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Estimation of Energy from the Developed Solar Artifact

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ABSTRACT

It has been found that the solar tree produces more energy than a conventional flat rooftop arrangement of solar PV system or modules. The solar energy converts the sunlight energy directly into electrical energy by making use of photo -voltaic or concentrated solar power. The energy demand is increasing with each period, as a result the grid electric supply unit prices are also increasing day by day. For example, with the supply of oil the quantity of oil is decreasing and the prices are increasing. Similarly in case of coal which is abundantly for the production of electricity is available for few more hundred years. So in order to fulfill the increasing demand of energy we must have some alternative sources of nonconventional sources of energy. The energy from the sun is the best alternative among all the renewable sources of energies. It is available free of cost, inexhaustible, non-polluting, eco-friendly and continuously. The main drawback of solar panels is the land requirement for the installation of solar panels. The developed solar artifact requires only 1% of the land compared to the flat rooftop to produce same amount of energy. A single converting cell or more generally known as a photo voltaic cell, but a combination of cells in series or parallel designed to increase the power output is called solar module or solar array. In this article the load capacity or energy requirement of a small house in India is estimated to 1.74kWhr/day [6]. All the calculations are done considering solar radiation data at Durgapur, West Bengal. As per experimentation it is found that tracking system can be easily employed in solar artifact, hence its performance will be better than flat solar PV system. The solar cells are mounted in a phyllotaxy pattern to avoid any obstruction from the others.

INTRODUCTION

The new design solar artifact or solar photovoltaic structure looks similar to trees like structure. They can be designed as small as like a bonsai tree to as large as like wind turbine [5]. It is a type of solar artwork which is a combination of artistic view and technological effort. This concept is conceived to be attempting to use new technology relating to harvesting and also to be used for solar energy. In solar artifact, PV panels or cells are arranged in a phyllotaxy pattern instead of leaves so that the entire PV cell will be directly exposed to sunlight without any obstruction. The solar artifact produces more power than a conventional flat arrangement of solar cells. It requires only 1% land as compared to the conventional flat arrangement [4]. The panels of a flat mounting for homes are not sufficient, as the angle of sun's rays varies throughout the day, particularly during the changes in seasons. There are some residential solar systems available to track the sunlight but these systems will increase the cost of solar system because they are expensive and requires regular maintenance. These solar trees are designed in such a way that they will provide different means of power in urban and other environments. This power can be utilized for powering mobile phones, electric cars, buildings and street lighting and covering large and small scale area.

The solar artifacts are really a means of practical solution for urban street lighting system. There is a rapid increase in the usage of solar PV systems in India due to the reduced price of solar cells as subsidized provided by the Govt.

But there are some hurdles for adoption of this technology in rural and remote areas considering the security aspect of the system as there is chance of theft of most of the components. Due to this reason the solar street light installed by the government in the rural areas are found not in working conditions. Hence presently the PV systems prove to be suited mainly for urban & corporate sectors use only. There is not much response for use of the solar PV system for domestic applications due to its higher initial cost and the area required for mounting of such systems. Hence due to land constraint this technology is proven to be the most useful for domestic application in the form of solar artifact, which will be the alternative source as compared to conventional flat or rooftop mounting [1].

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Fig.1. Conventional flat mountings solar PV system.

As the Installation of the solar artifact takes a very small area hence it could be installed near or in front of house or even on a terrace, where there is no shading throughout the day. This paper basically illustrates about the estimation of energy from the development solar artifact for domestic application considering the average requirement of small Indian house. The Fig.1 illustrate about the conventional mounting of the PV panels in the field and on the roof of the house inside our Institute campus for demonstration.

DIFFERENT ARRANGEMENTS OF SOLAR TREE STRUCTURE

The concept of solar artifact or arrangement of PV cell in a phyllotaxy pattern has been stated by many researchers in their work. Such combination of the solar cell can be done on trees like coconut, palm or other natural trees to reduce the cost of mounting [1]. The efficiency can be further improved by using nanowire. The Nanowire cells can collect 15 times more solar energy than the conventional PV cells [2]. The concept of nano leaf is an idea to maximize the various forms of energies such as solar, thermal and piezoelectric power by stalks, branches, and twigs of a tree [3]. The different design of the solar artifact has been designed at CMERI.

It is found that for the generation of 2MW power by using PV module system it requires a land of around 10 Acres approximately for housing the panels only. In India the land area is decreasing day by day in urban as well as in rural areas. The newly developed solar artifact is a tall pole-like structure which takes only 1% of land area in comparison to general PV housing [4] for generation of amount of energy. With due adjustment of load over the pillar or pole, solar panels can be fixed throughout the main tall pole following a pattern of spiraling phyllotaxy as found in the natural tree. The panels are fixed in such a way that to get the maximum sunlight in day time no one panel obstructs the bottom one. The each panel is hanging through their connecting stem system attached to the main trunk (Pole). It can also be locked at any position to withstand the wind pressure due to heavy storm affecting over the main pole/ trunk. The panels will be naturally facing towards the sun at an angle as required so that they can collect maximum solar energy in a daytime. The system can be mounted at the road sides, the islands in between wide roads / highways, on the boundary walls of paddy lands facing south direction.

Fig 2. Mounting of Solar Tree near house.

Fig 3. Simple Pole Structure of PV Cell.

The newly developed solar artifact like structure can easily be constructed either on terrace or near the house. The performance of the PV cell depends on its regular maintenance and cleaning of dust from its surface. In order to popularize and to aware of the usefulness this technology among the common man, the demonstration of the technology is very much essential [5]. The Organizations, hotels, schools, and the person concerned who are using this technology their feedback will give better insight into applications of the solar tree for use in the street lighting and other house hold applications. The progress of this technology could be better achieved by exhibiting the different models in during different occasion across the country. The Fig.2 and Fig.3 as shown above depicts the two different models of solar tree, which is being design and developed at CMERI, Durgapur.

WORKING OF SOLAR TREE

The Solar PV cell is directly exposed to the sunlight and it will absorb the energy during day time. This enormous energy could be stored by some mechanism otherwise this energy will be lost. At dusk, the solar tree switches ON the signal of LED light automatically as soon it receives the required solar energy. This stored solar energy further charges the batteries connecting with it. The solar energy which we are getting is in the from DC current which need conversion to AC for our use, which will be done by inverter attached along with the controller. The internal charge control system can regulate the amount of energy dissipated and the amount of charge left with the batteries. Based on our power requirement in kW the solar branches were formed to get the required amount of power, it is attached with a sensor which will measures the amount of energy produced and accordingly it will trigger the attached solar lamps to switch

ON automatically during sunset and OFF at dawn. The tracking system reduces solar cell output fluctuations caused by day and night cycle and during changes in weather condition.

METHODOLOGY

This newly developed work, we emphasis that this technology of trapping the solar radiation by using solar artifact concept will be very much helpful for domestic electrification, by reducing the electricity bills and also make us dependent from the supply line of electricity from grid power which is unreliable nowadays in India. This developed technology is totally clean energy source which will ultimately help in reducing the global warming. To describe the utility of solar energy the energy demand (load) of a small family is considered and accordingly the calculation is being made to determine the capacity of proposed system required to generate the power.

LOAD ESTIMATION

The average load profiles of a family are considered depending on daily usage duration in a day time [6]. Following electrical appliances are taken into consideration to determine the total load estimation as shown in Table.1

Table 1.

Appliances	Rated power	Qty	Hrs/day	KW	KWh/day
CFL	5	2	4	0.01	0.04
	10	2	3	0.02	0.06
	8	1	2	0.008	0.016
LCD/LED TV	30	1	5	0.03	0.15
Fans	60	2	4	0.12	0.48
Computer	80	1	2	0.08	0.16
Refrigerator	100	1	4	0.1	0.40
Total				0.368	1.306

Hence total load or power requirement is approx equal to 1.306 KWh/day

SELECTION OF THE SYSTEM VOLTAGE

Based on total load the required voltage is selected, since total load obtained is less than 5 kW, the system voltage is selected as 24 Vdc.

CALCULATION OF PEAK WATT POWER

Considering the efficiency of inverter and battery bank as 80 % and wire loss as 5%. The energy requirement for the PV cell would be

= 1/(ŋ of the battery x ŋ of the charge controller x ŋ of the wiring)

= 1 / (0.80 x 0.80 x 0.95)

= 1.644 = 1.65 approx

Hence energy needed from module

P_{arry} = EL x 1.65, Where E_L is estimated average daily energy consumption in wh/day

P_{arry} = 1306 X 1.65 = 2155 Wh approx.

$W_{peak} = P_{array}$ /6 = 2155/6=359 Wp

TOTAL ARRAY CURRENT

The total module current I_{dc} is calculated by dividing above peak watt rating by system voltage V_{dc}.i.e

$I_{dc} = W_{peak} / V_{dc}$= 359/24 = 14.95 A

The selected solar modules manufactured by CENTSYS Solar India, whose specifications are as shown in Table.2.

Table 2.

Peak Power Pmax (Wp)	60W
Open circuit voltage Voc	22.2 V
Short circuit current Isc	3.56 A
Maximum voltage Vmpp	18.2 V
Maximum current Impp	3.3 A
Module efficiency	14.22%

CALCULATION OF THE ARRAY SIZE

$N_{mp} = I_{dc}/I_{mpp}$ = 14.95 / 2.8 = 5.33

Approx 6 module will be in parallel

The no of module to be connected in series N_{ms}

N_{ms} = Nominal system voltage (V_{dc}) /V_{mpp}

= 24/17.89 = 1.34

Rounding above calculated value the total number of module in series=2

Total array size = 5 x2 =10

TOTAL BATTERY BANK REQUIREMENT BASED ON THE PEAK ARRAY

The total Dc load requirement = P_{array} / system voltage

= 2155/24=89.79 Ah

Consider the battery autonomy for two days total requirement = 89.79 x 2 = 179.58 Ah

Considering battery efficiency and DOD equal to 78 %

Battery capacity = 179.58/ (0.78x0.78) = 295 Ah

Accordingly we can choose one battery of 180Ah and other of 120 Ah meets the requirement. As the current handling capacities of both the batteries are different which causes adverse affect on the life of the low rating battery. Hence it is advisable to use to two nos of 180 Ah batteries of 24V DC rating with parallel connection to get the required demand of the system voltage and energy. High ratings of batteries lead to increase in cost; we can build a reliable system. Following are the recommended battery specifications.**Model of battery: 180 Ah AMARON** Tubular Battery.

DETERMINATION OF THE INVERTER SIZE

The inverter size should generally 25-30 % bigger than total power requirement (W) of appliances.

Size of inverter = 2155 W x1.25

= 2693 W

= 3.00 kW.

Hence the size of inverter equal to 3.0 kW or 3.0 kVA.

CALCULATION OF THE CHARGE CONTROLLER CAPACITY

The standard practice of sizing the charge controller is to ensure that it can withstand the product of the total short circuit current of the array (IscA= IscM X Npm) and a certain safe factor (Fsafe). The safe factor is necessary in order to allow for a reasonable system expansion. Thus, the desired charge controller current (Icc) is as given by equation.

Icc = IscM X Npm X Fsafe

Where, IscM = the short circuit current of the selected module.

Icc= 3.56 X 7.12 X 1.2

= 30.4 A.

≈ 30 A

SELECTION OF THE SYSTEM WIRING SIZING

Referring standard wire gauge and its current carrying capacity for copper conductor wire we used 4 sq.mm wire (cable).

The AC cable from the inverter to the distribution board (DB) of the residence.

Current Produced by Inverter Output is calculated as

Ioi = P total / (Voi X p.f.), Where, Voi –Input voltage, p.f – Power Factor

= 2693/ (230 X 0.8)

= 14.6 A. = 15 A.

For 15 Amp current rating, we used 3.0 Sq.mm. wires (cable)

Results Obtained by sizing the proposed solar tree system are as shown in the Table.3

Table 3.

Components	Description of component	Capacity
Load Estimation	Total Estimated load	1.828 Wh/day
PV Array	Capacity of the PV array	3.59 kW
	Number of modules in series	2
	Number of modules in parallels	6
	Total no of modules	12
Battery Bank	Battery bank capacity	295 A
	Number of batteries in series	0
	Number of batteries in parallel	2
	Total No of batteries required	2
Charge Controller / Voltage regulator	Capacity of voltage regulator/Charge Controller	30A
	Number of Voltage regulator required	1
Inverter	Capacity of inverter	3.0kVA
Wires	Diameter of dc cable	6.0Sq mm
	Diameter of AC cable	3.0 Sq.mm

FABRICATION PROCESS OF SOLAR TREE (PROTOTYPE)

As per the project proposal one working prototype has to be fabricated to estimate the energy produced from the developed solar artifact technology [6]. The solar PV panels are mounted on the main pole structure with the help of suitable supporting frame. The arrangement of solar panels maintains a 'Phyllotaxy' pattern this arrangement helps to expose all the solar panels directly to sunlight throughout the day without any obstruction from others. Based on the power requirement the no of branches are selected and fitted with the main pole structure which is made up of M.S. pipe having bottom ϕ = 400 mm, top ϕ = 325mm and max height of 20 feet (approx). At the bottom of the main pole structure a flange of thickness 10 mm is welded having 12 nos of free holes of ϕ 13 mm for tightening with the foundation. The main foundation is being constructed with RCC with having a depth 4 ft; the bottom size RCC structure is 1200mm sq and the top is having a ϕ of 800mm, with 12 nos of M12 foundation bolts maintaining the same PCD of the top flange for tightening the main pole structure vertically. This arrangement is better than pivot bearing assembly because it rotates as per requirement [4] but in this case it is not required. The branches were assembled and analyzed so that the structure will be fully balanced and it can sustain the load acting upon. The PV panel structures are mounted with the main pole structure by fabricating a hexagonal structure. The solar panels are mounted along with these branches by using a M.S pipe welded structure on the back side of the PV panels and tightened with bolts & nuts so as to restrict the rotation of the PV panels during heavy wind storm condition.

CONCLUSION

The generation of electrical energy by utilization of solar artifact concept is found to new; it will definitely help in fulfill the increasing energy demand of our country as an alternating source. The major advantage of this technology is, it will take only 1% of land area in comparison to general flat rooftop for generation of same amount of power. The concerned Ministry and other state Govt must pay attention towards this developed technology for its popularization and aware among the common peoples, so that people should know the utilization of the solar power.

If this technology will be implemented throughout India then it will definitely substitutes for the generation of electricity during power cut-off and also reduce the dependence upon grid power. In this paper the daily average energy requirement of the small Indian family is taken into consideration and found to be about 3.0kW [6]. The developed systems can be mounted on the terrace, in front of the house or near the wall avoiding shading areas. The initial investment cost of the solar tree is similar to same capacity rooftop PV [6] systems as other system components are similar in nature.

The overall cost of the domestic solar tree can be further reduced if we use the available local material and by making the design much simpler and innovative. The performance (MPP) of a solar artifact is found to much better than conventional rooftop as manual or low-cost auto tracking system can be easily incorporated. The initial investment cost is the major concern for any solar PV system but after that in long run there will not be any investment except maintenance. The payback period of proposed system seems to be high but due to continuous increase in the cost of grid power and reduction in the cost of PV cell due to technological advancement long payback period could be compensated.

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