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Design and Utilization of Solar Tree for Domestic Use

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Abstract—*Our traditional system of power generation from solar i.e. rooftop mounting solar system require huge area of land for power generation. In india as population is increasing with rapid rate we have major problems of land in both villages and in cities. Solar tree is best option for this problem which can be used instead of flat pv solar system. It can be used both in villages and in cities for power generation and lightning system. As in rular areas there is electricity problem 365 days so solar tree is most convenient source of power generation for these locations. In this paper we have considered energy requirement of house as 1.80kwhr/day and calculations have been done for solar radiation data at Ranchi , Jharkhand (solar irradiance - 5.15 kwh/m²/day) by using this technology cost of overall system can be reduced and efficiency can be increased by innovative design of solar tree. "*SPIRALLING PHYLLATAXY*" is the technique which is used for increasing the efficiency of system. Solar tree cost have a approximate cost of Rs 60000.00 and for this amount we can calculate it's payback period of 10 years.*

Keywords*: Solar Tree, spiraling phyllataxy pattern, solar PV system, Solar panel, solar tree system sizes.*

1. INTRODUCTION

As trees have branches and stems and they prepare their own food for human in that same way solar tree also have stems, leaves as solar panel, and branches and they provide power generation for human. it can be planted as per our need of power generation like for small power generation like bonsai tree and for large power generation also. it is very innovative and latest idea of power generation which includes both artistic and technological idea to develop it. In this technique solar panels are arranged in a series pattern which is known as Fibonacci series which looks like leaves of a tree. Solar tree produce more power than conventional pv system of solar panel for this spiraling phyllataxy pattern is used for more efficiency .

If we compare both types of solar tree arrangement we find that solar tree require only 1% land of conventional pv solar system. We have seen that the flat mounting are less efficient as the sun radiation is not constant. As season and environmental condition changes it's efficiency also changes for this reason we design tracking system so it tract sun radiation during the time period but it cost more and require more maintenance but for the same condition power generation is more in solar tree without installing tracking system.

Figure – 1 conventional solar pv mounting system

DIFFERENT ARRANGMENTS OF SOLAR TREES

Fibonacci series is the concept which is used for arrangement of solar pv panles these concept can be seen in different trees like coconut , palm etc. which reduces it's mounting cost. Nanowire cells are the latest technology which can be used instead of pv cells to increase it's collection efficiency. It's collection efficiency increases 15 times as compared to conventional cells.

Figure 2: Different type of solar trees

If we compare both types of power generation we find that in conventional pv generation system a generation of 2MW power plant requires 10 Acers of land for housing the panel and in India we have shortage of land in urban and rural areas. Solar tree need a pole type structure in which panels are planted over it and it needs only 1% land of conventional system of power generation.

WORKING OF SOLAR TREE

As it is a big issue to store electrical energy which can be used when needed .In solar tree we use batteries for storage of energy which get charge during day time and used at night by switching on the light and LED glows automatically. Internal controller system shows the amount of light produced in LED and how much charge is left in batteries and sensors used in it which measure the light present in environment according to it solar lamps automatically get Switched ON and OFF.

METHODOLOGY OF SOLAR TREE

By solar tree we have tried to provide the best solution for replacement of conventional solar system. Power generation by Solar tree is more effective and efficient which will reduce the dependency on power grid and reduce the electricity bill . Solar tree has major advantage that it does not create any pollution in environment and also helpful in reducing global warming Estimation of load

Table 1: energy demand for 1 day of a small Indian family

Appliances	Rated Power (W)	Qty	Hrs/ day	KW	KWh/ day
Lightning bulbs	7	5	5	0.035	0.175
	20	2	4	0.04	0.16
	6	3	3	0.018	0.054
T.V	40	1	4	0.04	0.16
Fans	60	2	5	0.12	0.60
Computer	80	1	3	0.08	0.24
Refrigerator	100	1	4	0.1	0.4
Total				0.325	1.78

We have calculated a average load estimation of daily usages of a household during a day. These appliances are used for total load evaluation.

So we can say that power required for one day is approximately 1.80kWh/day.

Selection of System Voltage

According to the demand of the system voltage is decided . As in this case AC-Load is less than 5Kw we will consider system voltage of 24 Vdc

Calculation of PV Array Size

Peak Watt Power

we take efficiency of inverter / controller about 90% and loses in battery and wire about 4% so the energy needed from pv module

= 1 / (ŋ battery x ŋ charge controller x ŋ wiring) …….(1)

= 1/(0.9* 0.9*0.96)

=1.28

= 1.3 approximately

Hence , energy required from Module (PV array)

$P_{array} = E_L \times 1.3$……. (2)

Where E_L = Estimated daily avg. energy consumption in Wh /day.

Hence , $P_{array} = 1.3 * 1780$ wh

= 2314 Wh

= 2400 Wh

As solar panels are defined for 1000 w/m2. We have taken data for daily sun insolation for Location At Ranchi , Jharkhand , taking average daily sunshine hour as 5.5 when solar panel is mounted horizontally and 6 hrs for angle of latitude (23.34 º).

Figure 3: Solar monthly data radiation for Ranchi horizontally and vertically

peak watt rating of solar module for this system will be

Wpeak = P array / average daily sun hours on tilted surface at latitude angle……(3)

W peak = 2400/6

= 400 WP

Total Array Current

We can get Total module current i.e. Idc It is calculated by dividing above peak watt rating by system voltage Vdc i.e.

Idc = Wpeak / Vdc ……. (4)

= 400/ 24

= 16.66 A.

We have selected solar modules for the following specifications for our system design.

Peak Power Pmax (WP) : 50 W Maximum voltage Vmpp (V) :18.8 V Maximum current Impp (A) : 2.6 A Open circuit voltage Voc :21.3V

Short circuit current Isc : 2.84 A

Module Efficiency (%) : 12.35.

Array Size calculation

The number of modules in parallel Nmp Nmp = Idc / Impp……(5)

= 16.66/ 2.6

= 6.40

From this we find Approximately 6 no. of modules will be there in parallel series.

Now we find No. of modules to that will be in series

Nms = Nominal system voltage (Vdc) / (V_{mpp})…..(6)

= 24/ 18.88

= 1.3

Rounding above determined value, we get total no. of modules to be connected in series = 2. Total array size = 6 x 2

= 12

Calculation of Battery bank Size

Total DC load demanded by system = Parray /System Voltage…(7)

= 2400/ 24

= 100. Ah

Assuming battery backup for two days we get

= 100 x 2 = 200 Ah

Taking battery efficiency and DOD depth of discharge as 80 %.

Battery Capacity = 200/ (0.8x0.8) = 312.5 Ah.

For this we have many other options to choose battery like we can select one battery of 180Ah and other of 150Ah for our design consideration but we have 2 batteries of different capacities both have different current handling capacities which may cause an adverse effect on battery life . so it will be more better to select both battery of 180Ah of 24 V DC rating connected in parallel to get required system voltage and energy demand.

Inverter Sizing

The inverter size of a system should be 25-30 % bigger than the total power requirement (W) of system device. So ,Size of inverter = 2400 W x1.25

= 3000 W

= 3.0 kW.

Hence we have the size of inverter as 3.0 kW or 3.0 kvA.

Charge Controller Capacity

We take charge controller sizing in consideration to ensure that it can resist the product of

= short ckt. Current of array i.e. ((IscA= IscM x Npm) and a certain safe factor (Fsafe). We have safe factor in order to allow for a feasible system expansion. So we have charge current controller equation as

Icc = IscM x Npm x Fsafe …… (8)

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

Icc = 2.84 x 6.08 x 1.3

= 22.44 A.

≈ 23 A

Total System wiring analysis:

We cannot imagine a solar power system if we do not have correct and precise sizing of wire selection which will be fit with the component .so it's consideration is also very important in designing a solar pv system so we can have some selection of wire as follows

1.The dc cable from the PV array to battery bank through the charge controller.

I_{rated} = Nmp x Isc x Fsafe…… (9)

= 2.84 x 6.08 x 1.3

≈ 23 A.

2. It is advisable to take standard wire gauge which have current carrying capacity for copper wire and for this we take 4 sq. mm wire cable.

3. The AC cable coming from the inverter to the distribution board (DB) of the residence. Current Produced by Inverter Output is given as -

Ioi = P total / (Voi x p.f.)…….. (10)

= 3000/ (230 x 0.8)

= 16.3 A. approx. 17

As current rating is 17 Amp we take 2.5 Sq.mm. wires for this

We can have the following table for our solar tree system

Table – 2 specification of component of solar tree

Component	Description of component	Capacity
Total Load Estimation	Total Estimated Load	1.78kWh/day.
PV Array	PV array capacity	4.0kW
	No. of modules in series	2
	No. of modules in parallels	6
	Total number of modules	12
Battery Bank	Battery bank capacity	312 Ah
	Number of batteries in series	0
Component	Total Number of batteries in parallel	2
	Number of batteries required	2
	The AC cable to be used from the inverter to the distribution board (DB) of the residence.	2.5 sq mm
Charge Controller/ Voltage Regulator	Total Capacity of voltage regulator/charge controller	23A
	Total Number of voltage regulators required	1
Inverter	Total Capacity of the inverter	3.0 kVA
Wires	The dc cable to be used from the PV array to the battery bank through the charge controller.	4 Sq.mm.

FABRICATION OF SOLAR TREE (PROTOTYPE)

A model of solar tree if fabricated so that it can be tested for it's sustainability . solar tree has pole at base and panels are mounted on the top which are attached with it's branches. This arrangement of solar panel follow a 'Phyllataxy' pattern . A pole is taken with 2.5" diameter about 6.5 feet in height. It has branches in different part of the pole and it's base has a box in which we can keep batter , inverter , charge controller etc. solar panels are mounted on nut- volt system . branches can be welded in pole of the tree .At the lower part of stem (pipe) a nut is welded at it's bottom part and screw is welded at upper part so that it can rotate in that nut. We can use this arrangement and it is better than pivot bearing assembly system because it can rotate as per it's requirement. In this system solar panel can be inclined or tilted to latitude or any other angle so that we can get maximum radiation on it.

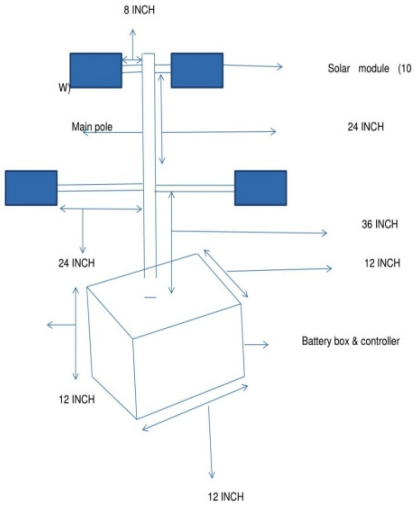

Fig- 4 Solar tree model (prototype)

Cost Estimation of solar tree System

We have calculated a nominal cost of system component as follows.

Table 3: Cost analysis of solar tree

Component	Qty	Unit cost (Rs.)	Cost per component (Rs.)
Solar Modules	12	2500/	30000/-
Batteries	2	10000/-	20000/-
Voltage Regulator	1	2000 /-	2000 /-
Inverter	1	5500 /-	5500 /-
Febrication and structure work			2500/-
Total cost			60000/-

Payback period of solar tree

We can calculate payback period of this solar system as overall cost of the system divided by average yearly electricity bill of an average Indian family (taking Rs.450.00) p.m. maintenance cost is neglected in this cost.

Payback Period = Overall cost of system/Average yearly Electricity Bill

= 60000/5500 = 10 years

2. CONCLUSION

This concept of solar tree is very useful and profitable by which we can fulfill the energy demand of peopl, land can be saved and it can avoid the problem of power cut so that we will have less dependency on grid- power. From survey we have found that a small family needs a power consumption of 3.5 kw so for these we can mount this solar system on terrace or in front of house where there is no shading problem. As far as we are concern of it's initial investments in both type of pv system cost. Is approx. same and component are similar.

If we want to reduce it's cost we can have others options also like we can use local material for structure or scraps at very less price we can designing an innovative solar tree if we compare performance of both conventional pv system and solar tree we find it has higher value at low cost and we can merge tracking system on it if we want.

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