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Solar based Charging Stations for E-devices

M.M. Elsherbini [*, **], Amaal Ashraf [*], Hager Hesham[*], Mohamed Amr[*], Mohamed Hossam[*], Omar Mohsen[*], and Reham Mohamed [*]

[*] Department of Electrical Engineering, The Egyptian Academy of Engineering and Advanced Technology (EAEAT).

[**] Department of Electrical Engineering, Shoubra Faculty of Engineering, Benha University, Egypt.

Corresponding author: motaz.ali@feng.bu.edu.eg

***Abstract*:** Egypt's Vision 2030 revolves around green energy and the facilitation of Egypt's massive unhabituated remote and urban landmass. Such areas lack the infrastructure to support modern life, such as energy grids, so simple things like charging your electronic devices (E-devices) i.e. Mobile phone, laptop, Tablets become a hassle. In this project; by building a mobile green energy source, all beneficiaries will be capable of charging the area's residents' electronics with minimum overhead cost and environmental effect. Leveraging solar panels provides a consistent energy source in a mobile charging station for electronic devices. Due to the nature of such a project no required prior infrastructure, hence ease of applicability. Using two solar cells that convert and store light energy into electric energy in the form of both direct current (DC) and alternating current (AC) are used for charging and running different electrical devices. This station operates under the control of different authentication methods such as face recognition, fingerprint, and Radio Frequency Identification (RFID). Collectively, the three methods aim to control the service for the people meant to get their benefit from it in the needed time. Authors have developed an integrated software system consisting of web and mobile applications. The goal of that system is to help the administrator monitor the charging-station, and the data coming from the hardware system as a whole, receive alerts if something went wrong, and monitor ports usage.

***Keywords*:** Solar Cells, Green Energy, Charging Station, E-devices charger, Authentication Methods, Software Applications.

I. INTRODUCTION

As smartphones get more technologically advanced, this is quite normal as screens get wider and devices' core chips are faster, the usage and dependence proportionally increase, and keeping their battery intact has become a challenging problem for the mobile phone industry. it will not provide a core solution to the battery draining issue, but will offer an alternative side solution, Chargers, it's quite simple when your battery gets low, charge it.

Although that seems easy it's not, as you don't always find an electric outlet to plug in your phone everywhere you go. Moreover, who carries a charger in their pockets, that's not realistic, this research comes in handy here to propose a charging station just like electric car charging stations but for smart devices, these stations can be implemented everywhere at bus stations, airports, hospitals, restaurants, standalone poles, and even old town bench can be made into a charging bench. The same problem may be still counted which is, how can these stations be connected to grid electricity? Authors offer full green charging stations based on renewable solar energy making these stations innovative, efficient and sustainable, and available for all.

Also in this paper, features added for companies, industries, and other various business entities that want a station working especially for their employees only, these features are in form of authentication methods that come in three ways either face recognition, fingerprint, or RFID.

The idea of this work is built upon using the solar panels to collect power passing it to a battery by supervision of a controller to check the status of this battery and when a person comes for charging, they face three different authentication methods once he chose one method and successfully login, the battery will begin to provide a stable 5-volt on the Universal Serial Bus (USB) available.

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Our station can be monitored through a software system consisting of Web and mobile applications that allow the administrator from monitoring the system starting with the solar panel output power, temperature going through the battery level ending with charging ports status, and access methods being used on these ports.

All components used in our design can be considered semi-portable components, making the whole station easy to move to different locations. It is noticeable from all the above specifications of our product that it can be implemented everywhere making it applicable in all different places outdoors as well as indoor use. Authors will discuss the version of this product that will be commercially available to business entities the one with authentication methods as it's the harder version of our design, and will go through different procedures and various criteria leading to the choice of each component used in our design and then show implementations of the design later.

II. LITERATURE REVIEW

In [1-2]; A system is made up of a 50-watt module storing the energy in a battery linked through a charge controller. The 12-volt battery voltage is then regulated to 5 and 4 volts of the universal charging port for any mobile phone to be plugged in. The Photovoltaic (PV) module is elevated on a pole and the battery and regulating circuits are kept in proper ventilated box.

Although system can be easily integrated under street lighting systems with low cost; the number of devices to be charged is fairly not sufficient compared to number of people that would be in public places.

In [3] a Solar Charging Station (SCS) developed to charge up to four mobile phones. Utilizing a lithium-ion battery; voltage is stepped down using DC-DC converter to 5volts for USB ports and an inverter for a 120-volt AC output used for charging two laptop computers at the same time. A maximum power point tracking (MPPT) charge controller designed with “perturb and observe” algorithm to increase efficiency. The thin film PV module is to be mounted on an umbrella.

The system is effective and semi-portable using components that are light enough to be moved and but it lacks in the safety department as there was no enclosure suggested to these components that could easily be damaged and the system was not integrated on a well-designed Printed Circuit Board (PCB).

In [4], the project aims to create a versatile, solar-powered charging station featuring AC and DC plugs, as well as wireless charging pads. It is intended to have a table and seats for user convenience. It is planned to support a wide range of devices, including smartphones, laptops, tablets, and radios, for a total cost of around $650, however the system uses voltage regulators to step down the battery voltage for wireless transmitter that dissipate heat.

In [5], Street lighting Stations that Charge up to 4 devices simultaneously provide and provide 600 to 1000 Lumens of light also utilize Lithium battery for charging at night. These Systems are convenient for public locations, but they are not equipped with MPPT controllers to use up the most energy provided from the solar module. Other studies for charging mobile phones are illustrated in [6] and [7].

After reviewing some of the previous work done in the SCS technology, in case of our project and to pick up from where these projects left off, some improvements are done such as monitoring the whole system through an application that can be run by the administration of where the station is located, providing access methods to the system (face ID, finger print, RFID) in addition to free charging methods.

III. PROPOSED STRUCTURE

Figure 1 is illustrating the structure of the station divided into following stages as shown:

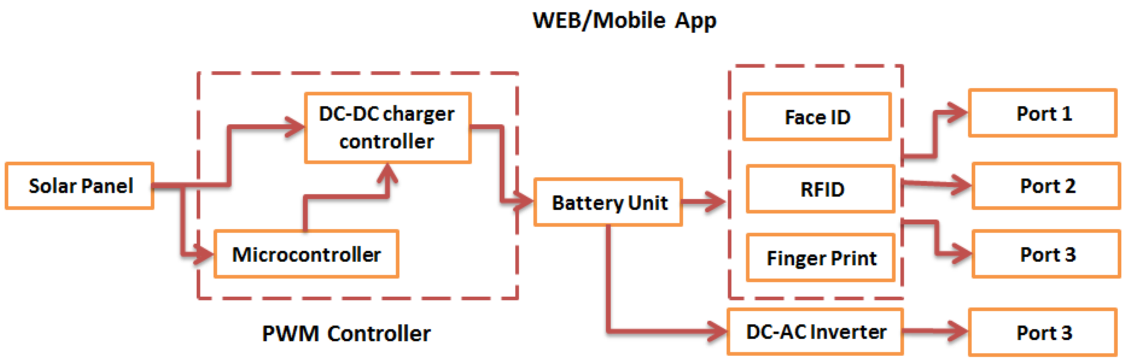

Figure 1- Proposed Structure

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Stage 1: Solar panels parameters

Used in this project two in series Kytron solar panels 160-watt each with specifications; open circuit voltage of 22.04-volt and short circuit current of 10-ampere, initial testing of the panels at noon time were of results; open circuit voltage of 20-volt and short circuit current of 8-8.88 amperes.

A. Overall current (I)

The following equation gives the overall current (I) flowing through a solar cell [**1**]:

$$I = I_D - I_L \qquad (1)$$

Where I is the overall cell current in solar , ID is the equivalent photodiode current and IL is photocurrent

B. Short circuit current (I_{SC})

The light-induced current that occurs when the load in the circuit is zero, i.e. both Terminals (positive and negative) of the solar cell are coupled together, is known as the short circuit current. The ISC in our case is 8 ampere (A) each.

C. Open circuit voltage (V_{OC})

The voltage across the solar cell when there is no current flowing in the circuit, i.e. when there is infinite resistance between the solar cell's terminals, is known as the open-circuit Voltage, the VOC in our case is 22.08 volt each. This may be calculated using the following equation [1]:

$$V_{oc} = \frac{KT}{q} \ln\left(\frac{I_L}{I_o} + 1\right) \qquad (2)$$

Where K Boltzmann's constant, and T temperature in Kelvin, q is electron charge, Io is reverse saturation current.

D. Maximum Power

A solar cell's output power is calculated by multiplying the output voltage and output current as shown below [1]:

$$\boldsymbol{P_{out} = V_{out}\, I_{out}} \qquad (3)$$

E. Solar efficiency (η_{ec})

The power conversion efficiency of solar cells may be expressed as:

$$\eta_{ec} = \frac{P_{max}}{P_{in}} = \frac{V_{max} I_{max}}{\text{Incident solar radiation} \;\; \text{Area of solar cell}} = \frac{V_{OC}\ x\ I_{Sc} x \;\; FF}{I(t) x A_c} \qquad (4)$$

Where η is solar efficiency, Pmax is the maximum power obtained from the solar and Pin the real input power incident to the solar. Voc and Isc are open circuit voltage and short circuit current respectively measured experimentally. FF is FILL factor, Ac I area of rectangular solar panel. This application must be more deeply to enhance our analysis. The station is designed to support three DC ports; each port draws voltage of 5V and current of 1-2 A for cell phones charging thus, the power calculated for each port is 10 Watt. So total power needed for the three ports= 3*10 = 30 Watt. In addition to the light system; 2 bulbs each consumes 22-watt so of 44-watt total power needed. Lastly, Hardware components used by access methods are of power consumption as follows:

1- Raspberry Pi III + ARDUINO UNO = 5.65 + 0.29 = 5.92 Watt

2- Raspberry pi camera=1.4 Watt

3- Finger Print Sensor R307=0.48Watt

4- RFID sensor= 0.858 Watt

5- Interfacing 16*2 LCD with Arduino= 200m*5=1 Watt

Thus, the total power needed for the station =10 + 44 + 30 = 84 Watt.

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Figure 2- Kytron Solar Panel [8]

A solar cell used here is 160 Watt with accuracy 85%. Authors used two solar cell panels from Benha 144 Company, one for DC functions and the other for AC features. Figure (2) shows one of the two selected solar panels.

Stage 2: Charge controller

Charge controller objective is to match between the output voltage of the solar panels and the battery voltage. The Charger circuit is Implemented using buck converter with pulse width modulation technique (PWM) to step-down from 44 output voltage of the series connection of two panels to 12 volts matching the voltage of parallel connection of two batteries. When the absorption voltage is reached, the PWM controller employs a transistor as a rapid switch to connect and detach the battery in order to keep the voltage constant and minimize the current to keep the battery safe from damage caused by heating and overcharging [**9**].

Stage 3: Battery

Two in parallel GALAXY batteries are used each has 12v - 12Ah specifications

Figure 3- GALAXY Battery

Stage 4: Output of the system

This stage is divided into 2 sub-stages which are authentication methods and charging ports in parallel with 1 sub-stage which is the inverter.

***A.** Authentication methods*

The charging controller is designed to limit the access to the station so that only specified users are allowed to charge, the controller identifies its target users using various authentication methods, once the controller verifies one of its users the charging port begins to conduct and users can charge their devices. There are three authentication methods shown in figure (4) ; (Finger Print, Face ID, RFID) made for the user to choose from or if the customer wishes to divide their targeted users into partitions either to change the specified duration for each partition or dedicate ports to different partitions. They connected to raspberry via relays.

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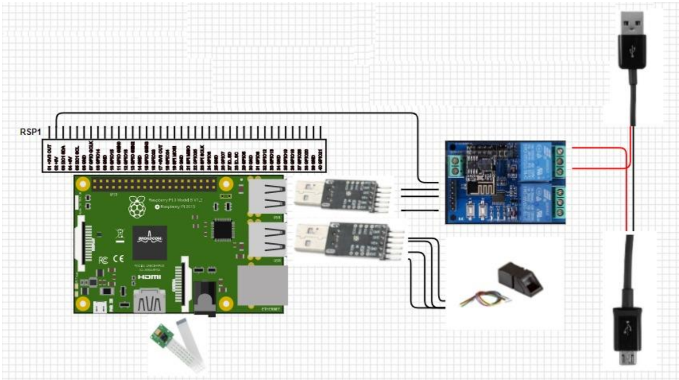

Figure 4- Finger print connection with the raspberry pi via relays

To make the interaction easier with the station we added a touch screen. That monitor helps the user to understand all the features that the station can provide with a simple way and Graphical User Interface (GUI). That GUI is used instead of using Liquid Crystal Display (LCD) with buttons which will make the process of accessing the station more complex to explain the features documentary and not all users will be able to understand that method but on the other hand, graphical user interface will make it easier.

i. Face recognition

So, what will happen if he chooses the face recognition system after-heat to click and chooses the face recognition system using raspberry pi camera [**10**]. as it fully compatible with the controller, the Camera will open and try to detect their face; after face detection, the system will match his face with the pre-configured database, and there are two options if the system found his face in the database and recognize it; either it will give access, and the user will start using the system, or the system can't find his face in the databases the system will close automatically after 30 seconds. Here in our system, we used this method to be only available for Professors, Associate, Assistant professors and teaching assistants.

ii. Fingerprint

The second method of our system is fingerprint using R307 module as it benefits in the capacity factor; when the user choses this option, it will give him two other options, it will ask them if they want to scan their fingerprint or enroll a new fingerprint, and they choose enrolling a new fingerprint the system will take their fingerprint and store it in the database with his academic ID [**11-12**].

The second option is to scan his fingerprint here after putting his finger on the sensor will take his fingerprint and search for it on the database if the system found his fingerprint in the database it will give him access to the charging otherwise the access will be denied. This method is available for students.

iii. RFID

The third option to have that access to our system is the RFID card using MFRC 522 as it is less power consuming and it's so easy to use there will be a sensor to read this RFID card and that sensor will it give the access to a specific RFID card if the user has one of it the system will give him the permission to the charging otherwise the access will be denied [**13**]. This method is available for employee.

B. *Ports*

In the system we have 3 ports for the devices that can be used in the charging process. These ports are supported by the raspberry pi. In addition to one extra port which is supported by the inverter, this port is meant to be used in lighting system integrated in the station for users who use it at night.

C. Overall design of the converter

The System consists of two voltage sensors and a current sensor used to calculate the power output of each solar panel, followed by directional current protection to prevent current reversal from the battery to the solar panel in case the overall power of battery exceeds the power generated by the solar panel, followed by a power converter we opted for a Buck Converter with PWM technique to match the 44 volts output voltage from the solar panel with the to 12 volts output voltage of the battery. Using the battery's voltage read by a voltage sensor, the system regulates the converter's duty cycle to prevent overcharging, for battery protection the system prevents any device charging at battery voltage of 12.32v to increase the battery lifetime. The voltage readings of the battery and the solar panel are sent to a controller which regulates the voltages and denies current reversal hence protecting both the solar panel and battery, figures 5, 6 and 7 illustrates the overall system schematic, PCB and

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breadboard circuit. The PCB consists of double Layers, due to its special high power constrains, it was fabricated on China.

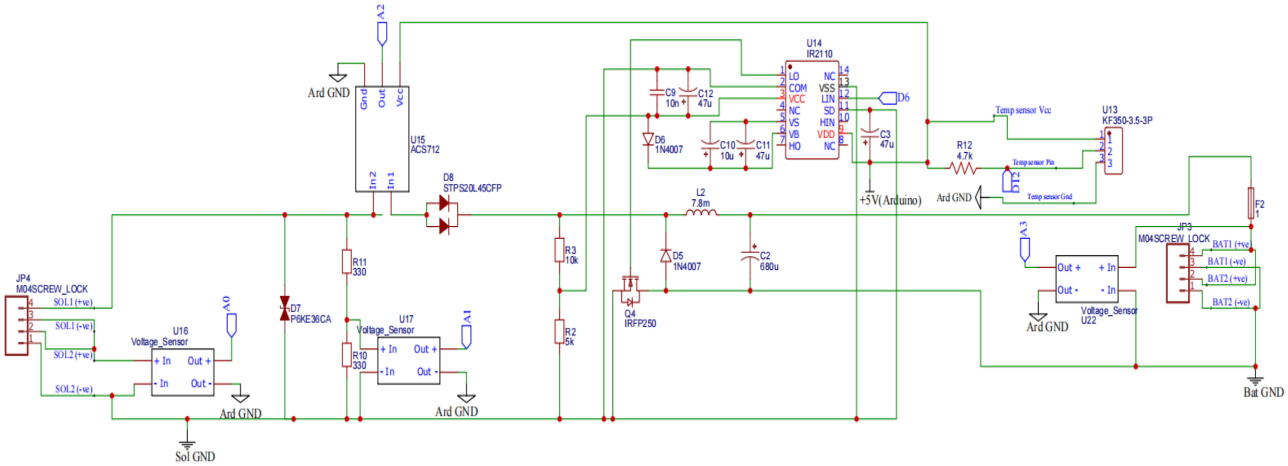

Figure 5- Overall controller Schematic using Proteus simulator

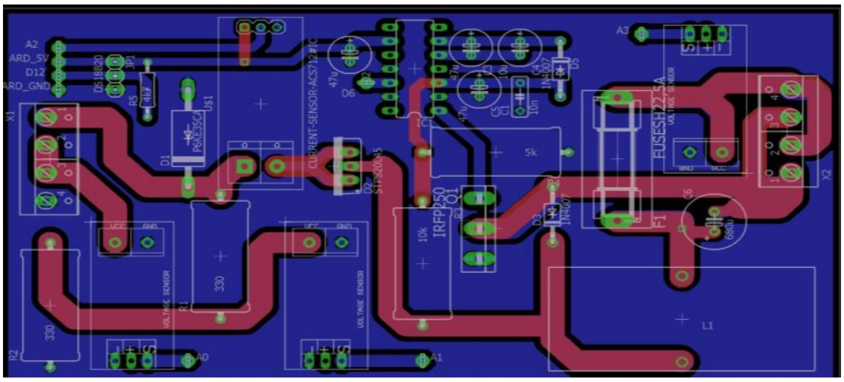

Figure 6- Overall System Layout Design using EAGLE layout

Figure 7-overall system PCB

DC–AC Inverter

The table 1 below compares between our designed inverter and commercial power inverters. Due to high cost of the transformer; a used one is selected instead with 20% of the original cost.

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Table 1 - Designed vs. Commercial Power Inverter **[14]**

Comparison points	1100 watt designed Power Inverter	1000w commercial Inverter
Input voltage	12v or 24v (DC)	12V DC volt
Output voltage	220 AC volt	220 AC volt
frequency	50/ 60 hertz adjustable	60 hertz
Power	1100 watt	1000 watt
Output wave form	Pure sine wave	Modifies sine wave (square wave)
price	Components price 700 EGP Transformer price 2500 EGP	800 EGP
Protection features	Low voltage protection Over V/I/T protection	Reverse connecting protection Over I/T protection Stable output voltage.
Reading Tolerance	90%	80%
Additional features	Could be modified to hold 10Kwatt	2 USB ports (5v/2A) Battery charger (12v)

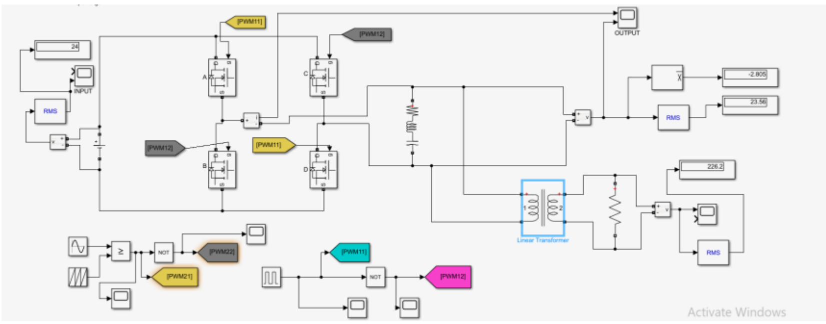

Figure 8 - Designed Inverter Circuit

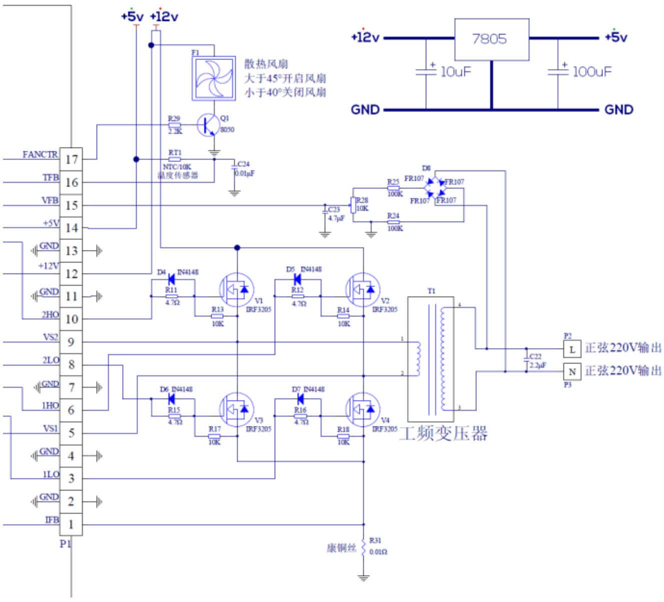

Figure 9- Commercial Inverter Circuit using Multisim simulator

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Stage 5: Software Applications

Authors have developed a software system consists of Web based application in addition to mobile application that allow the administrator from monitoring the station. The admin is allowed to monitor the solar panels reading (power - temperature), batteries level and ports status (busy- available).

A. Web Application

Web application model One Web Server, One Database simplest and least reliable model is to use single server - single database. Web application architecture Legacy Hyper Text Markup Language (HTML) web app it's consisting of business logic and web page construction logic [**15**]. Since the server is storing all data and logic of this architecture it is very secure, as the user has no access to it.

Responsive Web Design (RWD) is a way to make the web application adaptive with all kinds of browsers and varies with different sizes.

The following workflow in figure 11 illustrates the logic behind the Application Programming Interface (API) in our system. As the user selects and utilizes an access method and selects a charging port, the user's request is sent to the server database. If the user is authorized and the selected port is available, the port opens for charging; once the user finishes, their usage data such as remaining time in his subscription is sent to the database, and the port closes.

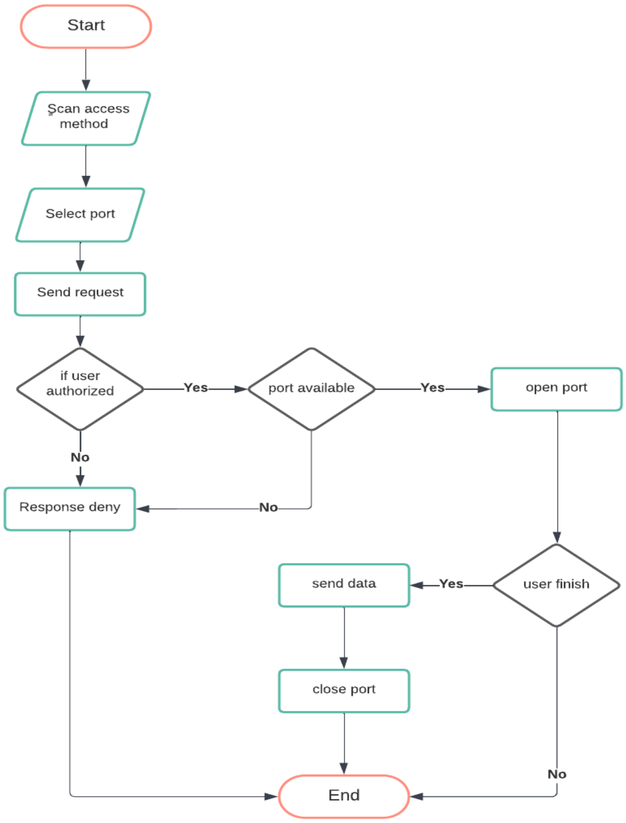

Figure 10- API flowchart

B. Mobile Application

The aim of the mobile app is to display and monitor the data by the administrator coming from the hardware, at anytime and anywhere. In addition to the problem of following up on subscription status by the user. The mobile app is developed in flutter which is framework from google based on dart programming language.

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IV. RESULTS

A. Charging Solar Panel System:

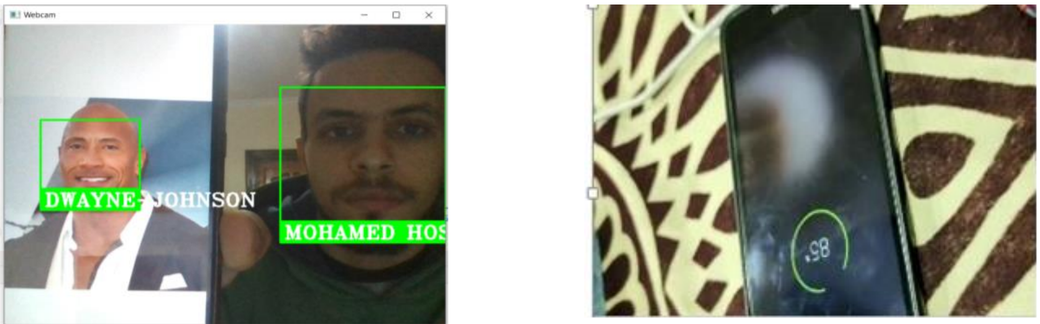
The Results below are taken in test for the first 3 stages of the system with one solar panel connected to charge one battery as a load. the solar panel outputted 20 volts under the test's weather conditions thus, the power converter's duty cycle is set at 60% so that the output voltage is sufficient for battery charging starting voltage of 12.9 as shown in figure 11(a) up to voltage of 13.18 as shown in figure 11(b). The last two figures are 5 minutes apart.

(a) **(b)**

Figure 11: (a) battery before charging , and (b) after 5 minutes charging

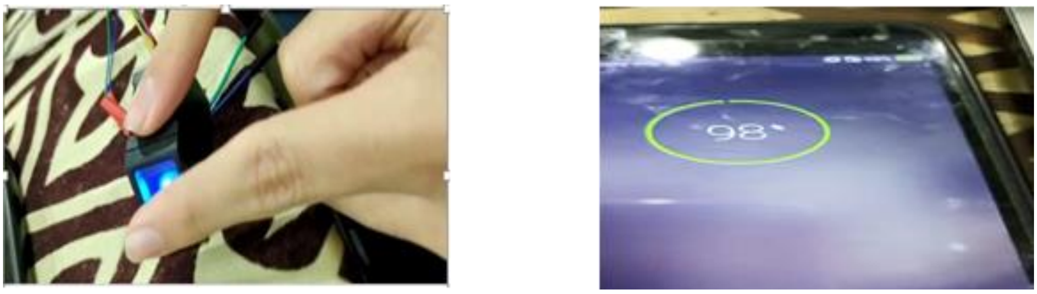
B. Sensors result

DC Charging ports are controlled with the authorization of access methods once authorized the port becomes available for charging as shown in fig12 (a) and (b) for the face ID authentication method, also fig 13 for finger print method, lastly fig 14 for RFID method.



(a) **(b)**

Figure 12: (a) face ID test and (14) face ID charging Test



(a) **(b)**

Figure 13: (a) fingerprint test , and (b) fingerprint charging Test

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(a) **(b)**

Figure 14: (a) RFID test, and (b) charging test

C. LCD results

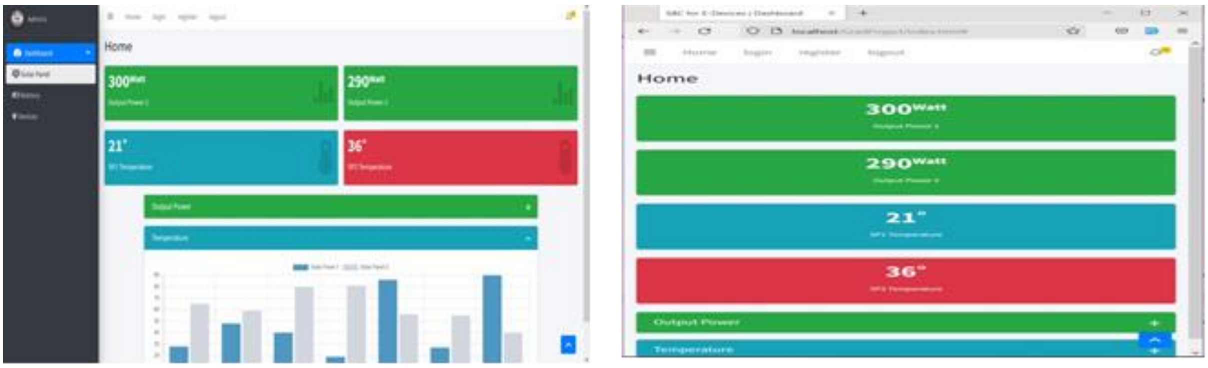
Interface method with the user is performed through LCD to show the ports available and the authentication method needs to be used to gain access for charging as shown in figure (15).

(a) **(b)**

Figure 14: (a) Login Interface, and (b) Authentication Method Selection of Touch screen LCD

D. Web Application:

Figures 16: (a) and (b) illustrate the outputted system data from an admin perspective and the web application responsive design.



(a) **(b)**

Figure 16: (a) WEB interface statistics and (b) Monitor status page

E. Mobile application:

For the mobile application, figure 16 is the User interface (UI) displayed in user account. While figures 17 a, b and c show the user interface for system admin.

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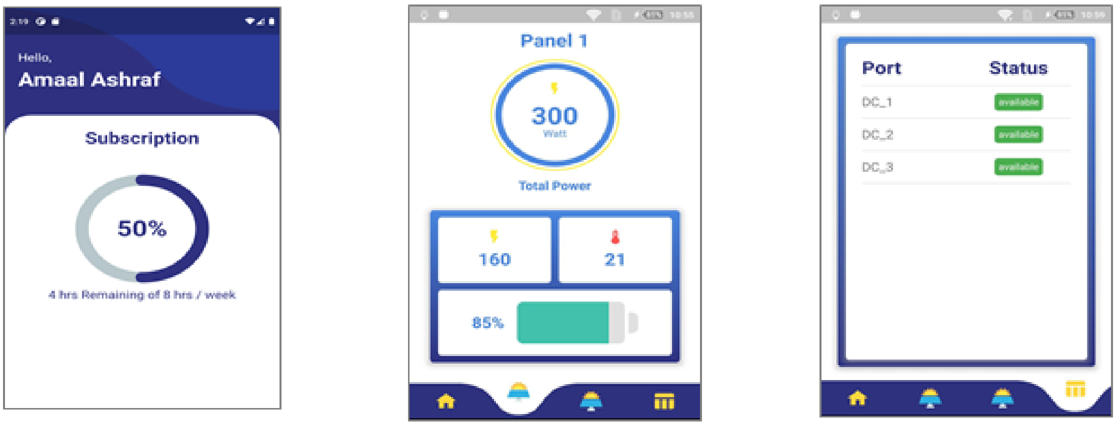

Figure 17: Mobile App. (a) User UI , (b) Admin UI_1 and (c) Admin UI_2

The total E-Mobile station integration starting with the power source being the two solar panels charging two batteries through a buck converter, the battery system power is then divided between the DC charging ports and the AC port outputted from a DC-AC inverter. In addition to LCD being the interface module with the user.

Figure 18: Overall Integrated System installation

V. CONCLUSION

As the main purpose of this work piece is to aid the steady integration of green energy projects starting from remote land mass reaching many vital areas, a solar based smart charging station for all kinds of electronic devices (mobiles, tablets…etc.) is implemented using two solar panels in series connection of 160-watt each tested successful in feeding two batteries in parallel connection of 12-volt each through a buck converter designed with PWM technique. The output of the batteries branched to three DC USB ports of 5-volts and 1-2 ampere each controlled by the authentication of an access method varying from (FACE ID, FINGER PRINT and RFID) to help control the usage of the station's power, in addition to an AC port as an output of 12-220volt dc-ac inverter for laptops. The system is provided with protection circuitry for the panels that is a directional current protection prevent current reversal and a charging system programmed to prohibit drawing current from the battery system at a voltage of 12.32 to prevent over discharging. The station is monitored by an administrator of its location, any charging process needs to be authorized by an algorithm as follows; as the user selects and utilizes an access method and selects a charging port, the user's request is sent to the server database. If the user is authorized and the selected port is available, the port opens for charging. The user is able to observe the remaining charging time for them at all times via mobile application.

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