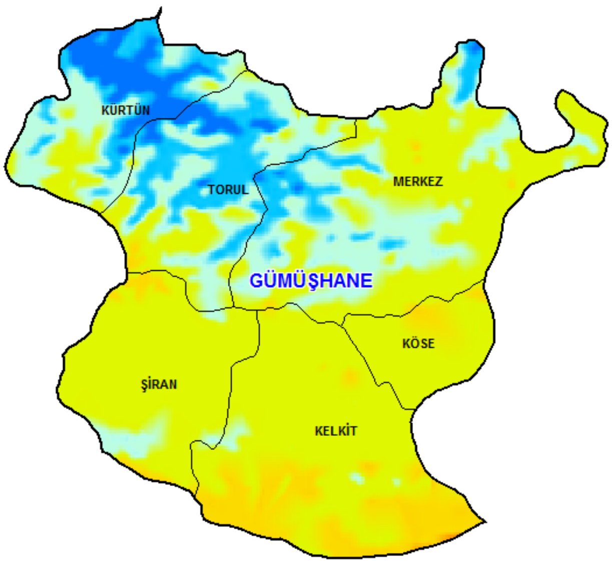

Figure 3. Solar energy potential map of Gümüşhane.

2.2. Photovoltaic Pole System

The electrical materials required for solar pole design can be listed as solar panel, battery, charge controller and USB module. The solar pole has been planned to have four USB modules, and since the charging voltage and current for mobile phones are determined as 5V-2A, 10W power will be needed for a mobile phone during charging. If 4 USB modules are used in the system, the total power requirement will be 40W. At the same time, 8A current should be obtained from the battery instantly for four USB outputs. The solar panel will need to produce 40Wh energy per hour. Although the determination of the battery capacity is relative, the excess capacity offers technical advantages when a cost is not taken into account. For example, when solar radiation is low, batteries cannot benefit from solar energy sufficiently. In this case, the battery capacity is high, allowing the user to charge their mobile phones without power interruption [15].

As seen in Figure 4, the system includes a solar panel, charge controller, battery and USB module. In this type of system, the rays coming from the sun are produced on the panel and electrical energy in DC form. This energy is stored in batteries. However, the voltage obtained at this stage should be converted to the voltage level at which the battery can be charged, and at the same time, full charge and full discharge of the battery should be prevented. For this purpose, a converter circuit or charge controller is needed. The connection of the charge controller is made between the panel group and the battery group. Voltage converter circuits are used between the battery connection and the USB modules.

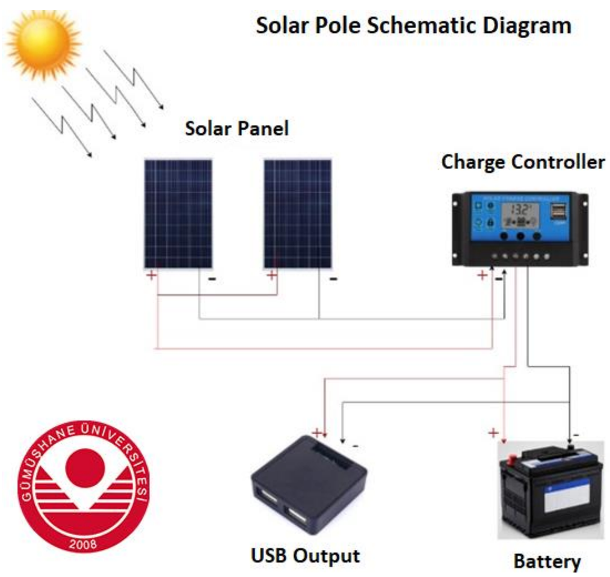

Figure 4. Schematic diagram of solar pole.

3. Results and Discussion

Within the scope of this study, the drawing of the targeted system was created with the help of SketchUp program. According to this drawing, the front, back and side views of the system are given in Figure 5.

As seen in Figure 5, since there will be a charge controller and battery in the section behind the solar panel, this section has been closed. The purpose of this process is to prevent damage to the battery and charge controller located under the solar panel in bad weather conditions. In addition, the sheet on the back of the solar panel is produced in a structure that can be opened easily so that it can be easily intervened in case of any malfunction or material change. Then, the system carrying the solar panel was fixed on the top of the iron pole to be used. At this stage, the anchorage system was finally made to the base of the pole. The purpose of the anchor system is to fix the substrate on the concrete and to mount the lower base of the pole to this structure. Specifications of the solar pole are listed in Table 1.

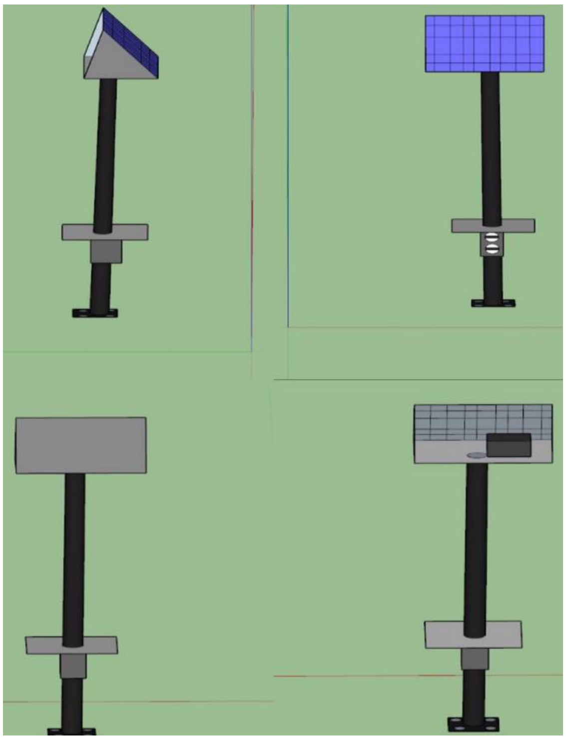

Figure 5. Technical drawing of the solar pole.

In the next step, the necessary electrical connections were made. In this part, the battery and charge controller are connected first. This is because the charge controller must recognize the battery type. Afterwards, the solar panel and the charge controller were connected. Then, a connection was applied from the device and the USB modules were connected to the system. Connection procedures are given in Figure 6.

Table 1. Specifications of the solar pole.

Maximum power	42W
Open circuit voltage	22.1V
Short circuit current	2.58A
Maximum power voltage	18V
Maximum power current	2.58A
Dimensions	670x430x25mm
Weight	3.8kg
Battery capacity	12V-9Ah
Recommended charge current	900mAhx10 hours

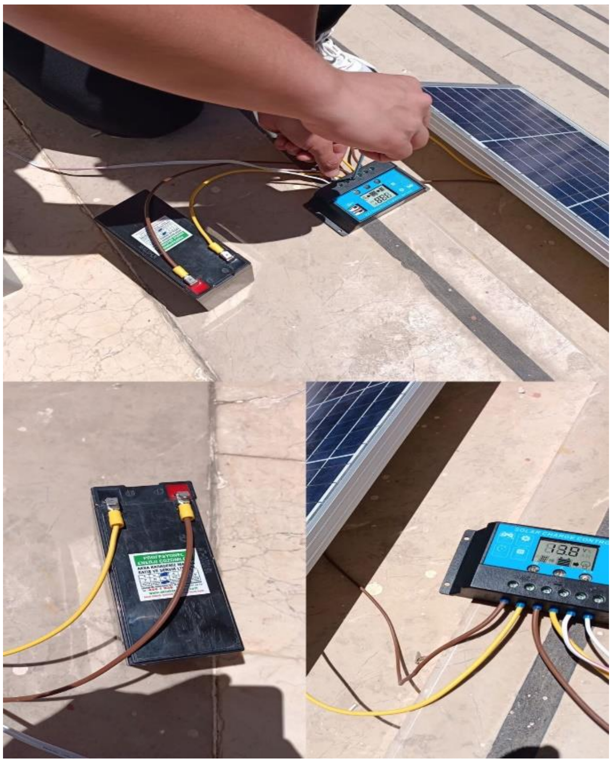

Figure 6. Electrical connection and testing of the system.

Finally, some improvements were made to the system. First, the output slot was designed with the help of a 3D printer in order to protect the connection parts of the USB modules. This design is shown in Figure 7. This design was placed on the body of the iron pole, which gets ready, by opening a suitable area. Thus, the system was completed and fixed on the concrete surface.

Different mobile devices were charged on the system for test purposes, and no technical problems were detected. In addition, it has been determined that there is a need for security protection against weather events such as rain and snow in the section where the USB modules are located. For this purpose, a design was made and a protection equipment was produced with the help of a 3D printer. Figure 8 shows the design of this part created in the SOLIDWORKS program.

Figure 7. USB outputs and their structure.

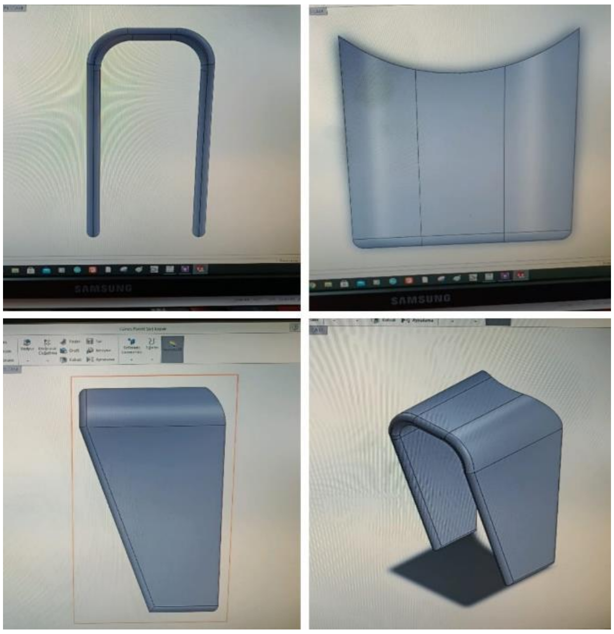

Figure 8. Image of the 3D design of the USB holder.

In Figure 9, the 3D printer output of this designed part is shown. Finally, this part is fixed on the part where the USB modules are located with the help of silicon, ensuring the safety of the system against weather conditions. Because of all these processes, the system has become completely ready. The image of the system in the planned area is given in Figure 10.

Figure 9. Image of the USB holder

Figure 10. Image of the solar pole.

4. Conclusions

Solar energy systems have become highly preferred systems with the widespread use of renewable energy sources. Harnessing these systems efficiently provides advantages in terms of energy production. Therefore, attention should be paid to factors that will increase efficiency. In this study, the solar pole was designed and constructed in such a way that it faces south with an inclination angle of 25°, considering the geographical conditions of Gümüşhane province. In the solar pole, a 42W solar panel, a 12V-9Ah lead-acid battery, a 10A charge controller and two dual-output USB modules were used in the system. The purpose of establishing this system is to perform the charging process of mobile devices that can be charged with 5V, and this aim has been achieved. In the continuation of the study, a solar tracking system will be implemented in order to benefit more from solar energy. Thus, more energy will be obtained from a single PV module.

Declaration of Ethical Standards

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Başoğlu M. E., Kazdaloğlu A., Erfidan T., Bilgin M. Z., Çakır B., 2015. Performance analyzes of different photovoltaic module technologies under İzmit,

Kocaeli climatic conditions. Renewable and Sustainable Energy Reviews, **12**, pp. 357-365.

[2] Brar A., Sanborn R., Radwan A., Jiang X., 2020. A mobile photovoltaic-battery system for off-grid applications. Paper presented at the 2nd International Conference on Electrical, Communication and Computer Engineering, İstanbul, Turkey, 12-13 June, pp. 1-6.

[3] Lee H., Kim K.A., 2015. Comparison of photovoltaic converter configurations for wearable applications. Paper presented at the IEEE 16th Workshop on Control and Modeling for Power Electronics, Vancouver, Canada, 12-15 July, pp. 1-6.

[4] Ray S., Tripathi A.K., 2016. Design and development of tilted single axis and azimuth-altitude dual axis solar tracking systems. Paper presented at the 1st IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems, Delhi, India, 4-6 July, pp. 1-6.

[5] Geng C., Schmidt K., 2021. Design and implementation of a photovoltaic system for self-sufficient energy supply of mobile robots. Paper presented at the 3rd International Congress on Human-Computer Interaction, Optimization and Robotic Applications, Ankara, Turkey, 11-13 June, pp. 1-5.

[6] Murugesh R., Hanumanthaiah, Ramanadhan U., Vasudevan N., 2018. Designing a wireless solar power monitor for wireless sensor network applications. Paper presented at the IEEE 8th International Advance Computing Conference, Greater Noida, India, 14-15 Dec., pp. 79-84.

[7] Oruganti K. S. P., Vaithilingam C.A., Rajendran, Ramasamy A, 2019. Design and sizing of mobile solar photovoltaic power plant to support rapid charging for electric vehicles. Energies, **12**, Article No. 3579.

[8] Illangarathna S., Binduhewa P., 2020. Energy management system for neighbourhood EV based taxi-parking station. Paper presented at the 15th IEEE International Conference on Industrial and Information Systems, Rupnagar, India, 26-28 November, pp. 69-74.

[9] Encinas S. H., Castanon N. J. B., Mamani V. S., Mamani L. E. H., Paredes R. I. T., Mamani R. J. C., Molero M. R. R., Apaza A. P., 2020. Photovoltaic charger system for mobile devices using quick charge 3.0 technology. Paper presented at the 18th LACCEI International Multi-Conference for Engineering, Education, and Technology, Buenos Aires, Argentina, 29-31 July pp. 1-4.

[10] Duque E., Isaza A., Ortiz P., Chica S., Lujan A., Molina J., 2017. Urban sets innovation: design of a solar tree PV system for charging mobile devices in Medellin-Colombia. Paper presented at the 6th International Conference on Renewable Energy Research and Applications, Sandiego, USA, 5-8 November, pp. 495-498.

[11] Başoğlu M. E., Kazdaloğlu A., Erfidan T., Bilgin M. Z., Çakır B., 2015. Seasonal based energy performance analyzes of Cd-Te and c-Si photovoltaic modules. Paper presented at the IEEE 15th International Conference on Environment and Electrical Engineering (EEEIC) Rome, Italy, 10-13 June, pp. 208-212.

[12] Başoğlu M. E., Üstek S. M., 2021. Prototype development of a solar-powered backpack for camping applciations. Journal of Science Part C: Design and Technology, **9(4)**, pp. 589-596.

[13] Al-Shagea E., Sezen S., Özdemir E., 2021. Lisanssız elektrik üretiminde şebeke bağlantılı fotovoltaik sistemlerin performans analizi. Paper presented at the International Marmara Sciences Congress, Kocaeli, Turkey, May, pp. 209-217.

[14] https://solarchargingstation.com/gallery/ (Access Date: 27 December 2021).

[15] Lin Y., Jiang B., Dai H., 2021. Battery capacity estimation based on incremental capacity analysis considering charging current rate. World Electric Vehicle Journal, **12**, 224, pp. 1-12.