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Research Paper

Development and Construction of Portable Solar Power Packs for Laptops and Small Devices

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Abstract
Power packs are on the rise in popularity as a result of the need for portable electronic devices and laptops to last as long as possible. The in-built battery in a laptop will only last a few hours before it drains out. As a result, external chargers must be used to keep electronic devices running, including mobile phones. The paper describes the evolution, construction and critical components of a laptop power pack to gain an understanding of its operation.It was constructed using available components, it comprises of charge controller which monitors the changing rate of the lithium battery (3.2V each with 4 arrayed in the system) arranged in the system with a Battery Management (BMS), Photo-switch incorporated in the charge controller which manages the energy by switching off the system even, Boost converter helps the boosting of energy when higher power is required in charging a system. It has a 50W solar cell (photovoltaic) and a system power of 78Wh which can conveniently charge any laptop full twice and can as well be charged using a power supply to all available systems. The converter wattage (Capacity) of 150W, stored charge of 72Wh, with mean charging hour for the reading lamp of 6.7hrs, HP laptop of 4.35hrs witha number equivalent to 2 and total efficiency of 83% with python Jupiter to plot the usage hour.
***Keywords**: Power-pack, Boost-converter, photovoltaic cell*

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I. Introduction

Excessive reliance on fossil fuels has damaged the planet. Global warming has been caused by the release of greenhouse gases, largely as a result of the burning of fossil fuels as an energy source. Increased sea levels, floods, forest fires, and glacier melting have all been the results of climate change. Climate change and other ramifications are some of the repercussions of our excessive reliance on fossil fuels for energy. Solar energy is a clean and environmentally friendly source of energy that can be used in place of fossil fuels (Narayan *et al*., 2022).

Solar energy systems have become more popular in recent decades due to their long-term low-cost and reduced environmental damage. Researchers have developed several ways to capture solar energy, including space heating, water heating, electricity generation, and others. The fusion of hydrogen atoms in the sun creates solar energy. This reaction releases high-energy particles known as gamma rays. These gamma rays are sent to the Earth as electromagnetic radiation from the sun, which is about 150 million miles away. Solar energy can be harnessed directly by using photovoltaic (solar cell) and solar concentration systems. Photovoltaics are used to generate electricity, while solar concentrators are used to generate thermal energy. Photovoltaics are used for electricity generation, while solar collectors are used for thermal energy (Hartona*et al*.,2018, Adeniran*et al*., 2020).

The major liability or drawbacks of the utilization of solar energy lie in the off period of the available solar energy; the use of the battery to charge the devices is also limited as it would be discharged eventually.

Then the idea of a solar power bank becomes necessary, the bank can charge our devices while in transit; this saves time, increase work output and ensures the long usage of solar energy to run our devices while reducing the devastating effect of over-dependency on fossil fuel. Even in rural areas with having scarcity of electricity, the solar power bank model is a sustainable approach through which the inhabitants can power their devices (Srilakshimi*et al*.,2021)

Power Backup/Generator

Most portable electronic equipment may be charged using these convenient, portable rechargeable power banks. High-powered batteries are necessary for mobile phones to extend their functioning time (Tahar and Wenjia, 2014). As a result, power banks with increased capacities between 2000 mAh and 20000 mAh or more are much sought after for charging mobile phones. Here are a few examples of portable electronics that the power bank may charge:

Figure 1.1: Mobile Power Bank

A lithium-ion battery, hardware protection circuit, and outside case make up the power bank. The power bank's battery is its most important component, and hardware protection also regulates the current, voltage, and temperature. The LED profiles gauge the battery bank's condition for improved gadget performance. Fig. 1.2 depicts the block diagram of the power and bank.

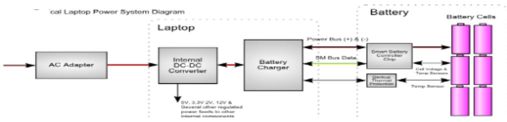


Figure 1.2: Solar Power Based Power Bank Block diagram

Solar Energy

The light from the sun can be used as a substitute energy source for electricity. Solar PV power generation is the project's primary focus. Solar radiation affects a PV system's architecture. The source of solar energy is the sun. It serves as a solar radiation emitter with; an averageof 25°C under typical test circumstances of 1000W/m2. 47% of the sun's total energy that reaches the earth's surface is absorbed. This is the only amount used for usage.

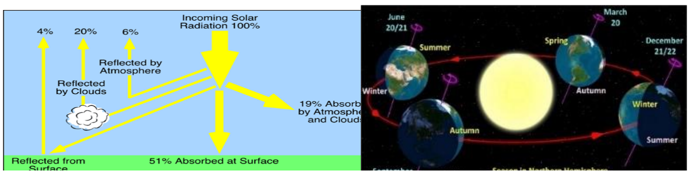


Figure 1.4: Solar irradiation and solar system

The earth rotates around the sun in an ellipse, which rotates around the sun in an ellipse. The earth's tilt on its elliptical axis is 23.5 degrees relative to the sun's axis. Seasonal and hourly energy variations appear at the earth's surface due to its annual rotational journey around the sun. Solar energy is measured by the amount of solar radiation that reaches the earth. Solar radiation, also known as insolation, is the quantity of solar matter. Solar power production is largely determined by the magnitude of direct radiation (Zainel and Kaveh,2019 &Agus, 2018). There are two types of solar radiation: direct and diffuse. Direct solar radiation is a beam of energy that is directly delivered to the earth. Diffuse radiation, in contrast, is the diffusion of solar particles with air (air, dust, and water).

Solar Energy Generation System

Solar power systems use PV modules to convert sunlight into electricity. Their purpose determines whether they store the electricity in batteries or use it directly. Components make up solar generation systems. The system type, location, and applications are taken into consideration when choosing these components. (Black, 2016) The following elements are necessary:

- PV module
- Solar Charger Controller
- Power inverter
- Battery
- Load

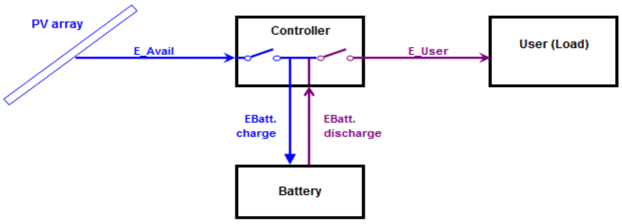


Figure 1.5: Complete Solar System

The use of solar generation systems can also be used to categorize into several categories. which include grid-connected applications and stand-alone applications. The electrical grid is not connected to standalone solar power plants. Only the applications are powered by solar panels. Direct-coupled systems and standalone systems with batteries are two further subcategories of standalone solar production systems. The existence of a battery is the primary distinction between a stand-alone system without batteries and a direct-coupled system. The stand-alone system with batteries provides electricity via the batteries, but the direct-coupled system delivers power from a solar panel directly to the application. The stand-alone system with batteries can be used at any time, however, the direct-coupled system can only be used during the day because of the energy in a battery-powered standalone system, the storage battery serves the following purposes:

i. Energy storage capability and independence: the ability to store extra energy and make it available when needed.

ii. Stabilization of voltage and current to produce steady voltage and current

iii. Supply surge current to loads in order to provide surge currents.

Technology for lithium-ion batteries

Power banks and other portable consumer electronics can be powered by lithium-ion batteries. Lithium-ion batteries have documented electrochemical advantages over conventional batteries in terms of operating potential, cycle life, footprint, weight, and other factors. Lithium-ion batteries, however, come in a variety of chemistries (Masaki et al.,2009 & Ramesh and Praveen, 2021).

Lithium Cobalt Oxide (LCO), Lithium Manganese Oxide (LMO), Lithium Iron Phosphate (LFP), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminum Oxide (NCA), and Lithium Titanium Oxide (LTO) are the most well-known chemistries of the Li-ion technologies (Naoki et al.,2015&Olabisi*et al.*, 2020). The four different designs for lithium-ion batteries are I button (iii) cylindrical (iii) prismatic (and iv) pouch. The button type is widely used for portable electronic devices, such as thermometers, wristwatches, and other kits of portable medical equipment. The most durable and trustworthy design is cylinder-shaped. The 18650 cylindrical type is a low-cost battery that is utilized in computers, power banks, and other cutting-edge uses including electric mobility.

Figure 1.6: Lithium Battery

The medium and big sizes of the prismatic variety have a strong exterior covering. Mobile phones often employ medium size, whereas a larger range is used in things like electric locomotives. Given its flexible geometry and lightweight construction, big-capacity power banks use the pouch type because it is the most flexible, lightweight, and compatible with electronic circuits (Masaki et al.,2009, Naoki et al.,2015). Despite having a 5000mAh capacity, the power bank's actual energy capacity for charging a phone is 3700mAh. In other words, the power bank's useful capacity is roughly 74%, while the remaining 26% of its capacity is used to offset the conversion factor for step-up and step-down through the laptop adaptor.

The variation of the capacities for the rated and practical values also depends on the quality of the components and the type of connectors that are used in the device. The energy consumption in the electrical circuit is expected to be 5% to 12% subject to the efficiency of the components in the circuit. Here the average consumption of energy is considered as 10% and the estimated net efficiency of the power bank device is 90%. By considering the compensation of energy through the laptop charger and electrical harness in the power bank circuit (Parker, 2009 & Scott,2019).

Methodology

Solar PV System Sizing

1) Determine power consumption demands
2) The first step in designing a solar PV system, we need to find the total power and energy consumption of all loads that need to be supplied by a solar PV system. The calculations needed are:

   a) Total watt-hours per day for load

   b) Calculate the total watt-hours per day needed from the PV modules using these parameters the values for the required parameters are obtained using equations I to i.vii.

3. Design and circuit analysis done following the block diagram shown in figure 1.4

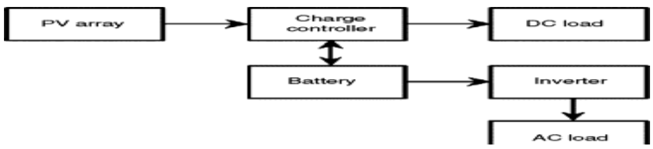


Figure 1.7: Block diagram for the System

Calculationsby Load analysis

The load analysis for a solar power pack system, which incorporates the battery, inverter, and solar cells, is the amount of power consumed. The voltage and current of every brand of laptop DC system are known to be 19V and 4.6A, respectively. The load power requirement is determined from the equation:

Power = Voltage (V) x Current (I)i

PV Sizing

Analyzing the load reveals that a PV panel is a pricey capturing device. The solar panel should be properly sized. The load analysis calculations determine the total average ampere-hour per day as 10 A-h. We assume that the average daily sun hours in some parts of Nigeria are 6-8 hours. We can estimate the peak amperes or current at maximum power by referring to the solar panel specifications. 1.5 A is the max.

$$DC\ Solar\ System\ Size = \left(\frac{Daily\ KWh}{Average\ \ Sun\ Hours}\right)1.5\ Efficieny\ factor \quad \text{i.i}$$

Battery Sizing

The following parameters were considered during the battery sizing; unadjusted capacity (C_{un}). Adjusted Capacity for minimum Depth of Discharge (C_{MDD}). Maximum Daily Depth of Discharge capacity (C_{MDDOD}), Maximum operating Temperature Capacity (C_{AK}), Design Margin Capacity (C_{ADM}), End of Life Capacity (C_{EOL}), System Efficiency (83%) and Aging Factor (AF) (Jignesh, 2015 and Goswami, 2015).

$$C_{un = Total\ \ Daaily\ \ Load\ \ x\ Number\ \ of\ \ days\ \ of\ \ Autonomy}$$

$$C_{MDOD} = \frac{C_{un}}{MDOD} = \frac{C_{un}}{0.85} \quad \text{ii}$$

Where MDOD is the Maximum Depth of Discharge and is obtained from the battery data sheet as 85% or 0.85. this is similar to C_{EOL} where EOL is also 85% or 0.85.

$$C_{MDDOD} = \frac{Total\ Daily\ Load}{MDDOD} = \frac{Total\ daily\ Load}{0.2} \quad \text{iii}$$

Where MDDOD is the Maximum Daily Depth of Discharge and it is obtained from the Datasheet as 20% or 0.2.

$$C_{AK} = C_{MDOD} \times K_F = C_{MDOD} \quad \text{iv}$$

Where the Temperature Correction Factor (K_F) is approximately equal to 1 from the datasheet.

$$C_{ADM} = C_{AK} \times Design\ Margin\ Factor = 1.25C_{AK} \quad \text{v}$$

Where Design Margin Factor is 1.25(10% - 25%)

$$Functional\ Hour\ Rate = \frac{C_{ADM}}{Maximum\ \ Running\ \ Current} \quad \text{vii}$$

$$Final\ Battery\ Capacity = C_{un} \times Design\ Margin\ Factor \times AF \times K_F \quad \text{viii}$$

Where K_F = 1 and AF = 1.25, hence

Final Battery Capacity = $1.563C_{un}$

The battery sizing is determined using the battery capacity equation:

$$Battery\ Capacity = \frac{Battery\ Capacity\ (Wh)}{Battery\ Voltage} \qquad \text{ix}$$

$$Battery\ Capacity\ (Wh) = Total\ Power\ Demand\ X\ Storage\ days\ X\ \frac{100}{Battery\ DOD} \text{x}$$

Power Bank Useful Energy

This determines the useful energy which is obtained using equation ix

$$Useful\ Energy = Stored\ Energy\ X\ Energy\ Efficiency \qquad \text{xi}$$

Average Laptop Power Consumption

$$Ave\ Laptop\ Power\ Consumption = \frac{Battery\ Energ\,y(W)}{Time\ of\ Use} \qquad \text{xii}$$

Inverter Sizing

The inverter is required to produce AC output, in order to ensure that the input rating of the inverter is not below the total watt of the appliances, the inverter size considered was made 3 times the capacity of those appliances.

$$Inverter\ power = Maximum\ load\ x\ 3 \qquad \text{xiii}$$

Solar Charger Controller Sizing

$$Solar\ Charger\ (Amps) = \frac{Panel\ Wattage}{Battery\ Wattage} \qquad \text{xiv}$$

Table 1.1: System Specification

Quantity	*Comments*
Power	**78w/h**
Supply	**15 -21Voltgae output**
Appliances	**Laptop: Hp and DELL**
Duration	**24hrs**
Solar Panel power	**50W**
Battery	**16 amp 13 volt**
Power Output	**78W**

Analysis

The number of charges for a power bank is determined using the equation xv

$$No\ of\ charges = \frac{Power\ Bank\ Capacity\ (mAh)}{Laptop\ Capacity\ (mAh)} \qquad \text{xv}$$

Efficiency is given as:

$$Efficiency(\%) = 100\ x\ \frac{Output\ Energy}{Stored\ Energy} \qquad \text{xvi}$$

Useable energy:

$$Useable\ energy = \frac{Energy\ efficiency}{Stored\ energy} \qquad \text{xvii}$$

Experiments and Results

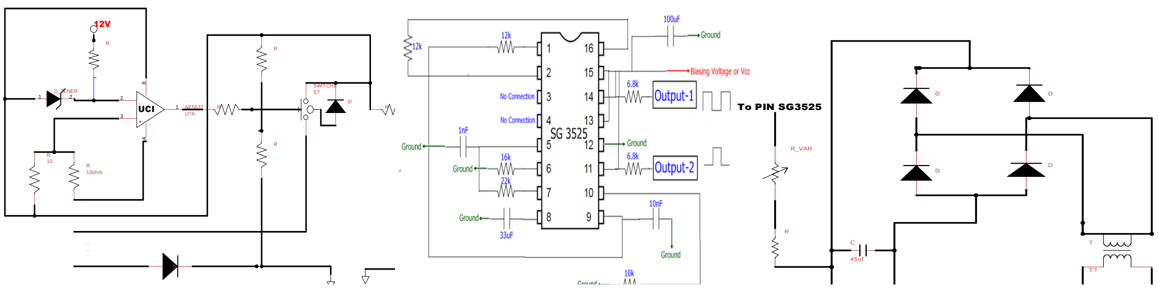


Figure 1.8: Solar Charger with the charge controller circuit and filter circuit

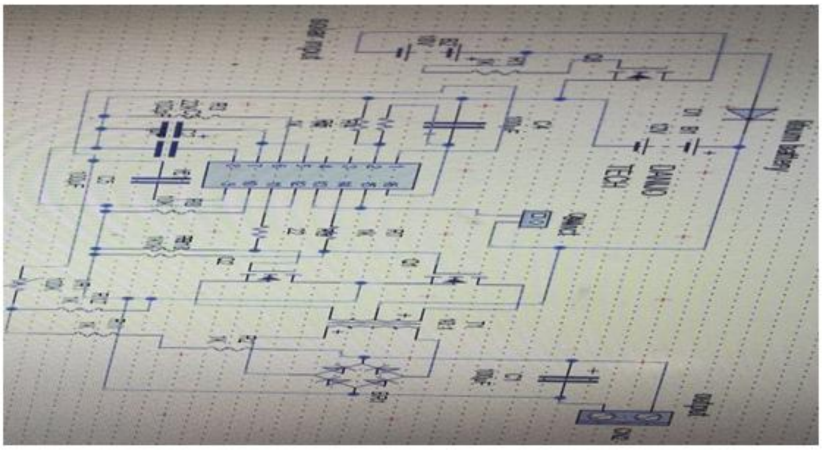


Figure 2.1: Complete System Circuit

Results

The construction is done using available components available and the complete circuit board for the system is shown in Figure 2.2 along with the arrayed 3.7 lithium battery. Figure 2.3 shows the complete system coupled in a customized package with labelled button descriptions forthe reading lamp as well as laptop charging with the system charging from a solar panel and tables 1.1 and 1.2 showing analysis done to observe the system for the period of 6 days to determine the mean period of operation when fully charged and the graph plotted using python Jupiter notebook platform.

Figure 2.2: On Board Complete Circuit and Arrayed Lithium Battery

Figure 2.3: Complete Solar Power Laptop Bank

Figure 2.4: Solar Panel

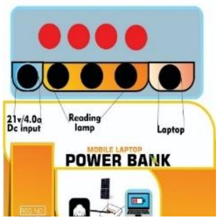


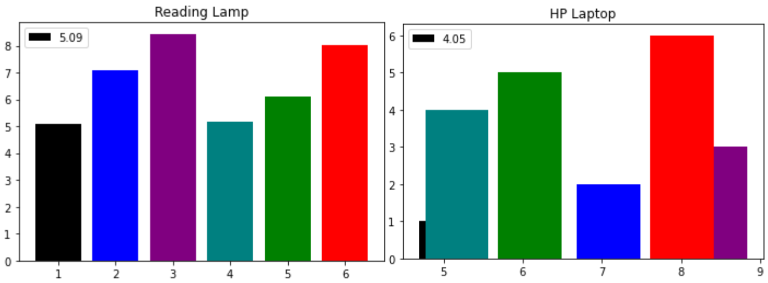
Figure 2.5: Complete Solar Laptop Setup Display

Table 2.1: 10W LED Reading Lamp Duration ON

Day	Duration (Hour)
1	5:09
2	7:09
3	8:44
4	5:17
5	6:09
6	8:01

Table 2.2: 10W Reading Lamp and Laptop ON

Day	Duration (Hour)	
1	4.05	
2	3.09	
3	4.50	
4	5.02	
5	5.06	
6	4.59	



II. Conclusion

Solar power backup has been designed and constructed using available components around us, the system was constructed to charge any laptop brands on the go. The system was put to use and shows a perfect function by changing the system full for two consecutive periods. This system was designed with a charging power of 72Wh and with a lithium 12.5Volt backup battery and laptop overcharging by disconnecting the rate when the system is full. The attached solar photovoltaic cell is 50W which helps the fast charging of the cells even when the solar energy is minimal. It has a 50W solar panel (photovoltaic) and a system power of 78Wh which can conveniently charge any laptop full twice and can as well be charged using a power supply to all available systems. The converter wattage (Capacity) of 150W, stored charge of 72Wh, with mean charging hour for the reading lamp of 6.7hrs, HP laptop of 4.35hrs with a number equivalent to 2 and total efficiency of 83%.

III. Recommendation

The design and construction of solar-based laptop power have been achieved, it’s now obvious that the system can be constructed locally in Nigeria using the available resources in Nigeria. I hereby recommend the system should be adopted by the university and financial implicit should be added so as to see how the system could be mass-produced in Nigeria, the mass production would reduce the cost of producing it drastically which will serve as a source of internally generated revenue for the school as well as Nigeria economy.

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