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Prototype development of a solar-powered backpack for camping applications

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Abstract

Solar energy, the use and importance of which is increasing day by day, stands out among renewable energy sources with many applications. In this study, the application of solar powered orthopedic back support backpack has been presented with a special photovoltaic module structure. The 2x12W photovoltaic panel system has been mounted on the backpack with a rail arrangement and optional use is provided according to the user's preference. Since there will be additional equipment in the solar self-energized backpack compared to a normal bag, the sections where the items should be put in the bag according to their weight should be specified to the user. Considering the center of gravity of the backpack, pockets have been made in the parts where heavy components will be fixed, and a 12V 7Ah lead acid battery is mounted in this section. There is a 5V - 1A USB output at the system output and a modified sinus inverter for AC loads. In addition, prototype production was carried out for the realized design, and a backpack was produced, which can be used for charging mobile phones and feeding simple AC loads such as heaters, coolers and shavers. It is thought that this bag will be an attractive product for camping applications and travellers traveling by hitchhiking.

1. INTRODUCTION

Solar energy has been a beacon of hope for the world in the current period where energy and water resources are limited and threaten the future. The wind is no longer just a cool touch, and again the sun is not just the effect of those beautiful views watched but for the whole world. The inspiration for this study was the widespread use of renewable energy sources and the development of a wearable technology-based product.

Photovoltaic modules are manufactured in many different material structures, from power levels of a few watts to several hundred watts. Their use varies from application to application, depending on the material and power conversion efficiency [1]. In particular, energizing portable devices, lighting applications in open areas, traffic lighting, smart bus stops, robotic applications, backpacks, power banks, solar tree, feeding low power auxiliary equipment of electric vehicles, tent applications, calculator applications with very low power requirements and photovoltaic-based energy supply in wearable devices such as wristwatches become widespread. There are different studies in the literature that include such applications [2-14].

In [3], a photovoltaic energy based power generation system is designed in remote locations from the electricity grid. With the photovoltaic modules in the system, 12V DC voltage lead acid batteries are charged based on the maximum power point tracking principle. In order to obtain 5V DC and 24V DC levels, buck and boost converters have been used, respectively. In addition, USB outputs are utilized for charging electronic devices. A 120V AC modified sinus inverter is also available for AC loads in the system. Another study focuses on fast charging stations for electric vehicles. In this context, it is stated that the prevalence of electric vehicles and the load they will bring to the grid will increase in the coming years. For this reason, it is expected that solar charging stations work like fuel stations [4]. One of the mobile

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robot applications, mars rover is especially used in environmental applications where it is not possible for humans to access and works according to the self-energy strategy [5]. According to the PV-based solar tracking system principle, the energy produced was increased by 44% by controlling the azimuth and elevation angle in a 20W mobile robot application. The systematic design stages of the solar-powered charging backpack were examined in [6]. Five different commercial products were compared in terms of power, voltage level, size, weight and cost. In this study, it is aimed to produce a different prototype and to charge mobile phones with a reasonable efficiency. A linear regulator approach is used as the charging circuit. Although a backpack in which mobile phones can be charged has been developed with this technique, it is a negative situation that the efficiency is around 45%. With the use of photovoltaic-based energy sources in unmanned aerial vehicles, significant savings in battery capacity and weight can be achieved. In [7], a solar-powered design was proposed to increase the flight time in unmanned aerial vehicles. As a result, 22.5% of battery capacity has been saved. In developing countries, three-wheeled electric vehicles are the cheapest option for short distances used for taxi purposes. In [8], a photovoltaic energy-based energy management system has been proposed for such vehicles. In a study presented in [9] proposes an optimal energy harvester (OEH) using a flexible photovoltaic (FPV) module to extend battery life for a wearable body sensor node in indoor and outdoor conditions. A fuzzy logic based boost converter with MPPT is proposed for optimum energy harvesting. A modeling was carried out to determine the photovoltaic potential of bus stops at city scale. In the modeling using geographic information system data, it was determined that 54% of the bus stops for the city of Lisbon are suitable for PV-based solutions [10]. In another study [11], a photovoltaic-based charging system equipped with 30 technology, which enables fast charging of mobile phones, has been proposed. In a project named [12] "To Wait in a new way", which aims to transform the classic bus stops in Torino, Italy into smart features, it is aimed to equip the roofs of smart bus stops with photovoltaic modules. With this project presented in [12], photovoltaic modules are used for purposes such as USB charging, Wi-Fi internet, air quality control unit and public lighting. In this context, data such as solar potential map and traffic flow have been analyzed to determine smart bus stops. On the other study, it is focused on smart bracelet which fed by small PV cells. This bracelet used by patients have sensors that collect some information from the body. In [13], a body sensor prototype has been developed as an example of wearable photovoltaic applications for biomedical purposes. This device, which collects data such as the amount of oxygen in the blood, temperature and humidity, can produce a power of 16mW in the outdoor environment and around 0.21mW in the indoor environment. Solar tree applications have started to be used a lot, especially in public squares, for charging mobile phones in open air and to meet the simple lighting load [14]. The prototype application developed has 12V DC voltage, 180Ah battery capacity and 200W inverter. There are six USB outputs and two 110V - 200W output ports.

The two main points referred to in this study are the renewable energy source and the electrical energy that people have access to when they need it most. In this context, dozens of people who spend most of their time on the roads, outside the urban area, in places that have not yet met electrical energy or in places where they cannot reach electrical energy for a certain period have been taken into account. In addition, it is an important issue that energy has a portable feature. Therefore, it is thought that solar energy will be suitable for mobility. Solar energy plays an important role in this regard. The solar powered backpack developed in this study offers very attractive features especially in camping applications. This study focuses on an original solar powered backpack design. With the structure obtained with the sled system in the designed solar powered backpack, optional solar panel use is provided according to the battery charge status. In this way, a shaded area is formed for the person carrying the bag in the position where both solar panels are active. Remains of the paper is as follows. In the second part of the study is about the solar powered backpack and design steps of this backpack. Finally, important features of the study is summarized.

2.SOLAR-POWERED BACKPACK: COMPONENTS & DESIGN STEPS

The solar powered backpack/camping bag has many functional features compared to an ordinary bag. In this section, the details of the selected bag, the components of the backpack and its features are mentioned. Image of the planned solar powered backpack is given in Figure 1.a. General block diagram of the photovoltaic system including charge regulator circuit, modified sinus inverter, battery and solar panels are presented in Figure 1.b. The working principle of the system can be understood from the block circuit given in Figure 1.b. The energy obtained from the solar panels is transferred to the batteries via the charge controller. The charge controller is designed for 12V and 24V batteries, and when the battery voltage is around 10.7V in a 12V battery, the battery discharge is automatically cut off. On the other hand, when the battery voltage is 13.7V, the charging current is cut off. The charge controller also has overcurrent, short circuit and open circuit protections. The modified sinus inverter in the system is powered by a 12V battery and provides 220V modified sinus voltage at its output. Devices such as simple coolers or water heaters can be connected as a load to the inverter outputs on the backpack. With the solar panels used in the system, the battery with a capacity of 12V-7Ah under ideal conditions is filled in approximately 3.5 hours. (12Vx7Ah/24W=3.5hours)

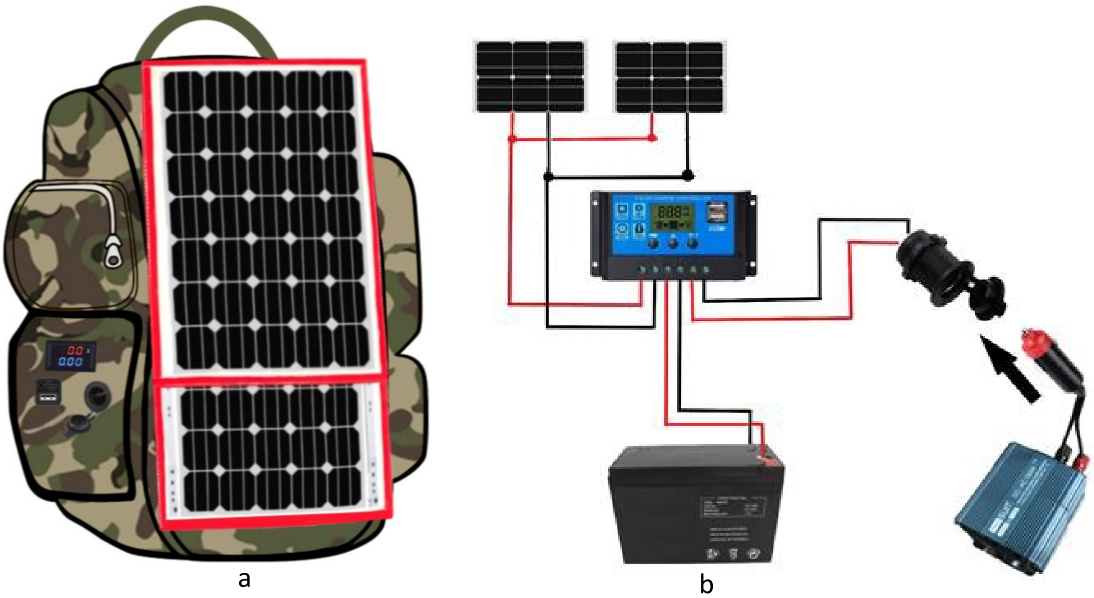

Figure 1. *Solar powered backpack a) Image of the designed backpack b) Electrical diagram of the backpack*

As a backpack, a bag with a volume of 75+10 liters and with lumbar and back support has been chosen. Then, in order to design a photovoltaic system suitable for the front surface of the backpack the dimensions of the area where the solar panels can be mounted on the bag surface were determined. According to the chosen backpack, a special solar panel is designed to fit on a 36cm x 65cm surface. On this surface, two specially designed frameless, approximately 4 mm thick tempered thin glass design flexible photovoltaic modules with 12W power are used. Since the solar panel has a thin design, it is aimed to benefit more from the same surface by choosing a double-layer structure.

2.1. Special Solar Panels and Use of Protection Diodes

The solar panels have a length of 34 cm and a width of 24 cm and weigh approximately 920 grams. Two 12W solar panels are used as a double layer on the surface of the backpack. Some features of these panels can be listed as being durable at -40°C and +85°C, being made of thin tempered glass, having a monocrystalline structure and having an open circuit voltage of 24V. Main specifications of the solar panels used in the backpack are listed in Table 1.

Table 1. *Specifications of the solar panel*

Specifications	***Value***
Open circuit voltage	*24V*
Short circuit current	*0.64A*
Maximum power voltage	*20.6V*
Maximum power current	*0.61A*
Maximum power	*12W*
Efficiency	*22%*
P_{max} *temperature coefficient*	*-0.40%/K*

Placing the panels on the surface of the bag made it difficult to use the bag. In addition, the strength of the panel that can be placed on the bag surface has decreased considerably. For this reason, in order to increase the power capacity of the solar panel and to offer options to the user, the panels are integrated into the backpack in a structure that can be opened and closed as in Figure 2. With the rails placed on the panels, it was possible to open and close the panels on demand. In addition, the option of generating energy with a single or double panel is provided according to the battery capacity. 320kg/10cm^2 strength adhesive is used for mounting the rails without damaging the panels. The adhesive is not affected by water, sun and any external factors. The panels are covered with protection seals as in Figure 3 for protection against impacts.

Figure 2. *Double layer solar panel*

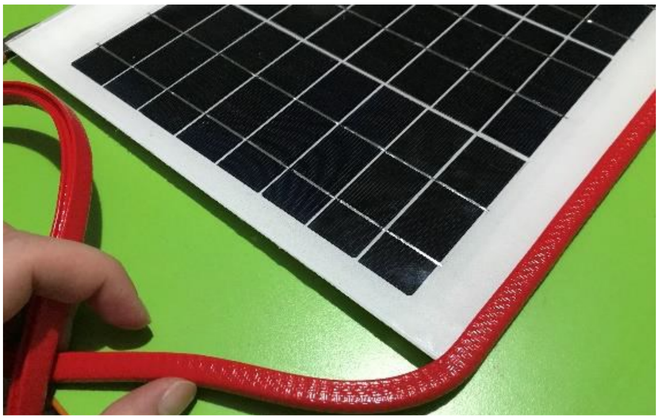

Figure 3. *Solar panel wick application*

In solar panel structure, two panels are connected in parallel so that when one of the 12W panels is shaded, the other can continue to work and provide uninterrupted charging. Four diodes are used in parallel connection of solar panels. These diodes are by-pass and blocking diodes. The bypass diode is connected in reverse direction between the negative and positive outputs of the solar panel as in Figure 4.a. The bypass diodes have no effect on the energy to be supplied at the output. External factors such as bad weather conditions have an effect on the solar radiation falling on the solar panel. Due to this undesirable situation, imbalances may occur in the solar panels during electricity generation. In this case, cells that do not see enough light or that are cut off may act as energy-consuming loads. To prevent this situation, a bypass diode is used.

When solar panels are connected in parallel, a blocking diode must also be connected to each panel. One of the events that are likely to happen in the PV system is this: thanks to the blocking diodes, there is no flow between the panels and the possibility of reverse current flow from the battery to the panels is eliminated. The use of blocking diodes becomes essential, as the panel voltage will decrease a lot in low radiation and may occasionally take values below the battery voltage. Blocking diodes were used in series with the positive terminal of the panels, as indicated as red diodes in Figure 4.b.

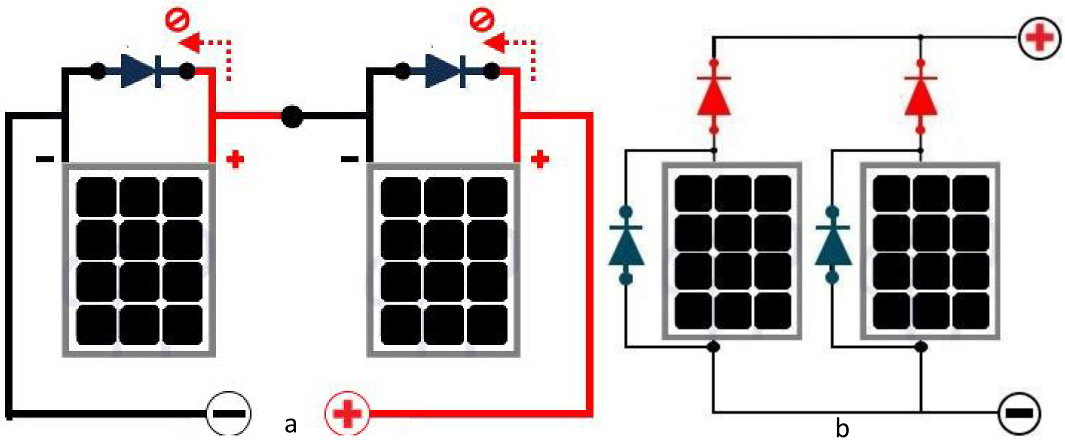

Figure 4. *Diode use for solar panel protection a) bypass diodes b) blocking diodes (red)*

2.2. Arranging the Bag for the Solar Panel

In order to make the connection between the backpack and the solar panels and to strengthen this connection, some changes should be made on the surface of the bag. For this purpose, two strips of clips are sewn onto the front surface of the bag, as seen in Figure 5, in order to fix the solar panel system to the backpack and to separate it from the backpack when necessary.

Figure 5. *Structure of the solar powered backpack.*

With the clip-on structure placed between the backpack and the solar panels, it has been beneficial both in terms of adjusting the tightness of the panels and ensuring that the panel can be separated from the bag for any reason (such as bag cleaning, panel failure, using the panel outside the bag). As seen in Figure 6, these ropes were passed through six channels and fixed behind the solar panel below.

The center of gravity in the bag is very important. The weights in the bag should be designed for comfort as shown in Figure 7.a. Putting all the weight on the shoulders makes it difficult to carry the backpack, and as a result, problems that affect the comfort and health of the user may occur. For this reason, a pocket has been made for the battery, which is the heavy element of the system, on the upper part of the backpack, close to the back area and not giving weight to the shoulders. While the chest and waist support of the bag distribute the weight equally to the whole body, the use of the battery, which is an important burden, in the right place has increased the effect of these supports. This sensitivity is for the fixed weights of the bag. There is no restriction for the materials that the user will carry. Figure 7.b and Figure 7.c show the backpack in single-panel active and double-panel active states.

Figure 6. *Structure of electrical connections.*

Figure 7. *a) Distribution of weights on the backpack b) Prototype of the backpack (one solar panel active) c) Prototype of the backpack (two solar panels active)*

The backpack will be located in the user's back area. USB and AC outlets are positioned to face the user's side, as shown in Figure 7.b, for comfortable and easy use of the outlets to provide electrical energy in the backpack. The 12V car cigarette lighter and 5V USB output appealing to the user are shown on the side of the bag in Figure 7.b. On the side of the case, an external solar charge controller display (seen as rectangles in red) can be seen. This screen provides access to control keys and displays battery capacity, charging current, charging voltage, etc. information can be tracked. In this way, the user is provided with information on how to use the solar panel system. Figure 8 shows the cigarette lighter outlet and the charge controller screen. The voltage read from the screen in Figure 8 is the charging voltage, and the battery is charged with a voltage of 12.7V. For detailed information about the prototype realized, the link is presented in [15] can be checked.

Figure 8. *12V DC output and display of the solar charge controller during charging*

3.CONCLUSIONS

In this study, a prototype application of a photovoltaic powered backpack has been carried out. A two-layer photovoltaic module design has been made in the bag, and the battery, charge controller and inverter have been placed in different compartments to prevent health problems for the person carrying the bag. This prototype is ideal for travelers who are camping, hitchhiking or needing energy after being outside for long periods. With the USB outputs used in the backpack, mobile phones are charged with 5V - 1A, and simple AC loads can be fed with the inverter outputs. The photovoltaic module design of the bag is unique and has a double layer rail structure. With the rail layout in the modules, an option is offered to the user's preference, with two modules or one module activated.

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