Solar Tree

Concept Note

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Introduction

Solar Tree is an environmental enterprise, an ecological sculpture, an artificial solar structure that looks like sculptural trees and exists from small scale (size of a bonsai tree) to large scale (about the size of a wind turbine) power plant. It is an independent unit that produces green energy and provides a place of comfort and energy for a wide variety of services. The structure is ground mounted solar system with a pole that supports many individual panels up in the air. The aesthetics of solar trees differ and they have been designed to provide different means of power to different urban and built environments.

It can be placed in residential areas and in urban areas, courtyards, schools and universities, parks and along hiking trails. It can also be placed in cultural institutions as an icon and a symbol of community, environment and green education.

Technology Description:

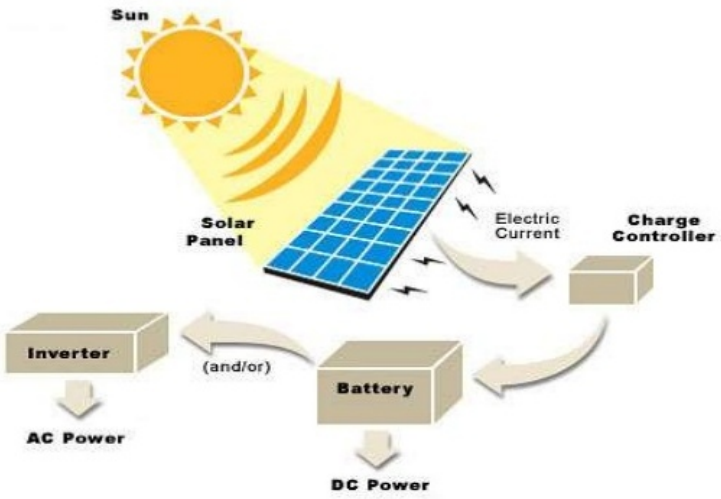
Solar tree has unique properties in terms of height and multi - angle orientation parameters. By employing the height parameter, solar tree requires less space consumption which can reduce the installation cost. Compared to the traditional solar farm which is oriented in a single direction, the multi-angle orientation parameter from the solar tree panels yields the potential capability to absorb higher sunlight intensity leading to higher output energy. At the same time, this parameter eliminates the necessity to install solar tracker which can reduce the operational cost. To increase the collection Generation of 1MW power from PV module system requires the land of 5-6 Acres approximately for housing the panels only. A tall pole-like structure would take only 1% of land area in comparison to general PV housing. In India there is scarcity of land in urban and even in rural areas. .

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. To get the maximum sun in a day time the top panel should not obstruct the bottom panels.

Working Principle:

Solar tree can be designed both for standalone and in synchronization with the power grid. It uses the generated energy form the solar panels and store the energy to the battery by a DC Charge controller. The controller may MPPT or PWM type. During the daytime when the sunlight is sufficient to meet the loads, the generated solar energy directly feed to the loads. Any excess solar energy after meeting the loads should be stored in the battery. The stored energy into the battery can be utilized when the generation from the PV is not sufficient. The inverter has proposed here to convert DC power to AC as most of the common appliances are AC and also facilitate to charge the Mobile, laptops under the shade of the solar tree.

The Solar tree used for lighting purpose is a sensor based lighting system. The automatic control and monitoring unit monitor the Solar panel output and at dusk, the solar tree switches on LED automatically. A sensor measure the amount of light at atmosphere and triggers the switch on automatically at sunset and off at dawn.



The Solar Tree consists mainly of the following components:

- Solar PV Modules
- PCU
- Module Mounting Structures
- Battery
- Monitoring Systems
- Cables and Connectors
- Lightning Arrestor & Earthing

Solar Tree Installation areas:

- Solar tree can be applicable in following fields
- In the field of Golf courses and resorts
- In Urban and Rural Areas
- Applicable in Recreational parks
- city parks In Penthouses, balconies, verandas
- Private gardens
- Applicable on Airports
- In Mountainous regions
- On Coastlines
- Applicable on Highways
- Applicable New housing estates
- In Crop Protection
- In De-forested areas.

Application of Solar tree:

Solar Tree provides green energy and a place of comfort in diverse settings and according to different requirements.

- Night illumination (bright top lighting / LED lamps)
- All possible electrical consumers such as a pump to operate the fountain
- Shaded recreation area with benches offers a **meeting place and social sharing**.
- Docking station to charge smart phones and tablets
- Services Free Wi Fi
- A water trough for animals
- Cold drinking water

Solar tree around the world:

By conducting surveys and exhibitions of different models of Solar Trees presented by many researchers can make a good platform for the progress of this technology.

The solar tree - the new symbol of Gleisdorf – was built in 1998 with a capacity of 7 kW_p and was connected to the public electricity grid. It stands in the ”solar street” which is a 3.5 km long street section, where about 80 objects are powered by photovoltaics, such as a public solar clock, advertising boards and street lights. Solar cells have also been used for art and the solar tree is one of these examples. It is 17.3 meters high and consists of a 12700 kilogram solid steel sculpture in the form of a tree with five branches holding 140 solar panels. The tree generates approximately 6650 kWh of electricity annually which can supply about 70 city streetlights in the centre of Gleisdorf.

Fig 1-1: solar tree - the new symbol of Gleisdorf

Ross Lovegrove’s Solar Tree:

Ross Lovegrove , a Welsh industrial designer known for his organic designs and designs, conceived an organic-looking solar structure with multiple curve stems and circular collections of photovoltaic cells. It was first manufactured by Artemide, a manufacturer of differentiated design products, based in Milan, Italy.

Ross Lovegrove’s original design consists of a sinuous tree constructed of steel pipes, measuring 5 meters, supporting a light bubble in which 38 solar cells, each with 38 watts of power, connected to a hidden 12V battery system which includes 1W LEDs at the tip. The solar cells for the project were commissioned by Sharp Solar.

Fig 1-2: Ross Lovegrove’s Solar Tree

Spotlight Solar structures:

In 2011, Spotlight Solar introduced a line of architectural products which customers refer to as solar trees. They offer four different model of solar tree: Lift, Curve, Trestle and Industry.

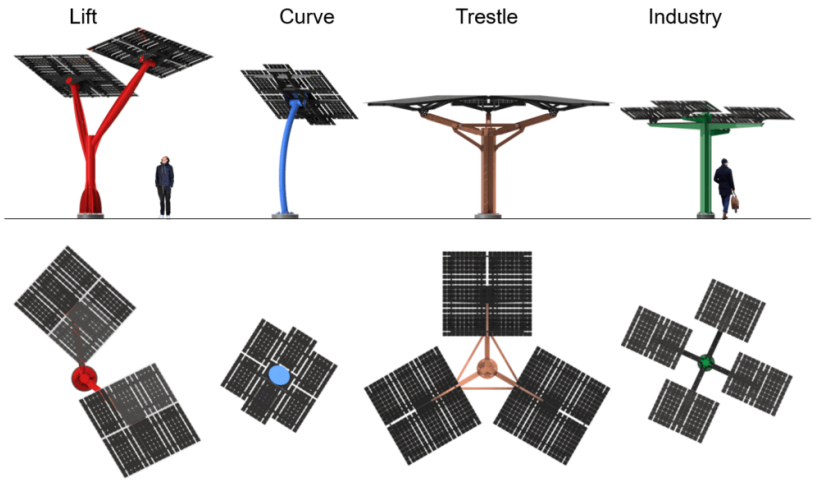


Fig 1-3: Spotlight Solar Structure

CSIR Solar Tree:

In 2016, CSIR- Central Mechanical Engineering Research Institute, Durgapur, India invented another model of solar power for its application at villages, besides national highway and power grid system to meet the electricity crisis. The developed structure is capable of generating the electricity in a 3-7 Kwh with a bare footprint of 2×2 sqft area. These solar trees are already installed and operating at the developer's campus, CSIR's Headquarter and at the residential campus of the Minister of Science and Technology of India to demonstrate the success of the technology. Researchers at

Fig 1-4: CSIR Solar Structure

CSIR-CMERI are also working on the need for public parks, gardens, market places, etc. The tree is installed with a built-in battery backup system so it can continue providing energy for up to two hours after the sun goes down, and is outfitted with a water sprinkler at the top for self-cleaning the panels. The solar tree's compact package makes it an appealing option for urban areas and rural regions with limited free space. It's already completed successful trial runs in three locations in West Bengal, India, as a pilot project. It could be a boon to a country where roughly 300 million people don't have access to electricity!

Design parameters

- Capacity / Requirement of Power (KWp)
- Height of Solar Tree
- Size and Numbers of Panels

- Wind Pressures
- Steps of Branches
- Phyllotaxi pattern of panels
- Orientation of Panels
- Maintaining Tilt-Angle
- System of tracker incorporation
- Circuit layout for final out-put (Voltage & Current) from Solar Tree On & Off-grid system.

Technical Specification:

Solar PV Modules

The Solar PV modules which have been supplied are minimum declared output of 100Wp at STC. The modules are IEC 61215 and IEC 61730 certified. The tilt angle and the azimuth of the module for this location are different and it is distributed throughout 360º angle.

Modules are made of crystalline silicon Solar cells. The SPV Modules has been tested & certified by an independent international testing laboratory.

The module frames should be made of corrosion resistant material, which shall be electrically compatible with the structural material used for mounting the modules.

The modules have been provided with a junction box with provision of external screw terminal connection and with arrangement for provision of by-pass diode. The box should have weather proof lid with captive screws and cable gland entry points.

Module Mounting Structure

The module mounting structure designed for this project is very innovative and challenging as the load bearing capacity should be calculated accurately for preventing any future difficulties. The main challenge of designing the structure is the stability maintaining the aesthetic view.

The mounting structure is designed for holding 10 to 15 numbers of modules of 100 Wp. The weight of the module is approximately 8kg/Module. The frames assembly of the array structures should be made of 80 micron Galvanized Iron.

Most photovoltaic modules are designed to last 20 years or longer. It is important that the other components in the system, including mechanical components, have lifetime equivalent to those for the PV modules. It is also important that the mechanical design requirements of the system be consistent with the performance requirements as well as with the operational requirements of the system. The mechanical design of photovoltaic systems cuts across a variety of disciplines, most notably civil and mechanical engineering and, to a lesser extent, material science, aeronautical engineering and architecture. More specifically, our mechanical design involves:

- Determining the *mechanical forces* acting on the system.
- Selecting, sizing and configuring *structural members to support these forces* with an adequate margin of safety.
- Selecting and configuring *materials that will not degrade or deteriorate* unacceptably over the life of the system.

- Locating, orienting and mounting the photovoltaic array so that it has *adequate access to the sun's radiation*, produces the *required electrical output* and operates over *acceptable PV cell temperature* ranges.
- Designing an array support structure that is *aesthetically appropriate* for the site and application and provides for *ease of installation and maintenance*.

The mechanical system which we are providing can affect the array performance in several ways:

- Increasing the amount of incident solar radiation
- Avoiding shading
- Allowing the array to operate at lower cell temperatures

The Salient feature of Solar tree Structure:

- The structures shall be for Design of Optimized Solar Tree for the different city of Jharkhand.
- The structure shall be designed to allow easy replacement of any module and shall be in line with the site requirements.
- Height of the module from the ground should be minimum 2.5 Meter
- Outfitted with a water sprinkler at the top for self-cleaning the panels.
- The structure shall be completely made up of Stainless Steel SS 304.
- The foundation for Solar Tree structure shall be preferably 1:2:4 PCC constructions or any other combination based on the local site condition requirement for which design details shall be submitted and approved before start of work.
- The support structure design and foundation shall be designed to withstand wind speed up to 150 kmph for which design details and drawings shall be approved.
- In general, bolt, nuts, shims, Fasteners and other hardware should be of stainless steel SS304.
- Structure should be designed so as to make the solar panels easily accessible for cleaning/ wiping.
- The solar tree structure should also contain enclosure made of Stainless Steel SS 304 for housing batteries and charge controller to prevent it from rain and other natural calamity. The battery housing shall consist of a platform which may be used for sitting purposes.
- All the drawings/design must be approved from JREDA officials before the start of work

Standalone Inverter

This is the heart of the system. The inverter converts the DC power to AC power to facilitate feeding into the grid. In addition it performs many other functions such as synchronization with grid.

Inverter should be having efficiency levels of 98% and above. Each inverter shall be with minimum capacity of 1-2 kVA depending on the design. The output power factor of the inverter should be of suitable range to supply or sink reactive power. The inverter shall have internal protection arrangement against any sustained fault in feeder line and lightning in feeder circuit. The inverter should be single phase static solid state type power conditioning unit. Both AC & DC lines shall have suitable fuses and contactors to allow safe start up and shut down of the system. Fuses used in the DC circuit should be DC rated. The inverter shall have provision for input & output isolation.
Inverter shall have arrangement for adjusting DC input current and should trip against sustainable fault downstream and shall not start until the fault is rectified.
Inverter front panel shall be provided with display (LCD or equivalent) to monitor the following:

- DC power input
- DC input voltage
- DC current
- Battery Voltage
- Battery current

- AC power output
- AC voltage
- AC current
- Power factor

Provision should be available in the inverter for Remote Monitoring of all the parameters mentioned under paragraph above and other important data.
The selection of inverter for a solar PV plant is important and project specific. The yearly power output largely depends on the selection of specific inverter. As our application a standalone inverter has preferred. The inverter for this project has been selected based on the following features:

a) Power Rating: Normally solar inverter is designed for three different power ratings; maximum input power, maximum output power and surge power. As it is a standalone inverter, the surge power rating is most important

b) Peak Efficiency: It is important to note the input power over which the stated peak efficiency is obtained. The inverter will deliver maximum power to the battery over a wide range of PV input power and will operate close to peak efficiency.

c) Maximum Power Point Tracking range: the inverter should have a widest range of MPP voltage which is 200V to 800V. It is thus capable of tracking maximum power for greatest flexibility in PV array design.

d) Harmonic Distortion: The Total harmonic Distortion (THD) should be less than 3%.

Salient features of the Inverters shall be as follows:

- The PCU should be designed to be completely compatible with the SPV array voltage.
- The combined kVA rating of all PCUs shall not be less than corresponding KVA at standard temperature.
- Optimum numbers of central inverter with MPPT shall be used with the power plant for maximum efficiency and shall be efficient based on PWM MPPT with IGBT/ reliable power based design.
- The peak inverter efficiency inclusive of built in isolation transformer shall exceed 85% at full load
- Inverter shall provide display of PV array DC voltage & current, Battery Voltage & Current, Inverter Voltage & Current, Grid voltage & Current, Battery charging status and required parameters when fault occurs. Remote monitoring of inverter parameters should be possible.
- Operating temperature Range shall be 0 to 55 deg C

Charge Controller Unit

- The Solar Charge Controller shall be microcontroller operated MMPT based technology and should be designed to execute the important functions of charge and discharge management of 48 VDC batteries.
- Suitable rating of Charge Controller to be provided based on the battery bank.
- This charge regulator allows the photovoltaic system to operate efficiently and prevents the batteries from any electrical shock or damage, improving consequently their average operating lifetime.

- The Solar Charge Controller should be designed for simple small-size stand-alone systems, is produced using advanced solid-state (MOSFET) and Microprocessor technologies. These technical features warrant to this charge regulator high reliability and a long average operating lifetime.

The main technical features of Solar Charge Controllers are:

- Control of the maximum charge of the battery by means of a steady-voltage charging
- Display of the state of low battery by Red LED.
- Display of the present charging mode of the battery with Green LED.
- Protection of the load output (electronic, resettable) against short circuit, overload and polarity reverse,
- Temp. Compensation
- The charge controller and the Battery for loads are preferably to be housed/mounted inside the SS 304 Enclosure on the Smart Tree. The requisite output and inputs from SPV is to be made with suitable sockets only.

Batteries:

- The Battery shall be Tubular Gel (VRLA)
- The battery bank should be able to provide backup for at least 24 hours with connected load which is around 48V
- The batteries can be installed at the base of the solar tree and should be protected from the environment.

Monitoring Systems

Computer Aided Data Acquisition Unit shall have features for simultaneous monitoring and recording of various parameters of different sub-systems, power supply of the Power Plant at the DC side and AC side. The unit shall be a separate & individual system comprising of different transducers to read the different variable parameters, A/D converter, Multiplexer, De-multiplexer, Interfacing Hardware & Software. Reliable sensors for Solar Radiation, Temperature and other Electrical Parameters are to be supplied with the data logger unit.

The data acquisition system shall perform the following operations, which include the measurement and continuous recording of:

- Ambient Air Temperature near Array Field
- Solar Radiation incidental to Array Plane
- Inverter Output
- System Frequency
- DC Bus output
- Energy consumed by the appliances

All data shall be recorded chronologically date wise. The data file should be MS Excel compatible. The data logger shall have internal reliable battery backup to record all sorts of data simultaneously round the clock. All data shall be stored in a common work sheet chronologically. Representation of monitored data

in graphics mode or in tabulation form will be displayed on the computer screen or can be printed out. All instantaneous data can be shown in the Computer Screen Provision should be available for Remote Monitoring through GPRS system.

Cables and Connectors

Cables used in DC side shall have the following characteristics:

- Insulation resistance: when 20°C >4.6100Ω.KM
- Nominal voltage: 1100V
- Without melting and flow at high temperature.
- Conforming IS1554
- Conductors are insulated with XLPE.
- Resistant for heat, temperature, abrasion, UV, Ozon and hydrolysis
- With high mechanical strength water oil and chemical resistance.

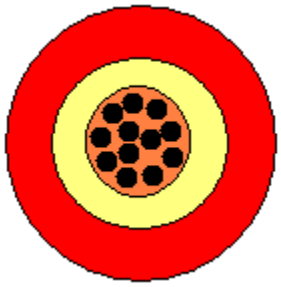


Figure: Typical photographs of DC cable

Lightning Protection

The Solar tree should be provided with Lightning protection. The Lightning Conductors are made as per applicable Indian Standards in order to protect the entire Array Yard from Lightning stroke. Necessary concrete foundation for holding the lightning conductor in position will be made after giving due consideration to maximum wind speed and maintenance requirement at site in future. Each Lightning Conductor shall be fitted with individual earth pit as per required Standards including accessories, and providing masonry enclosure with cast iron cover plate having locking arrangement, watering pipe using charcoal or coke and salt as per required provisions of IS.

Earthing

The earthing for solar array & structure shall be as required as per provisions of IS 3043:1987. Necessary provision shall be made for bolted isolating joints of each earthing pit for periodic checking of earth resistance. The complete earthing system shall be mechanically and electrically connected to provide independent return to earth. All non-current carrying metal parts shall be earthed with two separate and distinct earth continuity conductors to an efficient earth electrode.

Benefits

- It gives more solar power compared to conventional SPV layout – consumes 1% of land surface for same power.
- It holds the panels at a higher height – gets more sun.
- It can be facilitated with water sprinkler at the top of the SPT.
- Even the paddy lands, agro-gardens, roads or parks can be utilized for production of megawatts of solar power without hampering any cultivation work.
- It can produce 25% to 30% more power as because - all panels may be rotated by 180□ in the afternoon and morning towards the east and the west by an easy mechanism