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Design and Fabrication of Solar Tree

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Abstract: Recently with the rising population and energy demands to get an opinion of renewable energy source, which should not cause to pollution or natural hazards, solar energy is the best alternative. A solar power tree is the best innovative way, which requires very less place to produce energy efficiently, which is much better than the traditional solar Photo-Voltaic (PV) system in the area point of view and more efficient. Though it can be implemented all types of land and movingly focus on the development of remote and socially backward areas when there is a lack of electricity.

Keywords: Fibonacci series, PV cell, solar cells, solar energy, spiralling phyllataxy

1. Introduction

There is a big hue and cry over energy crisis from all over the world mainly for two reasons, firstly the natural resources are going to be exhausted very soon and the other is whether we should continue with the available natural resources of carbonaceous compound which is posing threat of greenhouse gas effect to human being every day. People are trying over different sources to find out non-conventional energies, mainly some sort of renewable source of energy or the green energy like solar energy, wind energy, tidal power, hydro power etc. Power from sun, is the only major alternative in comparison to other sources of renewable energies presently being tried to replace the conventional source of energies like coal, gas, oil etc. There are many ways being devised time to time for absorbing the sun rays coming towards the surface of earth, but most other methods of sun absorption like reflection, concentration, water heating etc. are the costly and complicated and efficiency is also less compared to PV modules. A solar tree is most relevant and economical way of harnessing the solar energy. It can harness the energy occupying less space as compared to traditional methods. An attempt is made to design and fabricate solar trees for the remotely located individual households by reducing or avoiding the electric energy consumption. Considering the minimum power requirement for a single household, the design analysis is done and a solar tree can be fabricated and installed in the premises of the house so as to fulfill the power requirement.

2. Literature Survey

The chapter reviews about the previously published articles and literatures, and by performing an online research for information related, which lays the foundation and basic for the further work.

Bharat Raj Singh and Onkar Singh [1] the solar energy is genesis for all forms of energy. The geographical location of India stands to its benefit for generating solar energy was discussed.

Immanuel Alphonse et al. [2], the designing of a solar powered Brushless Direct Current (BLDC) motor driven electric vehicle was done. Immanuel selected the appropriate components for the application and the various components for the same are subjected to various tests, cross checked with simulation results.

Fig. 1 solar tree structure

C Bhuvaneswari et al. [3] a new solar technology that emulates how trees convert sunlight into energy. Trees, shrubs and plants use an inherent structural design to expose their leaves, height dense to sunlight for photosynthesis.

Adis Muminovic et al. [4], solar tree represents steel construction that with its appearance reminds of the tree, on top of which are solar panels that by collecting solar energy, mobiles and portable computers will be charged. Also it can be used for charging of info panels and street lighting.

3. Components Selection

There are several components that are being used in the solar tree. The various components used are explained below:

- Solar panels
- Pipes
- Batteries
- Solar Charge Controller
- Solar Panel Tilting System

The Fig. 2 shows the 3D model of solar tree.

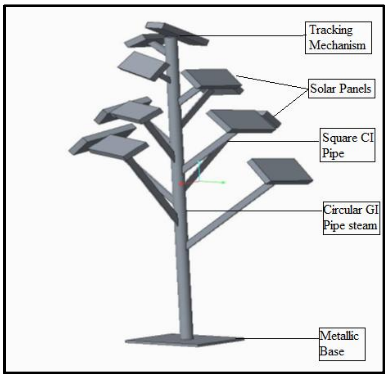

Fig. 2 3D model of solar tree

3.1 Solar panels

A solar panel is a series of interconnected silicon cells joined together to form a circuit. In greater numbers the amount of power produced by these interconnected cells can be increased and used as an electricity production system. Solar panels come in different sizes for different purposes. Mono-crystalline solar panels are slightly more expensive, but also slightly more space-efficient. If there is one poly-crystalline and one monocrystalline solar panel, both rated 220-watt, it would generate the same amount of electricity, but the one made of mono-crystalline silicon would take up less space. Fig. 3 shows the solar panel used.

Fig. 3solar panel

To make solar cells, the raw materials silicon dioxide of either quartzite gravel or crushed quartz is first placed into an electric arc furnace, where a carbon arc is applied to release the oxygen. The products are carbon dioxide and molten silicon. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current that is, electricity. In the solar tree 12V capacity solar panels are being used having 12W power. This is made of mono-crystalline silicon as it occupies less space and cost effective giving equivalent amount of power as other type of silicon solar panels based on the capacity. The size of the solar panel is about 0.5×0.4m from its length to its breadth and thickness of 0.03m. The total amount of energy that can be produced in an hour by solar tree is 144W.

3.2 Pipes

Solar PV modules are mounted on a single tall pole made of Galvanized Iron (GI) pipe having diameter 3 inches and 12 feet height. The branches of the solar tree are made of cast iron and are square in shape. The branches are tilted at an angle of 40-45^0 for acquiring more amount of sun rays.To get the required power for the small household purpose total of 11 branches are being installed containing solar panels at the tip and the top of the pole consists of one solar panel having tilting mechanism to tilt the topmost solar panel at different angles through the day. The fig. 4 shows the circular stem of the solar tree.

Fig. 4 circular stem

3.3 Battery

Here the use of 12V lead acid batteries is made. Despite having a very low energy to weight ratio and a low energy to volume ratio, its ability to supply high surge currents means that the cells have a relatively large power to weight ratio. These features, along with low cost, make it attractive. As battery used here isof less cost compared to newer technologies, lead acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. Large format lead acid designs are widely used for storage in backup power supplies in cell phone towers. Due to this reason lead acid battery is selected for storing of power from the solar panel. The fig. 5 shows the lead acid battery.

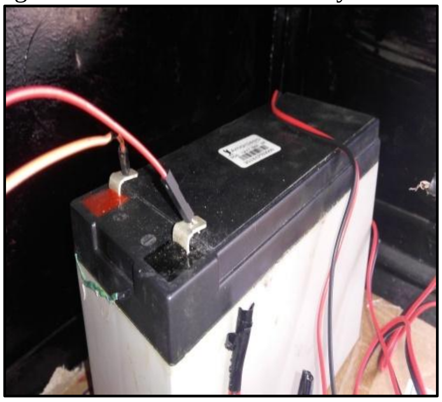

Fig. 5 lead acid battery

3.4 Solar 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 a battery or perform controlled discharges, depending on the battery technology to protect battery life. The fig. 6 shows the solar charge controller.

Fig. 6 solar charge controller

3.5 Solar Tracking System

A solar tracker is a device that orients a payload toward the Sun. Payloads are usually solar panels. For flat panel photovoltaic systems, trackers are used to minimize the angle of incidence between the incoming sunlight and a photovoltaic panel. This increases the amount of energy produced from a fixed amount of installed power generating capacity.

In Concentrator Photo-Voltaic (CPV) and Concentrated Solar Power (CSP), trackers are used to enable the optical components in the CPV and CSP systems. The optics in concentrated solar applications accepts the direct component of sunlight light and therefore must be oriented appropriately to collect energy. Tracking systems are found in all concentrator applications because such systems collect the sun's energy with maximum efficiency when the optical axis is aligned with incident solar radiation. The energy contributed by the direct beam drops off with the cosine of the angle between the incoming light and the panel. In addition, the reflectance (averaged across all polarizations) is approximately constant for angles of incidence up to around 50°, beyond which reflectance degrades rapidly.

4. Design and calculations

The following parameters are considered for the construction of solar tree. The length of the stem is 3.65m from ground to the top and the diameter of the stem is 0.055m. There are 11 branches and angle of each branch is 40^0 from its stem. The angle of solar panel fixed at the top of each branch is 45^0 to its branches. The base area of solar tree is 121.92 m^2 and it will be grounded.

Solar tree can run 4 bulbs each of 3W power and exhaust fan of 60W along with other home appliances for about 5 hours per day and the total load or power requirement is approximately equal to 0.228 Kwh/day. Based on requirements of the system voltage is selected. Since total DC load is less than 2Kw the system voltage is selected as $12V_{dc}$.

4.1 Peak Watt Power

By considering the efficiency of charge controller, about 85% and battery bank and wire loss is about 3%. The energy requirement from PV module: E

$$E = \frac{1}{(\eta \text{ battery } \times \eta \text{ charge controller } \times \eta \text{ wiring })} \quad \dots (1)$$

$$= \frac{1}{(0.85 \times 0.85 \times 0.97)}$$

= 1.42

= 1.40 approximately.

Hence, energy from module (PV array): E_A

$$E_A = FL \times 1.4 \quad \dots (2)$$

Where,

FL= Estimated average daily energy consumption in Wh/ day.

Hence,

P array = 228Wh x1.4

= 319.2Wh/day

= 320Wh/day (approximately)

The peak watt rating of module for solar tree system will be,

$$W_{peak} = \frac{P\ array}{\text{Average daily sun hour on tilted surface at latitude}} \quad \dots (3)$$

$W_{peak} = \frac{320}{6}$

W_{peak} = 54 WP

4.2 Total Array Current (I_{dc})

The total module current: I_{dc}

$$I_{dc} = \frac{\text{Peak watt rating}}{\text{system voltage}} \quad \ldots (4)$$

Where, Peak watt rating: W_{peak}

System voltage: V_{dc}

$=\frac{54}{12}$

= 4.5A

4.3 Array Size

The number of modules in series: N_{mp}

$$N_{mp} = \frac{I\ dc}{I\ mpp} \quad \ldots (5)$$

$= \frac{4.5}{2.8}$

=1.607

Rounding above calculation value, the total number of modules in series = 2. The number of modules to be connected in parallel: N_{mp}

$$N_{ms} = \frac{\text{Nominal system voltage } (V\ dc)}{U\ mpp} \quad \ldots (6)$$

$= \frac{12}{2.1089}$

= 5.69

= 6 (approximately), 6 modules will be in parallel. Total array size = 6 x 2 = 12.

4.4 Battery Bank Size

$$\text{The total DC load requirement} = \frac{P\ array}{\text{system voltage}} \quad \ldots (7)$$

$= \frac{120}{12}$

= 10A

Considering battery autonomy for two day total requirement = 10A

Considering battery efficiency and depth of discharge (DOD) equal to 80%,

Battery capacity $=\frac{10}{2(0.8x0.8)}$

= 7.8A

= 8A (approximately)

4.5 Charge Controller Capacity

The factor of safety (F_{safe}) is necessary in order to allow for a reasonable system expansion. Thus, the desired charge controller current (I_{cc}) is as given by the equation,

$$I_{cc} = I_{scm} \times N_{pm} \times F_{safe} \quad \ldots (8)$$

Where, I_{cc} = charge control current

I_{scm} = short circuit current of the selected module

N_{pm} = number of modules in parallel

F_{safe} = safe factor

I_{cc} = 3.04 x 5.84 x 1.3

= 23.07

= 24A (approximately)

4.6 System Wiring Size

The DC cable from PV array to the battery bank through the charge controller,

$$I_{rates} = N_{mp} \times I_{sc} \times F_{safe} \quad \ldots (9)$$

= 5.04 x 5.84 x 1.9

= 23.07

= 24A (approximately)

The Table 1 shows the daily energy demand of single household.

TABLE 1 Daily Energy Demand of Single Household

Appliances	Rated Power (W)	Quantity (Nos.)	Hrs/day	Kw	Kwh/day
Lighting Bulbs	3	4	4	0.012	0.048
Fan	60	1	4	0.06	0.24
Total				0.072	0.288

The total of 4 bulbs and 1 exhaust fan is being used of 3W each and 60W respectively which will consume the total power of 0.288Kw/day. More equipment can be used as per the requirements.

5. Conclusion

Solar tree is a revolutionary urban lighting concept that represents a perfect symbiosis between pioneering design and cutting edge eco compatible technology. The tree design made 50% more electricity and the collection time of sunlight was up to 50% longer. It helps the environment, saves money, cheap to use in any homes .It's free and last for lifetime and environment friendly. To fulfill the increasing energy demand of the people, saving of land, the solar tree concept is very successful one and should be implemented in India to provide electricity without the problem of power cut and the extra energy can be provided to the grid. Solar tree could be the best solution for the power needs.

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