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SOLAR TREE DESIGN

TEAM MEMBERS

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ABSTRACT

A solar tree is a structure that is meant to take advantage of renewable energy, while providing additional benefits when compared to traditional solar stations.
The concept of a solar tree is to generate electricity along with providing a shaded area. This area can be used as a charging station as well as a space that may include a vending machine.
A solar tree utilizes many of the same concepts that solar stations use including optimal angles to gather sunlight to produce energy, but at the same time, it reduces the land surface required and adds an aesthetic value to the landscape.
The desired outcome is to produce a design for the structure and electrical operation of a solar tree that can generate up to 4 kW of energy, at standard test conditions, while utilizing commercial solar panels. Structural and Electrical analysis were performed to validate the design.

OBJECTIVES

Design and perform elementary tests for the structure and electrical operation of a solar tree based on commercial photovoltaic modules, for a nominal energy production at standard test conditions in the order of 4 kW. The following objectives were established:

- Design the mechanical structure of a Solar Tree.
- Perform a force analysis for the structure and select optimal materials.
- Design proposal for a sun tracking system (one axis).
- Perform electrical analysis and draw an electrical diagram.
- Gather data from experimental testing to verify performance.

BACKGROUND

A novel structure for producing renewable electricity, may resemble a natural tree but with solar panels instead of leaves.The main objectives of a solar tree are:

1. To reduce the land required for traditional PV systems.
2. To enhance the efficiency of solar PV systems.

Solar Trees are a relatively new concept dating back to 2011. At first the concept was compared with traditional roof top solar panels. The original design was said to be 20 percent more efficient than solar panels that are mounted on rooftops.

Figure 1. Solar Tree designed by Ross Lovegrove.

For an optimal design the solar panel must be placed at the angle of latitude where the panel is going to reside. The most efficient designs have capabilities of tracking the sun to achieve the desired angle of incidence at all times of the day.

METHODS AND APPROACH

In order to design the solar tree, according to the requirements given by CENAM advisors, the project was divided into 3 specific stages:

Mechanical design.

- A comparative chart of actual solar trees designs was created with the information gathered form the state of art, including pros and cons for each one.
- Three preliminary designs were created with different features, but one design was selected and improved about the shape and weight (to achieve the lowest weight possible), while some force analysis and fluid dynamics analysis were performed .
- A proposal of sun tracking system was done according to the optimal range of movement for one axis, using a hydraulic cylinder.

Electric design

- An analysis of electrical consumption loads was done considering the use of generated energy to supply a vending machine and a charging station for devices such as cellphones and computers.
- An electrical diagram is being developed to clarify the connections between the electronic components.

Experimental testing

- Experimental measurements will be performed in order to compare the collected data, (temperature and irradiance) with the data base of Red Universitaria de Observatorios Atmosféricos (RUOA) at UNAM-Juriquilla's station.

RESULTS

Solar Tree Design

The Solar Tree design that was selected includes 12 PV modules aligned at the same plane, meaning that none of the solar panels shades another.

It's fixed facing south at 20 degrees and considers a one axis tracking system (oriented east to west), so that the energy production is maximized. The shade of the Solar tree is optimal for a sitting area.

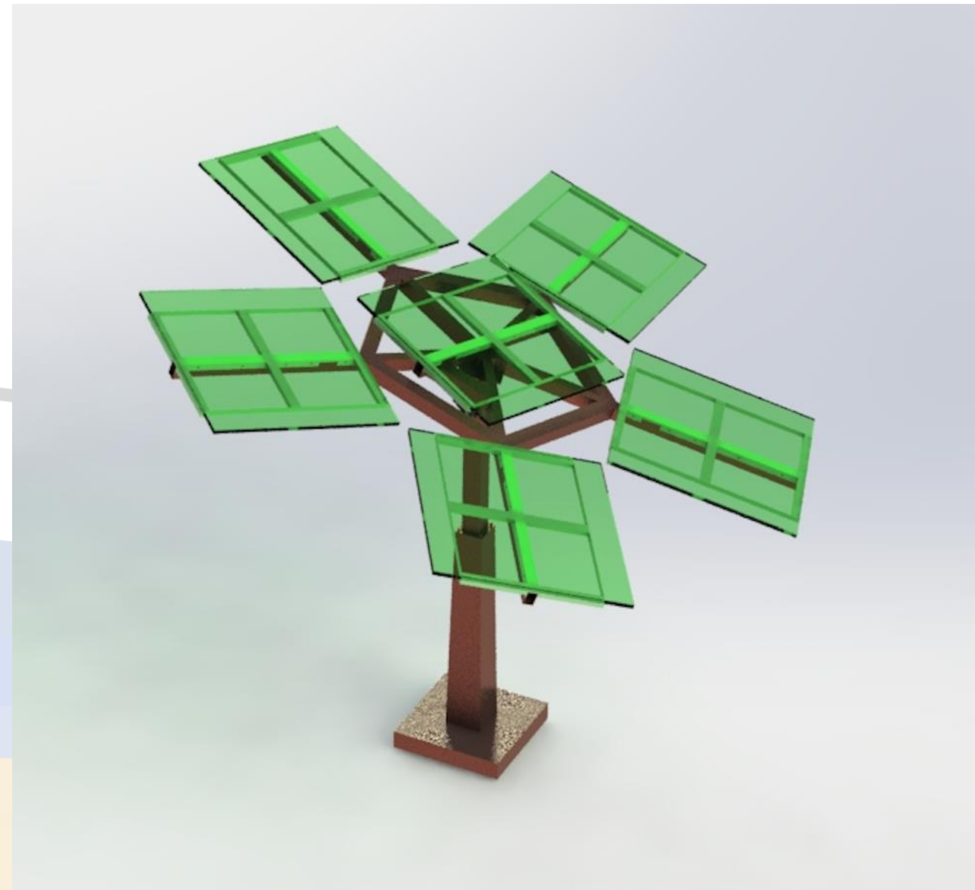

Figure 2. Solar Tree design selected by CENAM.

Electric Design

- Installed capacity in DC: 4.08 kW
- Installed capacity in AC: 3.94 kW

The annual production of the PV system was calculated using the Global Horizontal Irradiance measured by UNAM, and considering the effects of temperature:

- DC Annual Production: 8465.96 kWh
- AC Annual Production: 8169.65 kWh

The annual production could be raised up to 25% with the tracking system.

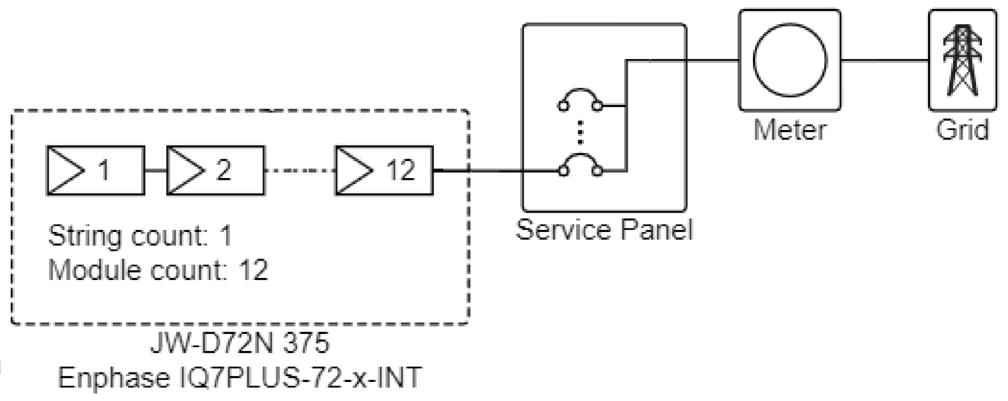

Figure 3. Electrical Diagram of the PV system.

The electrical design will be grid-tie since this type of system requires less cost due to a small number of electrical components and maintenance is generally cheaper. Grid-tied systems are also simpler to install.

Experimental Testing

For this stage of the project collecting local data is required, to do so, experimental measurements and tests will be performed. It is expected to obtain cell temperature, power output and irradiance data for future analysis. Therefore, 2 PV modules supports were designed and built and placed on the roof of CENAM building D. For cell temperature measurements 4 thermistors were installed on the back of the modules, along with a data logger. A pyranometer was used to get local irradiance values. From this data we determined that the net irradiance of the panel is lower then when measured by the pyranometer.

Tilt angle: 0° (flat support)			
Day (July)	Global horizontal Irradiance (KWh/m2/day)	Power Output per day (KWh)	Net Irradiance
16	6.9032	1.291	4.5298
17	7.1055	1.416	4.9684
18	8.0359	1.592	5.5860
Total	**22.0446**	**4.299**	**15.0842**
Power output / global Irradiance =		0.1950	

Tilt angle: 20° (support facing south)			
Day (July)	Global horizontal Irradiance (KWh/m2/day)	Power Output per day (KWh)	Net Irradiance
19	6.4776		
20	5.8170	3.229	3.7766
21	6.6410		
22	7.1243	1.217	4.2702
Total	**26.0599**	**4.446**	**15.6000**
Power output / global Irradiance =		0.1706	

CONCLUSIONS

The solar tree design has a clear advantage over fixed PV power plants since the tracker increases the possibility of producing more energy with the same number of electrical components. With 12 PV solar modules the installed capacity of the solar tree reaches the 4kW at standard test condition that has been required by CENAM, although it must be taken into account that inherent losses will occur due to climatic conditions, electrical components and wiring, as well as weak radiation.
After the static and dynamic simulations, it resulted in a Factor of Safety of 1.7, under the maximum wind speed conditions (120 Km/h).
A hydraulic cylinder was selected in order to complete the tracking system.
It has been decided to implement a grid-tie system, meaning that one micro-inverter per panel will be required. Having a grid-tie system is more economical because there are fewer components when compared to an off-grid system.

REFERENCES

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