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Establishment of Solar Powered Green Canopy Smart Device Charging Station

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Abstract— Solar powered canopy style smart device charging station is a new and very unique idea in the context of Bangladesh. Student or other official personnel of any public or private organization will be beneficial if they find their work place, equipped with such useful, sustainable power station with sitting lounges where they can relax, can do group studies or work and can charge their smart devices i.e.; laptops and smart phones in an environment friendly way using renewable solar energy. With this point of view, this paper represents development of a canopy style solar energy based smart device charging station having capacity of 600W, with 200 Ah battery backup at Patuakhali Science and Technology University campus. This could be an iconic idea of using green energy and to serve people with electrical energy conserving the natural ecosystem harmlessly.

Keywords—Solar canopy; solar powered bench, solar charging station; smart device charging lounge.

I. INTRODUCTION

Among 99.9% energy flow on Earth's surface as solar energy, our percentage of use is negligible [1]. Conversion of solar radiation through PV cells have now been used in various off grid, on grid and battery supported daily life applications likewise in large aspect such as commercial power projects as well as in small domestic run for example rural electrification, solar water pumping, to dry agricultural products etc.[2,3,4]. Our lifestyle has been changing day by day and getting gadget dependent. Mobile phone is such an evolutionary gadget that it is opening new door of technology every day and has changed its identity from a simple wireless phone to a rather impressive and entertaining smart phone. Smart phone comprises complex but powerful software and hardware circuitry for all of its applications or gadgets to perform well which causes a lot of power consumption. Use of data packet service which keeps running even when the phone is not in use can cause quick draining of battery and people can suffer low battery problem within a couple of hour after the battery was fully charged. Portable solar charger that uses PV cell to convert solar energy into electric energy and then stores in battery; is an alternative to expensive and heavy battery banks. But the generated power is insufficient to fulfill the user demand [5, 6]. At those points people rush to nearby shops or restaurants to recharge battery of their smart device. Our paper presents an idea to put an end to these sufferings and introduce mobile canopy charging stations where green energy will be converted to electrical energy which can be used to charge mobiles and other portable electronic devices. The canopy bench solar panel systems raised above a canopy top that allows maximum energy absorption while providing comfortable shaded seating below.

This unit can work alone or can be grouped in doubles or quads to create a unique seating arrangement or "Smart Charging Lounge" when coupled with Wi-Fi Hotspot [7]. Parks, zoo's, community centers, university campuses where people usually go for group study or business purpose, for a walk or just to relax, are ideal places to install canopy bench type charging stations as it provides free internet connectivity, comfortable shaded place to sit and relax and most importantly emergency charging facility.

II. System Structure and devolopement

2.1. Methodology

Solar energy is the richest among all other renewable sources. A solar cell, also called photovoltaic cell, is thus a device that directly converts solar radiation into electricity. It is based on the photoelectric (or photovoltaic) effect [1]. PV cells capture energy from sun as photon which frees electrons which can flow through the cell. Upon appearance of a slightly created electric field the electron movement become unidirectional and through a wire outside connecting two terminals, electrons as well as current can flow through the wire. The performance of solar cell depends on various environmental factors. Two main parameters are solar irradiance and temperature. Irradiance has a proportional impact where temperature effects inversely. Other factors are cloud cover and angle of exposer to the sun [2].

2.2. Selection of equipment

- *Solar Panel*

A solar panel is a group of electrically connected photovoltaic cells made of most common semiconductor material silicon [8]. Typically they have a lifetime of 25 years [9]. Among 3 types of panels, mono crystalline and thin film seems the best for long term public usage.

- *Battery storage*

Solar panels can generate power only during daytimes. So storage battery is required for using it at night. Batteries that can be frequently discharged down to such a value (at least 50% or even 80%) are called 'deep-cycle' batteries and are intended to use in solar power systems. Fig.1 shows a complete block diagram showing the system connectivity.

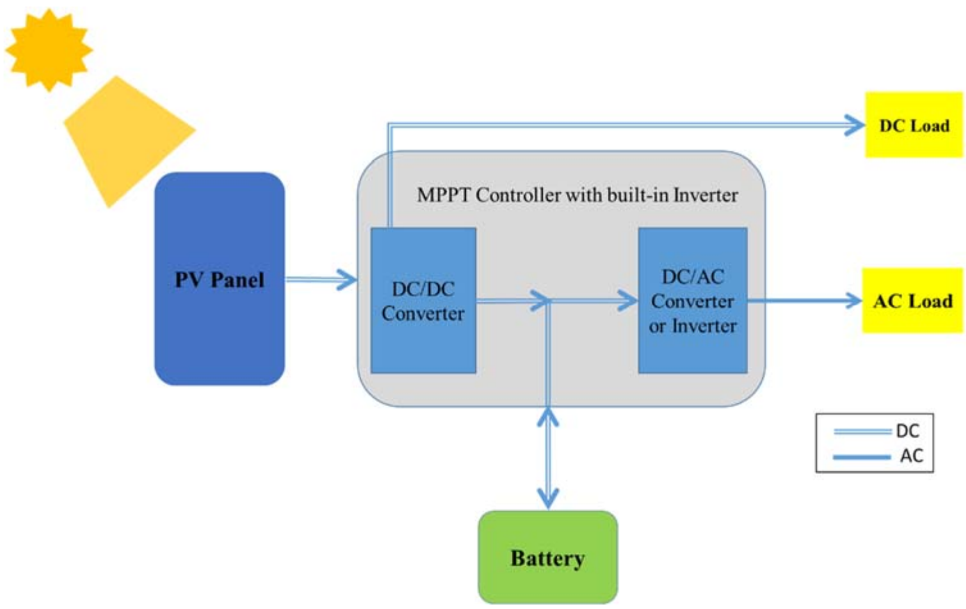

Fig. 1. Block diagram of complete system showing connectivity of major equipment

- *MPPT Charge Controller with inverter*

A charge controller performs regulation of voltage and current in between solar array and battery that protects the battery from overcharging or over discharging. It can control charging at the correct voltage. It can connect and disconnect the solar charger to the batteries thus protects the battery from damage [10]. MPPT (Maximum Power Point Tracking) charge controllers are expensive yet popular over PWM ones since those are 30-40% more efficient at low temperatures [11].

The main function of an off-grid inverter is converting the output voltage of either the battery bank or the solar array to AC voltage. It is not mandatory for every off-grid solar system. An inverter is not needed, if power is to be provided to DC loads only. An off grid inverter can be connected directly to the solar panel or through battery bank. Since our structure is going to be used after day time also, battery storage is must. An MPPT controller with built in inverter will be suitable for our system structure [12]. Total system connectivity with storage and inverter controller is shown in fig.1.

2.3. System Sizing and Design

The features need proper sizing are solar panel, battery, charge controller and inverter. All the factors are related to each other and to the peak load condition the system needs to serve. The inverter should handle the DC power provided by the battery and supply it to AC loads. The inverters continuous ratings should be a bit higher than both the peak power of the solar array and also the total ratings of all the loads intend to work at the same time. Inverter input voltage should also match our system voltage.

- *Load Consumption*

For the total structure to be planned the first step is to estimate the energy requirement. As it will be installed inside our PSTU campus we need to configure the structure according to student demand. The two most important things they use randomly are mobile and laptop and we have to consider the working period from 8am-8pm (12 hours). Firstly our plan is to provide 4 mobile charging ports and 1 laptop charging port. For a rough estimate of the power consumption of these devices, assuming 60 watt for laptop and 10 watt for mobile phones, load consumption during day time (for 6hours) can be calculated as shown in table 1:

TABLE I. LOAD PROFILE/ DIRECT POWER CONSUMPTION DURING SUN HOUR

Device	Wattage w	Quantity	hours	Total Wh per day
Smartphone	10	4	6	240
laptop	60	1	6	360
Total power usage W/h	=100			600

The load profile shown in table 1, is assumed on least usage. Developed system can support more devices like 2 laptops and 5/6 mobile phones simultaneously during day time.

- *Battery Sizing*

Considering 6 hours of backup per day after sunset and usage of 100 W per hour; the average daily energy target for battery (Eday) turns out to be 600 Wh. The equation used here for determining minimum battery capacity for average 6 hours of backup [8]:

$$Q = (Eday * DoA * BTM) / (DoD * CE * SV)$$

- Q is the minimum battery capacity required (in Ah),
- Eday is the average daily energy target (in Wh*)= 600 Wh*
- DoA is the Days of Autonomy =*3,* (Assumed)
- BTM is the Battery Temperature Multiplier =*1* (Negligible)
- DoD is the permissible Depth of battery Discharge = *80%*

- CE (Cable Efficiency) denotes the losses in the cables = *95%*(Assumed)
- SV is the System Voltage =*12V* (for small system)

TABLE II. BATTERY SIZING (CONSIDERING 6 HOURS OF BACKUP OUT OF TOTAL 12 WORKING HOUR)

Backup hr	E_{day}	DoA	BTM	DoD	CE	SV	Battery Capacity, Q AH	≈Q Ah
6	600	3	1	0.8	0.95	12	197.3684	198

- *Estimation of Solar Panel*

Solar panel should have enough capacity so that it can charge up 198 Ah battery and be able to power up smart devices connected for charging, all together simultaneously during day time. Total power of the panel required can be figured out from table 1 and 2,

Direct Power consumption during sun hour = 600 Wh

Power consumed by battery for backup = 198 Ah×12 V=2376 Wh

Total power needed to be generated per day = 2976 Wh

Total power needed to be generated per hour = (2976 Wh)⁄(Avg Sun Hr)=(2976 Wh)⁄6h=496 W

Total power needed to be generated should be higher than total power required, compensating system inefficiencies. A multiplication factor of 1.3 was used considering the stated fact [5].

Thus total power of solar panel required =496 W×1.3=644.8 W≅645 W

Considering architectural design and convenience, the additional 45 wattage had been ignored and our system capacity was finalized as 600 W. 4 solar panels of 12V, 150 W was chosen to develop system structure.

Panel specifications:

Unit	Rated amount
Dimension(mm)	670*1400*35
Rated Maximum Power (Pmax)	150 W
Tolerance of Pmax	±3%
Rated Voltage (Vmp)	18 V
Rated Current (Imp)	8.57 A
Open-Circuit Voltage (Voc)	21.5 V
Short-Circuit Current (Isc)	9.08 A
Maximum System Voltage	700 V DC
Maximum series fuse	15 A
Module Weight (kg)	9 kg

2.4. 3D System Design

Fig. 2 shows 3D preliminary system design that was done before system development.

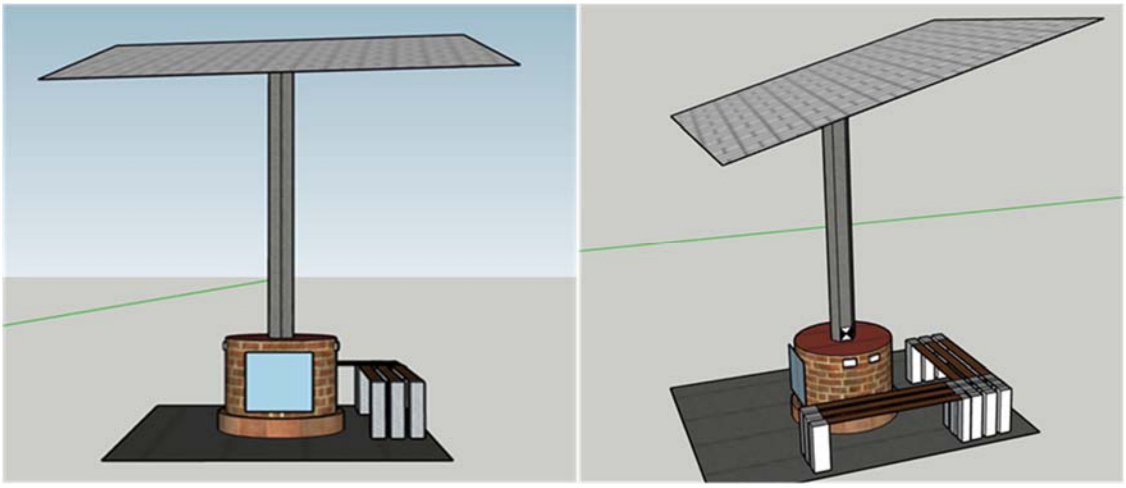

Fig. 2. Preliminary 3D system structure

Software based 3D structure was followed during the establishment of the system. Fig. 2 shows front and right, side view of the entire system architecture.

The main structure consists of a large canopy made by 4 solar panels of 150 W. A central strong SS beam supports the canopy structure. A round shaped hollow RCC structure at the center, keeps the electrical entities (battery, controller with inverter, circuit breaker) inside and also holds the DC, AC device charging ports or sockets on its round shaped side wall. The top surface of the RCC hollow structured chamber, serves as the round table or workspace. Since it is an outdoor structure, sockets are installed inside waterproof safety boxes with lid. The whole space is under coverage of an automatic motion sensor light to facilitate it's usage during night time. The sitting lounge was slightly modified from the preliminary design considering the space allowance. Instead of a one L shaped bench the actual system consists of two single SS bench placed face to face on right and left side of the round RCC structure. The base part and the whole round RCC hollow table is furnished with tiles. Fig. 3 shows the real pictorial top view of the established system structure.

Fig. 3. Top view of the system structure

III. Result Analysis

3.1. Voltage and current from solar panel without load

This analysis reveals the performance of the solar panel installed in the system. The measurements of voltage and current were taken at four different times of the day to analyze four different solar condition or solar insolation. Tab. 3, bellow shows the meter readings of open circuit voltage and short circuit current obtained from one single solar panel out of four since all the four panels are of same quality and have same capacity. Data readings were taken on four different times of a particular day observing four different solar intensities.

TABLE III. VOLTAGE AND CURRENT OBTAINED FROM SINGLE SOLAR PANEL

Sl. No.	Solar Insolation	Voltage, V (open circuit)	Current, A (short circuit)
1.	Mid Sunny	20.7	7.6
2.	Too Cloudy	19	2.9
3.	Cloudy	20.3	4.9
4.	Sunny	21	7.9

From the data measurements it is clear that, weather plays a vital role in case of current obtained from the panel. Due to sudden change in solar intensity, current changes abruptly whereas the change in voltage is very little or negligible (fig. 4).

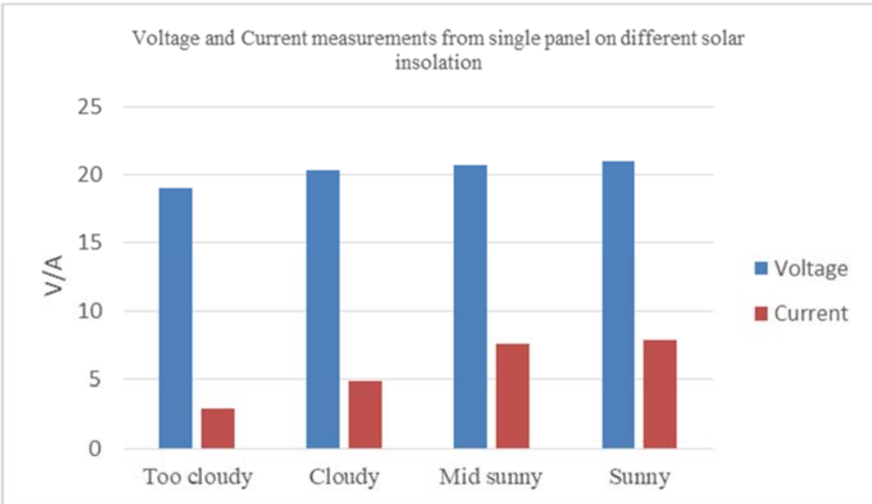

Fig. 4. Voltage and current measurements from solar panel

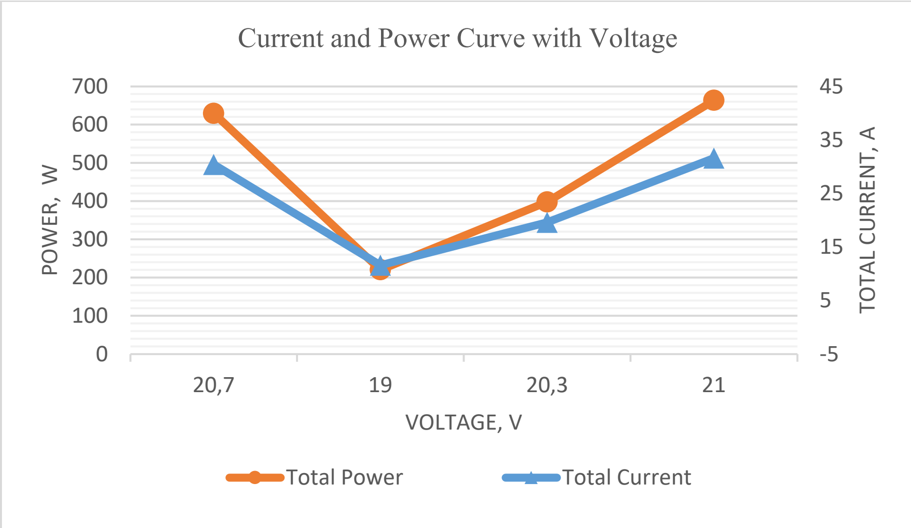

Fig. 5. Power and current curve with voltage for total system

Our Green Canopy Smart Device Charging Station has total 10 charging ports among which, 6 are AC ports for laptop/ mobile and 4 are USB ports reserved solely for mobiles. Though our system is of 600W but due to some system loss the actual output for any average sunny day, found out to be 477.79 ≅ 478 W approximately (from fig. 5). Thus even on any average sunny day, the system has capacity to serve more no. of devices at a time than recommended. The charging station can charge more than five devices simultaneously (including more than one laptop) but in that case battery charging will get little slower and charging process of smart devices may also become slower than normal.

3.2. Battery charging time

On a normal sunny day, current of 7A can be obtained from a single panel on average and summing up from other three more panels, we can say our system will be able to avail 28 A current on average. Again since our system includes MPPT controller with built in inverter; system output will always be at 12 V. So with that power rating our system storage battery of 12V and 200Ah capacity will take almost *200Ah/(28 A)=7.14 H* ≅ 7 hours to get fully charged in no load condition and for a highly sunny day the time requirement can be reduced down to *(200/32= 6.25)* ≅ 6 hours as the system current on a sunny day have found to be 8A from each of 4 panels. The system has been designed such that it can simultaneously provide charging facility to smart devices while storing extra energy to battery storage for using after sun set. According to preliminary system design, maximum no. of devices that are allowed to be connected at a time, is limited but not restricted to one laptop and four mobile phones. That means, up to that no. of devices the developed system will be able to serve smoothly while storing charge to the battery at its required rating of charging current. Once the battery gets charged it can provide 18 hours of continuous power backup for our estimated no. of smart devices.

IV. Conclusion

Here we have conducted primary calculations overload profile and according to that a solar energy based canopy style smart device charging station has been established. The structure has a nice view with sitting lounge to sit and relax. The workspace looks suitable for group studies too. System being validated to have the capability of providing charging facility to basic smart devices with expected power output. Laptops and smart phones found to be charging as fast as charging from mains.

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