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Design, Development and Construction of a Solar Powered Phone Charging Box

O.O. Shoewu[1*], N.O. Salau[2]
[1,2] Electronics and Computer Engineering, Lagos State University, Lagos, Nigeria
*Corresponding author: O.O. Shoewu, E-mail: engrshoewu@yahoo.com
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ABSTRACT:

Due to increase in the use of mobile phones especially on G.S.M networks today, which according to NCC's report presently in Nigeria have over 138 Million subscribers, coupled with inadequate and sporadic electricity supply, hence for constant operation, a power solution more robust than power bank (which still requires initial charging with electricity or generator) for private and commercial use has been developed with solar as its primary source of energy. This paper focuses on the design, construction and operational advantages of portable solar powered phone charging box (PCB), for mobile phone users as an alternative to what is used today in a reformed and modernized form at school campuses, bus stops, motor parks, shopping complexes, markets, office complexes, airports, social gatherings to mention a few, where pockets of phone charging points with conventional loop wiring of about 10-25, 13A sockets supported with 900W/1.2KVA generator is used to charge people mobile phones say at a minimum rate of fifty Naira per phone. In order to eliminate noise, smoke pollutions injurious to health and also save the cost of fuelling and generator maintenance, the design and production of portable solar powered –Phone Charging Box- (PCB) became imperative.

Keywords: *GSM, Solar, Charge Controller, Electricity, Generator and Mobile Phones.*

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INTRODUCTION

Apart from availability of network services, the major concern of any mobile phone user is constant power supply on the mobile unit whose level of usage is indicated by the battery indicator icon showing rate of charging and discharging of the phone's battery.

Since the user is usually worried whenever the battery power level is getting low and especially when there is less hope of electricity to restore energy for the phone, therefore, this project provides an alternative charging system for numerous phone users today without depending on national electricity grid, which is unpredictable, but to depend on natural gift of the Sun to generate electricity, so that this part of the world remains a good place of living.

The portable solar powered charging box – (PCB) consists of a 20A solar charging and discharging controller unit, 500W inverter, 15W photovoltaic solar panel, and 12V, 18 AH Deep cycle battery. The controller unit enables the solar cell to supply 12V DC power to load and 5V DC to USB Hub while supplying power to the battery and the stored energy in the battery further supply power to charging sockets via the inverter.

The inverter unit converts the 12V DC from the battery into 220V AC for loads (AC sockets).

Problem Statement

Today most mobile telephone users either depend on national grid hydro-powered electricity which is not reliable or generator which causes noise pollution and attracts high cost of maintenance for charging their phones, in fact generators especially those ones without AVR-Automatic Voltage Regulator often destroy phone chargers and occasionally along with the phone, in order to make life easy and eliminate these challenges this project was conceived and implemented for your pleasure.

Technical Features

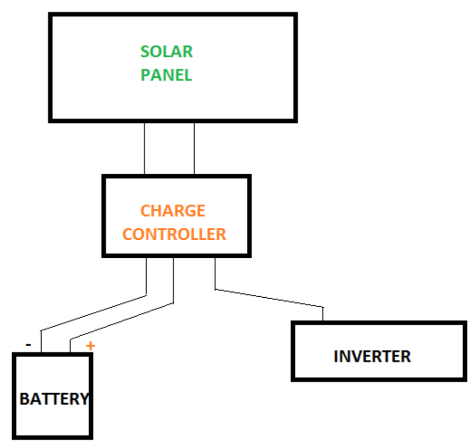

Fig. 1. Block Diagram of PCB

Materials / Components used

The following materials were used for the project

- Box (17" x 12")
- Solar Panel – PS36M15W1108109
- PWM Solar Charger Controller USB –CM 2024
- Power Inverter –DC/AC -500W
- 12V 18A.H Battery
- 4mm – Cable
- U.S.B Hub (4-ports)

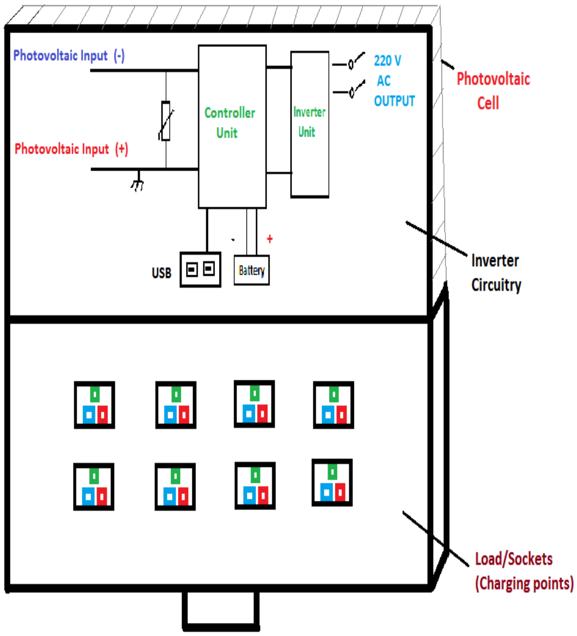

Fig. 2. Pictorial View of PCB

Description of Components used

Solar Panel

The main energy source is from solar panel unit which is used for conversion of sunlight into electricity.

Sun energy can be converted directly into electricity using photovoltaics (PV) cells as shown in figure 2 above or indirectly with concentrated solar power (CSP), which normally focuses the sun's energy with the use of lenses or mirrors to boil water which is then used to provide power. Solar panels harness the sun's power to generate electricity, provide clean power for homes, communities and businesses and help cut global carbon emissions. [1]

Photovoltaics can be utilized to power small and medium sized devices such as calculator powered by a single solar cell to off-grid homes powered by a photovoltaic array.

As shown in figure 3 below, in this project a single 15 Watts solar cell is used as transducer to convert sunlight to electric current using phototoelectric effect.

The solar cell produces direct current (DC) power, which fluctuates with the intensity of the radiated light; the DC power is further stabilized by the charge controller to a desired voltage of 5V, as USB output, and 12V D.C for battery which the 500W inverter converts to a required voltage of 220V A.C.

Fig. 3. Researcher fixing Solar panel of PCB

The Charge Controller

A charge controller, charge regulator or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, based on the battery technology, to protect battery life. Its Pulse-width modulation (PWM) characteristic is a modulation technique used to encode a message into a pulsing signal. Although this modulation technique can be used to encode information for transmission, its main purpose is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers, the other being maximum power point tracking.

Fig. 4. PMW Solar Charge Controller of PCB

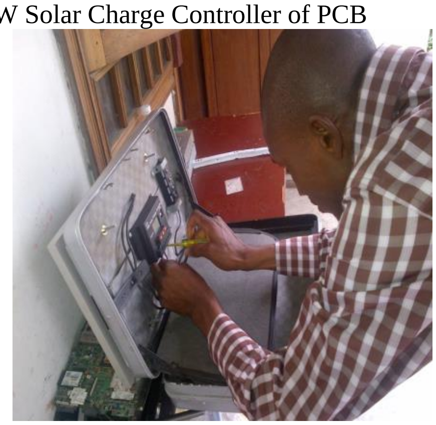

Fig. 5. Researcher fixing Charge Controller of PCB

The Power Inverter

An inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC) [2]

The inverter does not produce any power, the power is provided by the DC source, which is the photovoltaic cell as we have it in the figure 2 above.

The inverter unit only converts the DC output of the photovoltaic cell stabilized by the controller unit to a desired voltage. The inverter converts the 12V DC voltage to AC – 220V in our own case as required for charging the handsets.

Fig. 6. PCB showing the Power Inverter and DC Battery

The Battery Unit

Solar energy is not available at night, making energy storage with the use of batteries an important issue in order to provide its continuous availability of energy.

The battery unit is used to store energy supplied through the sunlight during the day to be used at sunset, for this project a-12 V, 18AH battery is used.

Batteries practically create electron flow in a circuit by exchanging electrons in ionic chemical reaction and there is a limited number of molecules in any charged battery available to react, hence there must be a limited amount of total electrons that a battery can motivate through a circuit before its energy reserved are exhausted.[3]

Batteries capacity is measured in terms of total number of electrons, but this would be huge in number hence Amp-Hour is used.

Amp-Hour (AH) is a unit of battery capacity, equal to the amount of continuous current multiplied by the discharge time that a battery can supply before exhausting its internal store of chemical energy. [4]

The USB Hub

A **USB** hub is a device that expands a single Universal Serial Bus (USB) port into several so that there are more ports available to connect devices to a host unit e.g. Laptop computers may be equipped with many USB ports.

Physically separated USB hub also referred to as an external USB was used in this project (looking similar to an Ethernet or network hub) connectible with a short cable, so that it can be directly plugged into a USB port of the charge controller. The charge controller has two USB ports by default. See figure 7 below:

It is called external USB hub because it enables one-step attachment and removal of all the devices (phones to be charged).

It is also categorized as a bus-powered hub (passive hub) since it is a hub that draws all its power from the host (charge controller) i.e. USB interface that does not need a separate power connection.

Technically the USB hub adopted for this project is electronically designed to use one or more integrated controller ICs, hence it is synonymous with high-speed, and specified as USB 2.0.

The USB's electric current is allocated in units of 100 mA up to a maximum total of 500 mA per port.

Therefore as a compliant bus powered hub, it can have no more than four downstream ports and cannot offer more than four 100 mA units of current in total to downstream devices (since the hub needs one unit for itself).

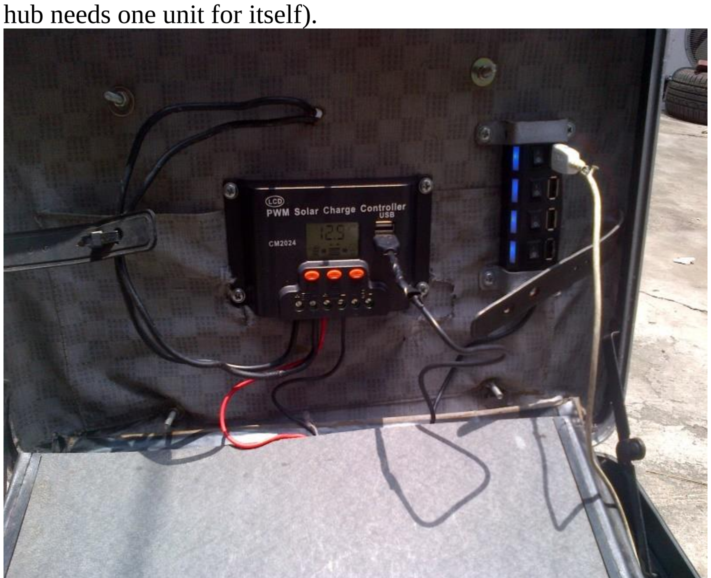

Fig. 7. PCB showing the USB Hub

Design and Methodology

The solar powered PCB consists of 15W photovoltaic solar cell connected to a 20A, 12/24V (auto) solar charging and discharging controller unit.

The solar charging and discharging controller unit enables the solar cell to supply power to load via the controller through which the connected battery is charged and allows energy retained in the 12V, 18 AH DC battery to supply power to the loads (USB Hub and A.C Sockets) during the day and at sun set.

Algorithm of Project Research Work

STEP 1: Drill appropriate holes in the Box

STEP 2: Connect the solar panel with appropriate bolts and nuts

STEP 3: Connect the cables to the solar panel that will further connect to the solar charge controller

STEP 4: Connect the Solar charge controller to the box with right screws and nuts

STEP 5: Fix the USB Hub to the Box

STEP 6: Bolt down the Power inverter to the Box

STEP 7: Fix the DC battery to the box likewise

STEP 8: Connect the cable from the inverter to the battery terminal.

STEP 9: Connect the cable from the battery terminal to the battery ports on the solar charge controller.

STEP 10: Connect the solar panel cables to the solar panel connection ports on the controller.

STEP 11: Connect the USB Hub to the charge controller for charging phones with USB cables.

STEP 12: Finally connect the multi-socket to the inverter output that supply electricity to phone chargers.

(i) SOLAR PANEL CURRENT

Solar panel rated power =15W

From Power = Voltage * Current = VI

$$I = P/V = 15/12 = 1.25 \text{ A}$$

CHARGING TIME

Theoretically the charging time of the battery is given as:

$$T = \frac{AH}{I}$$

Where AH is the Ampere –hour rating of the Battery = 18 AH and I = current of the Solar Panel

Hence $T = 18/1.25 = 14.4$ Hours.

i.e when the Battery is flat it will take 14.4 Hours to fully get charged. However due to the Charge Controller characteristics that prevent the battery from total drain when the Voltage begins to sag at full load or over loading, it was observed that it took about 5-6 Hours instead depending on the intensity of the Sun.

CHARGE CONTROLLER

The charge controller used is rated 20A 24/12V, i.e. it can accommodate up to 20A load and 12V or 24V Battery can be used due to its auto switch characteristic. See Table 1 above.

BATTERY

Its 18AH capacity is capable of powering load that will draw 18 Amps in 1Hour at 12V before getting exhausted, i.e. Voltage begin to sag below 12V.

Considering the two charger rating normally used

(i) Black Berry / I Phone : Input -100 -240V @ 50 - 60Hz, Output – 5V / 2A
(ii) Others (Chinco) : Input – 110-240V@ 50 - 60Hz, Output – 5V / 500mA

Therefore at maximum load:
9 Chargers of (i) above will be required, i.e. 2*9 = 18 A, while 35 Chargers of (ii) above will be required i.e. $500*10^{-3} * 35 = 17.5$ A
Observations are documented under discussion of results.

Protection

The solar powered PCB is equipped with measures for protection against battery counter connection, reverse discharging from battery to solar cells component at night, open circuit of batteries, battery over discharging, battery overcharging, and load over current and short circuit.

Apart from overcharging voltage and over discharging voltage of battery as well as high and low voltage of loads, the solar powered PCB can detect battery temperature and supports temperature compensation.

The inverter used also has short circuit protection feature, over heat protection and high voltage and / or low voltage protection.

Battery Connection

A GDK deep cycle 12V 18AH battery is used to maintain 12 V voltage output required for the inverter and chosen based on solar panel wattage rating for adequate charging of the battery.

Two batteries rated 12V 9AH can also be connected in parallel to give same Voltage 12V, but double current to 18AH.

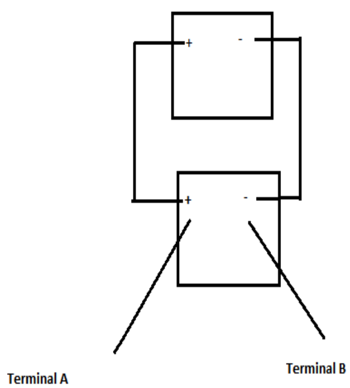

Fig. 8: Battery connection in parallel

Battery pack achieve the desired voltage by connecting several cells in series, each cell adds its voltage to the total terminal voltage, but parallel connection attains higher capacity for increased current handling each cell add to the Ampere-hour(AH) count.[3]

However, it is essential to use same battery type with equal Voltage and capacity (AH) and not mix different makes and sizes to maintain efficiency.

A weak battery will cause an in-balance especially in a series configuration, where it may not fail immediately but will get exhausted more quickly than the strong ones when on load, but in a parallel arrangement, a weak battery will not affect the Voltage but will provide a low run-time due to reduced current handling [3], therefore the need for effective battery management.

Battery Management

The solar powered PCB has shown above has about 8 AC sockets points and the battery is required to be charged regularly with at least four hours of sun energy per day after use.

The battery is also required to be replaced if noticed it no longer store required energy or discharges quickly.

Typically batteries have an average life span of 12 months, before they are considered replaced.

Testing and Results

Tests were carried out during the day and at sunset at an Airtel service point as shown in figure 9 below. Tests were done using 5-40 chargers and the result of time duration is as depicted in figure 10 below.

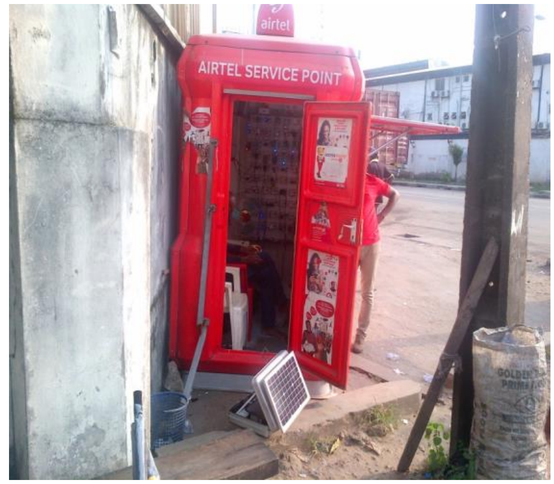

Fig. 9: PCB powers service point sockets

DISCUSSION

The solar powered PCB was tested with about 35 phone chargers with typical rating of 5V, 500mA output rating, that is at maximum use during the day and all the phones were properly charged.

Similarly, at sun set the solar powered PCB was put to test at maximum use and power supplied only lasted for about 1 Hour 12 minutes this has to do with the rating of batteries, but with lesser number of phone chargers, the PCB charges more than 1 hour 12 minutes.

The results are as shown in the table and chart below:

Table 1: No of chargers and Time taken to be charged

No of Charger	Time(Hr)
5	8
10	5
15	3.5
20	2.3
25	2
30	1.5
35	1.2
40	0.8

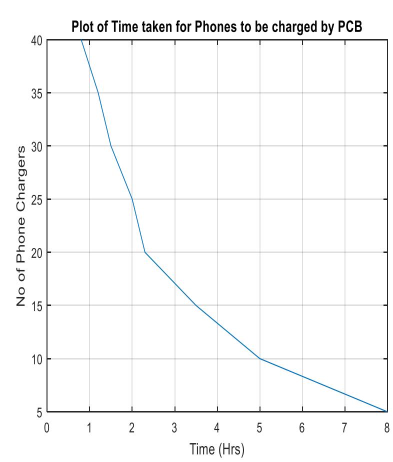

Fig. 10: Plot of Time taken for phones to be charged by PCB

CONCLUSION

Engineering is a profession that proffers solution to mankind problems through research and innovations, it is my belief if this effort is encouraged it will not only be an addition to the field of knowledge, provision of comfort to man, but it will also be a source of income generation for unemployed, private business owners and government.

Future research may include other forms of electricity sources like generator or national grid alternative source of power as additional primary source to the solar source so that its batteries can also be alternatively charged by these sources too in places where they are available.

With PCB, all you need is the SUN!

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