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# Solar Tree Manufacturing

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**ABSTRACT:** Solar energy is one of the most abundant and free form of energy. To harness solar energy different techniques are being used today and once such technique is the use of solar tree. Solar tree or solar photovoltaic tree are installed with solar panels on its branches to that they can capture solar light which further gets converted into useful form of energy i.e. electricity using suitable equipment. Solar trees have the advantage of occupying less land space, hence they are very beneficial in urban areas.
This paper deals with studying different factors which are considered while installing solar tree, different equipment, various designs, different advancements that can be done in solar tree.
**Keywords:** Solar tree, Solar energy, Solar panels, Power generation

## I. INTRODUCTION

Solar tree is a revolutionary idea with only a pillar and solar incorporating solar energy technology . This represents an ideal combination of innovating style and eco-compatible technology. It divulges new possibilities for modern lighting .

Inspiration for the solar tree is directly taken from nature, reconsidering the morphology of the tree and presenting the essence of the nature into the modern setting. A nature inspired tree with a natual process like photosynthesis , bore LEDs as its fruits and satisfy the hunger of the light-phallic night , The aesthetic design of the tree and the technology used is just like a beauty and the beast . It just fulfills the present most squeezing environmental, cultural , social, and aesthetic requirements.

**Why Not Other Conventional Energy?**

The prices of oil have increased because the supplies are decreasing , other sources are being debated over there pros and cons as well , so it was a high time to use a better source instead.
Wind turbines produce high output, but residencies living near them have objections on that.
Biomass is a traditonal technology, as per some researchers estimation, powering the whole world with biofuels means increasing the amount of land used for farming.

Nuclear energy produces a large amount of power, but everyone fears the repercussions of catastrophes such as Chernobyl. The benefits of fusion energy, produced when two atoms are fused, could last for millennia. It requires a number of the foremost advanced machinery on earth.
Solar tree seems like the right solution for our future energy needs. The sun is consistently sending energy to the planet and all we need to try and do is to catch it and then use it. Unlike current energy sources, this will never stop happening, it wouldn't contribute to Global warming either, and it's out there all over.

**The Global Solar Potential**

Study says there is a quick growth in the demand for renewable sources of electricity [1], and it is possible because of the efforts to cut back CO2 emissions. For each developed and developing countries solar power plays a promising role. Despite this however, solely a restricted quantity of electricity is presently produced from solar energy[2-4]. The primary step in helping countries notice the importance of switching into solar power is showing the potential quantity of electricity that metatheoretically be produced this manner. This informationis crucial for assessing the potential for solar installations in urban areas.

In spite of the advantages of solar energy, the current global solar production is just a minor fraction of what is potentially available to develop,

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since solar energy covers only 0.05% of the total primary energy supply [5].

**Indian situation**

Solar Tree's biggest demand is that the solar energy.

The potential of solar energy in India is in abundant . As of 30 June 2020, solar installed capacity in India has reached 35.12 GW. In India , installing a solar power plant has the lowest capital cost per MW globally.

With about 300 clear and sunny days in a year, the calculated solar energy incidence on India's land area is about 5000 trillion kilowatt-hours (kWh) per year (or 5 EWh/yr.)[6, 7]. In India , in just a single year ,the solar energy available exceeds the possible energy output of all of the fossil fuel energy reserves. The average solar-power-plant generation capacity on daily basis in India is 0.20 kWh per $m^2$ (of used land area), equivalent to 1400–1800 peak (rated) capacity operating hours in a year with available, commercially-proven technology.[7, 8]

India is one of the few countries with plenty of sunshine and long days, especially in the Thar desert region. This zone, is suitable for harnessing solar energy for a number of applications for having abundant solar energy available. Solar energy could be easily harnessed in areas with similar intensity of solar radiation.

**Research Gap**

There is still a lot of research gap in Solar Trees which can be filled by the upcoming promising researchers. Some of them are:

- New material development to increase system lifetime and reduce operation and maintenance (O&M) costs.
- Optimizing processes to reduce product defects, and consequently further reduce costs and increase module efficiencies.
- Continuous research on manufacturing techniques and module technologies which require less material, have high efficiencies and low production cost.
- Inclusion of module components' recycling (cables, inverters, etc.) in order to minimize cost.
- Carbon footprint evaluation using Life-Cycle Assessments (LCA) considering Solar PV and heating/cooling devices as a single unit.
- Research on technological advancements enabling efficient heat removal from the PV surface and its direct use for heating applications.
- Research on ways to utilize wind energy by installing small turbines on branches of the solar tree.
- Research on different ways to make the solar tree more attractive like:
- The Pole and Branches of the solar tree can be colored with various attractive colors. Small LED lights can be used to lighten it up in the dark also.
- The branches of the Solar Tree can be Shaped in a specific curved way to make it look more attractive.

## II. METHODS AND METHODOLOGY

**Essential components of solar tree**

- **Photovoltaic modules:** PV modules are generally made from silicon as it is seen that they are most efficient for domestic and commercial uses and about 80% of total solar tree sold worldwide are made from silicon only.[9]
- **Cables for connecting modules:** for the proper functioning of a solar tree under severe weather conditions like dust-storms, excessive rain, snowfall, solar irradiations., it is crucial to have a safe and secure connection. Therefore cables should have excellent mechanical so that they can be used in conditions with high mechanical tension, in dry and wet conditions, higher temperature conditions and high solar insolation, also in buildings with a high risk of explosion and fire. [10]
- **Inverter:** inverter converts the Direct current (DC) produced by solar panels into Alternating current (AC) The purpose of an inverter is to convert the DC voltage produced by solar panels into AC voltage of grid frequency. Modern devices can be operated with an efficiency of around 98% [11]. An inverter is also responsible for power optimization in which it continuously tracks the maximum power and monitors the energy yield of the PV plant and secures the tree in case there are some faults by disconnecting it from the grid.[12]
- **Batteries:** Deep-cycle batteries have been used in renewable and sustainable energy applications throughout the world for decades. Lithium-ion batteries lead-acid batteries, lithium-ion polymer batteries, nickel-cadmium batteries" etc. are some of the most commonly and popularly used batteries in PV applications.[13]

Besides the above components, solar charge controllers, steel structure, wooden base

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structure,PVC (polyvinyl chloride) rods for supporting the solar tree.

**Design methodology**

The efficiency of a solar tree or in other words the power output from a solar tree mainly depends on the orientation of solar tree leaves i.e., solar panels if other components efficiency are not taken into account. Optimization of a solar tree can be done by proper alignment of solar panels at different angles so that solar irradiation on panels is maximum.

The main steps for the design of a solar tree are:

**Step 1: Site Inspection**

It is the first step of the design of not only a solar tree but every PV system. Our output will depend on geographical location and timings. In this step, we will locate the site, find out if sunlight comes there in sufficient amount, cost of land, dust, etc. The site must be shadow-free so that no object cast shadow on it and direct sunlight falls on panels.

**Step 2: PV system sizing and orientation**

a) In this step, we will design the most important component of our solar tree that is solar modules. We will find out the type, sizing and number of PV panel to be used in order to have the maximum power output.

We will first calculate the total power and end energy consumption of loads that are going to be operated by a solar tree. This will help us in deciding the size and number of solar panels that are going to be used. We will also select the type of solar panel for our solar tree. Better the solar panel, more conversion of solar energy into electricity is possible. Most commonly used one is the silicon module. It always better to design PV modules based on the worst-case scenario. By worst case, we mean the time of year during which sunlight is present for a minimum duration that is in winter or rainy season. On that basis, we will find out the peak watt of a solar module using equation-1.

(1)

After selecting the solar panels for our solar tree, it is very important that the orientation of solar modules with respect to the sun is proper as this will lead to maximum solar yield. As the orientation of sun is different in different places, so proper calculations about various angles for installation of solar panels must be performed.

**Step 3: Selection of battery bank**

Since we know that sunlight is not present during nights, in rainy seasons and very less in the winter season, so it becomes very important to use batteries so that energy can be stored in them and can be used during these times, selection of battery depends on the amount of time (days) for which the solar tree can provide the electricity without sunlight. This time is known as days of autonomy. In other words, the battery must have a high capacity so that it can store a sufficient amount of energy. The battery can either be connected in series or in parallel combination depending upon the capacity desired.

**Step 4: Selection of a charge controller**

The purpose of a controller is to monitor the yield of every PV panel and maintain maximum power extraction from the PV panels, which is done through an MPPT based on maximum power transfer theorem. [14]. In simple words, Charge controller basically regulates the voltage and current coming from the PV panels which then goes to the battery bank and thus prevents overcharging of the battery and hence it helps in enhancing the battery life. A charge controller also estimates the amount of current that needs to flow into the battery bank for maximum performance. The commonly used charge controller is Maximum power point tracking (MPPT) or Pulse width modulation (PWM).

We will select the solar charge controller, which matches with the PV array voltage and batteries and then identify which type of solar charge controller is right for our application.

**Step 5: Selection of an inverter**

The inverter converts the DC power to AC power that runs most of the appliances. The inverter must be chosen such that they have very high efficiency. The inverter rating should be greater than the overall power demand of the AC so that it can withstand the load fluctuations. Input DC voltage of the inverter is equal to the battery output voltage. The output voltage is equal to the standard AC voltage for domestic applications (230 V,50 Hz in India). The power rating of the inverter is given by the following equation-2 [15], [16]

(2)

**Step 6: Balance of system design**

In this step, various other elements like breakers, meters and wiring designing are done. For wiring, our aim is to match the type of wire with the current which will pass through it in order to maintain the reliability and the performance of our system. Suitable breakers are chosen that protects the system from over current. We generally use copper wire. Sizing of wires can be done using the following equation 3

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(3)

**Step 7: Cost estimation**

After choosing all the component, we will now estimate our total cost for setting up our solar tree and running it. This includes the sum of the cost of components, cost of balance of system component, maintenance and operational cost of the solar tree per year. Operational and maintenance cost of the solar tree is meager.

**Design parameters of solar PV tree**

- **Area ratio**

It is the ratio of the actual area of solar panels to the land footprint area of the solar tree structure.[12]**.** The land footprint of the solar panel must be minimized as much as possible.

- **The angle of orientation of the panel**

The angle of orientation of panels dramatically affects the amount of sunlight received by the solar tree. As the sun position keeps on changing during the day, therefore panels must be arranged at different angles so that sunlight can be captured in the best way. Angles of the orientation of solar tree changes from place to place.

- **Number of layers of leaves**

It may be possible that some solar panels do not get any sunlight because of their orientation. This will lead to reduced output of electricity. So to avoid it, solar panels must be arranged in the layered form so that even if one layer doesn't get the sunlight, the second layer will be able to get it. This will increase the efficiency of the solar tree.

- **Shape and size of the solar panels**

Shape and size of a solar tree also affect the performance of a solar tree. Greater the size of the solar panel more is the sunlight captured, and hence more electricity will be produced. But it should not be very large as it will increase the land requirement and cost also.

- **Design of tree structure**

Suppose solar panels are to be put on an artificial structure like steel structure than it must be strong enough to support all the panels and other components that are used. The structure must be taller so that it can capture more sunlight. Branches must be strong enough to handle the weight of solar panels.

**Technologies in solar tree**

Climate changes are one of the great challenges mankind is facing. Based on registered data and relevant indicators it is estimated that climate changes will have a serious impact onthe economy development of everycountry in the world. Renewable energy is energy produced from naturalsources like sunlight, wind, rain, wavesand geothermal energy which are renewable (power naturally). In most of the cases renewable energy comes from sun energy, wind power, hydropower, biomass, biofuel etc. These Sources gives us energy with almost negligible effects on environment.[17].Renewable energy have really a big potential, but only when we use it properly.

**Production of Electricity using photovoltaic solar cells**

Solar energy can be converted to electricity by usingphotovoltaic solar cells (FN) andothers differentexperimental techniques. Photovoltaic solar cells aremainly used to power small and middle size application, from calculators which is powered up with one cell, to the house which is powered upwith panel. Solar energy is variable source of energy, because ofthat. It needs alternate source which will take grid load when sunlight is limited.[17]

**Designing of solar tree**

Possible design solutions do vary according to many different factors. Below are some of the standard steps:

- **Location regarding light consideration**: One of the important factors is the potential location where the tree shouldbe placed. Urban environment is veryspecific regarding the surrounding objects whichsubstantially influence light conditions around the tree. The potential location should be chosencarefully to enableoptimum lightconditions during the day.[17]
- **Location regarding the final purpose:** The majority of solar trees in urban environment is dedicated for two potential assignments: Street lighting or poweringdifferent consumers e.g.battery chargers fordifferent types of mobile device, LCD monitors etc. According tothe chosen aim of the tree, the finaldesign is influenced especially in the ground attaching area.[17]
- **Available type and design of solar panels**: According to thefact thatthe panels are the most important part in a solar tree construction it is therefore acrucial part which influences the final lookof the design. Mass, shape, number and the arrangement of the panels finally influence the rigidity, center of gravity and other calculation outputs of the tree which lead to the final look of the design.[17]
- **Aesthetic requirements:** If the design of the tree and its looks should be preferred in regard to the purpose then this will eventually lead to more complexitythroughout the whole design

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process. But this is generally among the most important one, as everybody like good looking products, even when there performance is a little less.

- **Financial costs:** Even though it is mentioned as the last one, it is probably the most influencing criteria in every project. The complexity combined with the variety of previously mentioned parameters sets this criterion as a finaljustifier for everypossible solartree design solution.[18]

**Applications**

- **Solar tree proposal for powering consumers**

We are free to use Solar Panels on roofs of our homes to generate electricity for home usage.

- **Cooking**

Many kitchen appliances can use solar energy to work their function, some successfully implanted products are solar cooker and solar dryer.

- **Water Pumping**

Solar power is commonly used for water pumping facility which has been proved more effective in villages for agricultural purposes. The energy from the solar panel is used to operate the pump that is used lift the water from lower level to higher level.[18]

- **Heating**

Solar water heaters and air heaters have been very common since decades even before PV cells could exist. Solar water heaters alone help reduce the consumption of energy to a major extent. These trap the heat energy from the sun, and store hot water in the containers.[18]

- **Lighting**

Solar photovoltaic lighting system can be used for street lights, and rural areas. Small sized panels can easily harness enough energy to glow a street light and LEDs.

- **Traffic Signals**

Traffic signals at all areas can easily be operated using solar panels. Shadow free area is the only concern for this.

- **Cold Storage**

Solar energy can be used for cold storage as well as air conditioning application. Vapor compressor system using solar photovoltaic panels and vapor absorption system using thermal collectors can be used for these purposes.[18]

**Economic Cost Consideration**

The cost consideration for the project is a major part of the whole process of designing a solar tree. The solar tree is a device that is expensive to setup and requires a lot of maintenance therefore economic consideration before setting up of the solar tree is of utmost importance. But there are various benefits (economic and Environmental) of using solar trees which we will see in this literature.

After the setting up of the solar tree, the initial cost can be made back and that too with a lot of profit, making Solar tree a very profitable investment. The best part of in solar energy is the fact that it's a sustainable source of energy. Eventually, there'll be no oil to drill, no fossil fuel to frack or coal to mine. But the sun has billions of years of life yet. Also, our country receives a good amount of sunlight and solar trees can utilize this potential very well.

There are various components that should be considered when we talk about economic cost of solar tree are:

- **Photovoltaic Modules**: An assembly of Photovoltaic cells mounted in a framework. It's an installation designed to provide usable solar energy by means of photovoltaics.

- **Solar Charge Controller**: In order to forestall battery overrun or inadequate currents, a charge controller set controls the voltage from photovoltaic module.
- **Batteries Bank**: An electric battery bank stores the energy generated by the Photovoltaic module.
- **Inverter**: It converts the DC voltage created by the PV System to AC voltage of grid frequency.
- **Cable for Connecting Modules**: Cables are used to provide good connection between all the modules.
- **Metal Structure**: A structure on which the Solar panels are mounted to make the solar tree.

**Let's take a look at each component of cost in detail**

- **Photovoltaic System Cost:**
- **Photovoltaic Modules**: The building blocks of a photovoltaic system are solar cells. A solar cell is the electrical device that can directly convert photons energy into electricity. To get an idea of the prices of Solar Panels in India, below is the price data of Luminous solar panels taken from an online store:

Luminous Solar panel prices are dependent on capacity of solar panel and technology variant. The price of the solar panel will always dependonthe capacity of the panel. In Luminous, you get 40-watt, 75-watt, 100-watt,

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160-watt, 270-watt, 335-watt solar panel. The price range of Luminous solar panel varies from INR 35-INR 65 per watt.

| Solar Panel Ratings | Selling Price | Per Watt Price |
|---|---|---|
| Luminous 40 Watt / 12V Solar Panels | 2650 | 66 |
| Luminous 60 Watt / 12V Solar Panels | 3700 | 61 |
| Luminous 75 Watt / 12V Solar Panels | 4300 | 57 |
| Luminous 100 Watt / 12V Solar Panels | 5400 | 54 |
| Luminous 160 Watt / 12V Solar Panels | 8300 | 51 |
| Luminous 200 Watt / 12V Solar Panels | 9700 | 49 |
| Luminous 270 Watt / 24V Solar Panels | 11500 | 43 |
| Luminous 300 Watt / 24V Solar Panels | 14200 | 47 |
| Luminous 335 Watt / 24V Solar Panels | 14500 | 43 |

Loom Solar. (2020). Solar Panels. Https://www.Loomsolar.Com/Collections/Solar-Panels/Brands_luminous.

- **Solar Charge Controller:** A charge controller or charge regulator is basically a voltage and current regulator that stops batteries from overcharging. It regulates the voltage and current coming from the solar panels reaching to the battery. To get an Idea of the price of the price of the different Charge Controllers here's the latest price list from an online marketplace:

**Luminous Solar Charge Controller Price**

| Solar charge controller model | Selling price |
|---|---|
| 6 amps, 12 volts, pwm | 600 |
| 10 amps, 12-24 volt, pwm | 1,050 |
| 20 amps, 12-24 volt, pwm | 1,500 |
| 20 amps, 12-24 volt, pwm | 2,500 |
| 50 amps, 48 volts, pwm | 7,500 |
| 50 amps, 96 volts, pwm | 11,000 |
| 50 amps, 120 volts, pwm | 15,500 |

Loom Solar. (2020). Solar Charge Controllers. Loomsolar.Com. https://www.loomsolar.com/collections/solar-chargers-controllers

- **Battery Bank:** Battery banks are the storage unit of the solar tree which store direct current (DC) electrical energy for later use during night. Mostly lithium ion batteries are used as they have an extremely long life as compared to lead acid batteries.

**Solar Battery Price List in India (2020)**

| Solar Battery Model | Average Selling Price |
|---|---|
| 20 Ah Tubular solar battery, 5 years warranty | 4,000 |
| 40 Ah Tubular solar battery, 5 years warranty | 5,500 |
| 60 Ah Tubular solar battery, 5 years warranty | 7,500 |
| 80 Ah Tubular solar battery, 5 years warranty | 9,000 |
| 100 Ah Tubular solar battery, 5 years warranty | 11,500 |
| 120 Ah Tubular solar battery, 5 years warranty | 13,000 |
| 150 Ah Tubular solar battery, 3 years warranty | 15,000 |
| 150 Ah Tubular solar battery, 5 years warranty | 18,000 |
| 200 Ah Tubular solar battery, 3 years warranty | 19,500 |

LoomSolar. (2020). Solar Battery. Https://Www.Loomsolar.Com. https://www.loomsolar.com/collections/solar-battery

- **Inverter:** The direct current (DC) produced by the solar tree needs to be converted into alternating current (AC) because all our appliances are made to work on AC. The inverter takes direct current (DC) and converts it to alternating current (AC) and helps in voltage fluctuation too.

Below is a table that shows the various cost data of different types of Inverters (taken from Wikipedia):

Wikipedia.(2014).PhotovoltaicSystem.Wikipedia.Com.https://en.wikipedia.org/wiki/Photovoltaic_system#Inverter

- **Cables for Connecting Modules:** Electrical wires that connect the components and complete the circuit to facilitate transport of electrical energy from and between each component. Wires must be UV radiation resistance because of their outdoor usage.

**According to an online retailer the cost of a Solar DC Wire, 4 sq. mm, 15 Meters Pair is INR. 1,800**.

- **Metal Structure:** As there is no standard structure for the solar tree, it can be creatively designed in order to make it look pleasing to the public eye and consume less area while avoiding shading effect on leaves/panels. Therefore, the cost to make the structure for the solar tree can be determined by taking into account what material will be used to make the structure, how the structure will look like and how tall the structure is going to be.

These structures are generally constructed from steel or aluminum. This mounting structure make sure that sunlight falls perpendicular on solar panels so that maximum output can be obtained.

- **Transportation and Installation Costs:**
- In remote areas such as mountainous the costs of transport and installation are high. Though the organizations involved are aware of this they still carry on the projects due to the modular nature of the solar tree.
- Generally, transporting to long distances is very expensive and also causes loss of power, hence the produced power should be utilized locally as much as possible.

- **Overall System Cost**

The relative cost breakdown of different PV system components for 1 kWp system are as follows (excluding metal structure cost):

- module 53%
- inverter 22%
- mounting 12%
- rest 13%.
- **Miscellaneous Costs:**

Other costs such as:

- Labor costs
- Cost of machining the parts
- Cost of Maintenance

Are also considered when we take into account the various economic cost considerations regarding the manufacturing of a solar tree.

## III. CONCLUSION

In this paper, we mentioned solar tree manufacturing by reviewing the various research papers and also how to effectively use solar tree in poor area, specifically in India and how it works and what are the advantages and application of solar tree,

The Solar power tree is very efficient to capture large amount of solar energy by utilizing a very small surface area of valuable land. As India is the third largest country in the world as per energy requirement that can be easily reduces up to some requirements by this project. Due to global warming, the temperature is always on a higher range usually than assumption range so that can be used and generate electricity in large quantity. A simple calculation shows that if a National Highway having length of 300Km is installed with solar power trees would produce 110MW of poweras this is the efficient way to produce

electricity without any maintenance or other activities. Just a onetime installation and gives us a continuous output for long time. So, this energy requirements can be solved by the innovative ideas by our youth generations and everyone should start such individual project to support government and make environment healthy for human life.

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