

# Solar Tracking System Installed with photovoltaic (PV) Panels to Connection Grid Tie Low Voltage (Sunflower)

H. J. Loschi<sup>1,\*</sup>, R. Ferrarezi<sup>1</sup>, N. M. Rocha<sup>2</sup>, A. A. Silva<sup>2</sup>, Y. Iano<sup>1</sup>

<sup>1</sup>Department of Communication (Decom), The Faculty of Electrical and Computer Engineering (Feec), The State University of Campinas

<sup>2</sup>The University of São Paulo (Unip)

**Abstract** The electricity is an essential factor in everyday society, and this consumption is increasing exponentially. Beyond this fact, there is also concern about the impacts suffered by the environment, caused by the current system of generation electric power system. Systems for solar, renewable and clean energy is one of the most used and implemented around the globe. This article presents a proposal for a solar tracking system installed with photovoltaic (PV) panels to connection Grid Tie low voltage, named Sunflower. The main content of this research focuses on the operating principles of Sunflower, as well as the development of a prototype Sunflower in reduced scale. The principal experiment focuses on tests between the Sunflower prototype and photovoltaic (PV) panels, to compare the efficiency of solar tracking. The deductions, based on the research tests, confirm that the Sunflower prototype is more efficient than photovoltaic (PV) panel. Furthermore, the cost of energy production is close to the price of electricity, for residential customers in Brazil.

**Keywords** Photovoltaic (PV), Tracking, Residences

## 1. Introduction

NOWADAYS, renewable energy sources provide approximately 8% of world energy (increasing to 22% if we include all uses of biomass) in many parts of the world this percentage is increasing significantly. Wind energy is the energy source whose use is increasing faster in the world. Then comes to photovoltaic (PV), with 24% growth per year in the world. Some recent studies indicate that renewable sources should increase its share to 30% to 40% of the total in 2050, assuming global efforts in public policies for environmental issues, especially those related to climate change [6], [9].

The Grid-Tie concept, attributed to solar energy, tries to enable the implementation of photovoltaic (PV) systems to connect of the electricity transmission grid, promoting economic growth, improving the living conditions of the population and as an important factor in generating employment [9].

Photovoltaic (PV) systems are composed of modules, inverters, protective devices, system of fasteners and cable. In addition to the usual components of a photovoltaic (PV) system, the Sunflower because of its logical tracking also has linear actuator, auxiliary relays, Programmable Logic Controller (PLC), power supply, single-pole circuit breakers,

among other features.

The dimensioning of a photovoltaic (PV) system for residences is done in order to produce part or all of the electricity consumed, and can exchange the surplus of energy in credits of kW. In the case of residence export energy, its electricity generation ends up benefiting other consumers, who use the energy injected into the utility distribution network [1], [9].

Typically, it can be conceptualize as follows:

- When the residence consumes more than the photovoltaic (PV) system is generating, the part of the consumption is lacking is supplied by the power grid [9].
- When the photovoltaic (PV) system generates more than is being consumed by the residence, the excess energy is automatically injected into the grid. The meter records this energy and the client shall be in kW credits to utility [9].

The use of photovoltaic (PV) systems in all Brazilian households could reduce energy deficit and sustain the Brazilian industrial growth in the coming years, as households could generate power during the day, precisely at a time when residential consumption is lower and the industries demand more energy [6], [9].

The next sections of this article will be organized as follows: Section 2 will address the potential of insolation in Brazil. Section 3 the development and the operation principle of Sunflower. Section 3.1 will present the development of a prototype small-scale and their results. Section 4 will present a projection of the results of the

\* Corresponding author:

loschihermes@gmail.com (H. J. Loschi)

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prototype and their strategies for achieving the Sunflower. Finally, in section 5 will be the final considerations.

## 2. Potential of Insolation in Brazil

The solar irradiation maps for Brazil and South America were developed by the National Institute for Space Research (INPE) under the project "Solar Wind Energy Resource Assessment (SWERA)" who did the survey about the solar energy resources in Brazil. The project's key objective is to facilitate the inclusion of renewable energy in the energy matrix of a group of selected countries. The coordination of activities in Brazil and Latin America was with the Center for Weather Forecasting and Climate Studies (CPTEC).

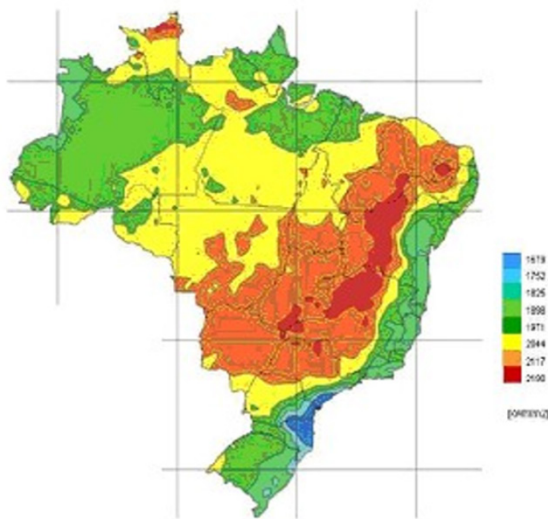


Figure 1. Solar Radiation Brazil



Figure 2. Solar Radiation Germany

In 2010, the National Institute for Space Research (INPE) published in Brazil, as result of the project Solar Wind

Energy Resource Assessment (SWERA), the Brazilian Atlas of Solar Energy.

The figure 1 shows the global solar radiation (annual average) of Brazil. Observed daily average concentration of radiation from 4.8 to 6.0 kWh/m<sup>2</sup>/day (scale, right side), while in Germany, figure 2, and the maximum value is 3.4 kWh/m<sup>2</sup>/day (scale, right side). I.e. the location with lower insolation in Brazil is better than most sunshine in Germany, which is the country with the largest installed capacity in photovoltaic energy [5], [6], [9].

## 3. Development and Operation Principle

To develop the Sunflower was necessary to consider the inclination of the axis of rotation of the earth relative to the elliptical orbit around the Sun, forming an angle of 23.45°, approximately, that determines the seasons depending on the position of the planet in its translational trajectory [2]. The Sunflower through its operating principle ensures full tracking of the azimuthal angle during the daily period of higher solar radiation and through a system of mechanical actuation, corrects over the course of the seasons (Winter Solstice will Midsummer) solar declination, according illustrated in Figure 3.

The energy provided by panels into DC (direct current) converted to AC (Alternating Current) through the inverter, in the proper tension (the same as the grid) with frequency and waveform more close of electrical current of grid [1]. For safety and reliability of the system, between the equipment above a single-pole circuit breaker installed to ensure that no peak voltage and / or current can damage the inverter.

The inverters have a MPPT algorithm (Maximum Power Point Tracking), in order to optimize the operation of the equipment and ensure that maximum power is achieved in photovoltaic (PV) panels. The inverter and responsible for the direct connection to the power meter bidirectional, which performs the measurement of consumption and generation system [1], [9].

The metal frame was sized as you can see in Figure 4, in order to behave panels and other components, consisting of a system of joints and pulleys that allow movement of the photovoltaic (PV) panels, performing the tracking of apparent motion sun (including solar declination) [2], [3].

Simplistically, we can describe the position of the drive system of pulleys and the course of the actuator stem as Fig 5.

Structural analysis were performed as following considerations:

- Materials and dimensions used in all profiles;
- Mass of photovoltaic (PV) panels and all other materials;
- Wind action with reference to NBR 6123 (1988);
- Application of wind power in each photovoltaic (PV) panel in the horizontal direction.

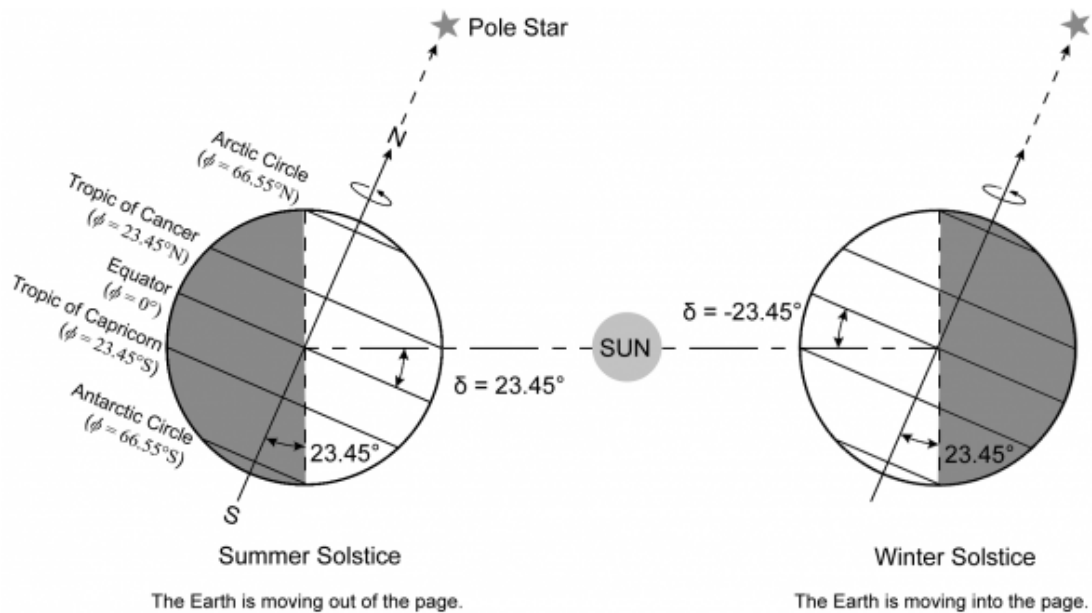


Figure 3. Solar Declination Illustrated

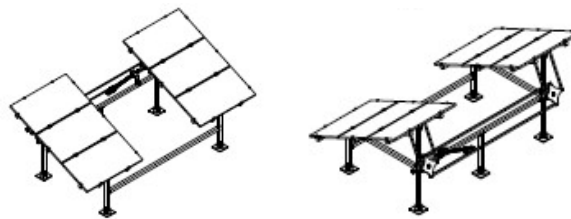
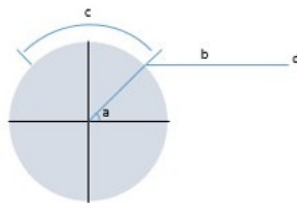
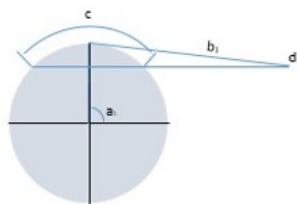


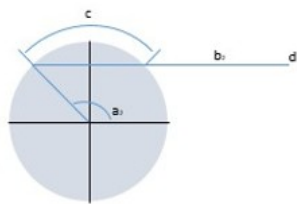
Figure 4. Metal Frame Sunflower

**Initial position, where:**

- a: initial position angle, panels inclined to eastward *Sunrise*;
- b: length of the actuator arm at rest;
- c: total course to be travelled by the actuator on the circumference of the pulley;
- d: actuator position.

**Operation position, where:**

- a: position angle, as orientation of the panels;
- b: length of the actuator arm at operation;
- c: total course to be travelled by the actuator on the circumference of the pulley;
- d: actuator position.

**Final position, where:**

- a: final position angle, panels inclined to westward *Sunset*;
- b: length of the actuator arm at final condition;
- c: total course to be travelled by the actuator on the circumference of the pulley;
- d: actuator position.

Figure 5. Representation of Cinematic Actuation Pulleys

Through the Von Mises graph [3], [7], according Figure 6 e 7, has been found maximum values of 14,3MPa or  $1,47 \times 10^7$  N/m<sup>2</sup>, less than the yield stress of the material used in the

structures of the module who is from 210MPa for carbon steel and low alloy value.

The solar tracking is possible through automation,



consisting of a PLC, which performs the function of control over the linear actuator, responsible for actuation the joints and pulleys system. Was developed a logic of time control, to meet the need to control and the linear actuator for the period from 10:00am to 16:00pm hours where we have the highest levels of solar radiation, and consequently also the period of greatest generation energy [6], [2], [8].

The logic developed for the timed advancement of the linear actuator has the following function: PLC transmits 90 commands timed along the 6 hours of operation. These commands are divided into 90 actuation every 238.7 seconds with pulse duration of 1.3 seconds this means that every 4 minutes the panels to move 1 degree, and the total actuator stroke of 353.7 mm, that representing a 90 degree movement of the panels [8].

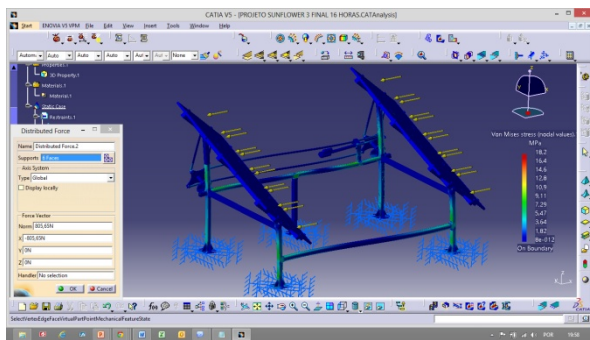


Figure 6. Analysis of Strain on Structure

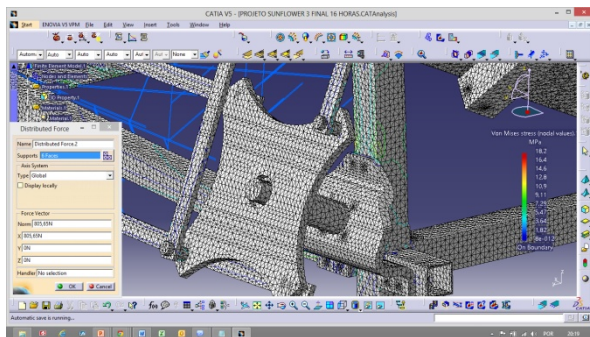


Figure 7. Analysis of Strain on Structure

### 3.1. Development of Prototype

For the prototype, the operating principle follows the concept of Sunflower project however on a reduced scale (panel's 5W each). Not made use of inverters to obtain the load values, was used fan, compatible with the power of the panels were used to simulate the load operation, the tests were performed daily during the month of August 2013 (winter), October 2013 (spring), January 2014 (summer) and March 2014 (Fall), thereby obtaining results in all seasons.

To performance tests between Sunflower prototype and photovoltaic (PV) panels (5W), according Figure 8 e 9, to provide an analysis about efficiency of solar tracking.



Figure 8. Installation of Sunflower Prototype



Figure 9. Installation of photovoltaic (PV) Panels

The Figure 10 presents the comparison of the values obtained from the tests of photovoltaic (PV) panels (Blue) and Sunflower prototype (Orange), resulting from measurements made during the period from 06h00min am to 18h00min pm.

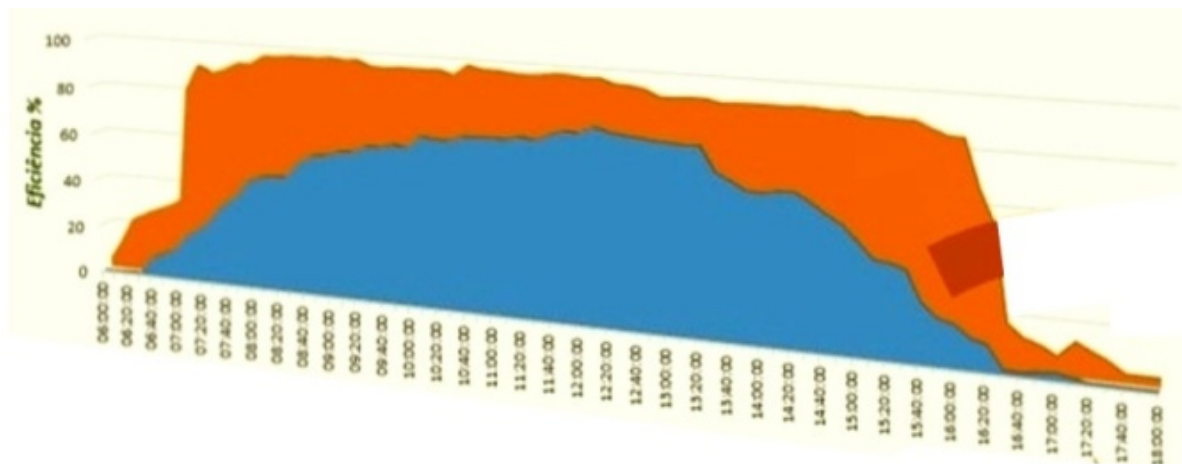


Figure 10. Comparison Results of the photovoltaic (PV) Panels and Sunflower Prototype

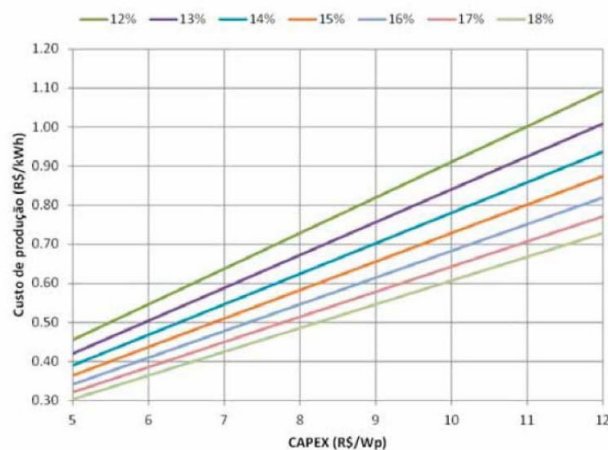
## 4. Results

Through comparison analysis of the results obtained, it is possible to observe the difference in efficiency that according to the tracking system prototype Sunflower keeps completely perpendicular to the apparent motion of the sun panels. After conducting several tests, we observed a difference of 31% with a variation of  $\pm 0.8\%$ , higher than the prototype Sunflower compared to photovoltaic (PV) panels.

This result already considers the following factors used in the sizing of photovoltaic (PV) systems for residences:

- Loss in power inverter DC to AC;
- Any shading on installation;
- Possible accumulation of dust or dirt on the modules, reducing the absorption capacity of the irradiation;
- Losses (Ohmic) in the wires, both in AC and DC side of the facility;
- Power consumption of the system.

The Figure 11, presents the cost of electricity production (R\$ / kWh) for investment costs (X axis) and curves with capacity factors (FC) ranging between 12% and 18% bands, as caption at the top of the graph [4], [9].



**Figure 11.** Production cost (R\$/kWh) vs. CAPEX (R\$/Wp) vs. Capacity Factor

Through the graphical is perceived that an installation with 15% capacity factor (national reference), investment cost of 9 R\$/Wp (projection of Sunflower project) has costs of energy production of 0.65 R\$/kWh. This value is close to the order of magnitude as price of electricity for residential customers of different concessionaires in Brazil, including taxes and charges [4].

## 5. Conclusions

The Sunflower project in defining of their concept sought to follow business models standard for photovoltaic (PV) energy of ANEEL (National Electric Energy Agency), development of electronic components in search of the best cost benefit, reliability and technical excellence in quality and the development of a product as an entrepreneur factor to generate employment, always focusing on residences. Especially considering the data of production costs, the Sunflower project is able to perform the installation in most Brazilian states [4], [9].

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