

Article – *Smart Energy*

# Development of a Standard of Solarimetric Stations SONDA

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## HIGHLIGHTS

- Shadowing simulation of a solarimetric station.
- Description of equipment from the solarimetric station.
- Structure for a SONDA standard solarimetric station.

**Abstract:** With the increasing of energy demand in Brazil and the unprecedented popular support for the use of energy sources with low environmental impact, the market for photovoltaic energy has become progressively relevant. Thus, it is of strategic importance to

gather information of the solar resources either for a particular location or a specific region. This paper presents all the steps taken in order to design a solarimetric station intended to be used as part of the National Institute for Space Research's (INPE) Environmental Database System (SONDA) network, from the specification of the devices and sensors that will take part in it to the structural dimensioning necessary in order to accommodate them. This high-quality network mainly collects and stores surface solar radiation data, indispensable for the solar energy study and prospecting, therefore of great importance for the generation of energy of the State of Paraná– Brazil.

**Keywords:** solar energy 1, solarimetric station 2, applied instrumentation 3.

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## INTRODUCTION

The use of solar energy is currently one of the most promising alternatives to provide the necessary energy for the human development [1]. According to [2], all the energy arriving on the surface of the Earth from the Sun in a single day is higher than the current annual energy demand of the planet. In 2017, the total solar capacity installed in the world was 402 GW. In the same year, it was installed more than 99 GW worldwide, a rise of almost 30% compared to the previous year [3].

Within this context, the mapping of the solar irradiation is of vital importance to its resource planning. For this purpose, The Brazilian Solar Energy Atlas was published in 2006, having all its surface and satellite imaging irradiation data, in conjunction with other information needed for processing, collected between 1995 and 2005. The second edition of the Atlas was only published in 2017, using a database from 1999 to 2015 [4].

Focused on a stated level, the Solar Energy Atlas of the State of Paraná was published in December 2017, as a partnership between the National Institute for Space Research (INPE), *Itaipu Binacional*, through the *Itaipu* Technological Park (PTI), and Federal University of Technology - *Paraná* (UTFPR). In this project, besides the Atlas, an interactive WEB Tool was developed in order to allow any user to identify the solar potential of any location inside the State of Paraná.

However, during the development of it, the need to obtain more accurate information of the surface solar radiation has been identified, mainly related to the components of the diffuse, direct normal and latitude inclined irradiance. This information has never been available in the state, except for a station located at TECPAR (Paraná Institute of Technology) in Curitiba, whose measured data and the current state of operation are not public [5]. Therefore, the installation of solarimetric stations, which can measure these magnitudes for the different microclimates in the State of Paraná, are propitious. With this goal in mind, in 2017, a partnership was signed between *Companhia Paranaense de Energia* (COPEL) and UTFPR for the development of a research project, in which, among other objectives, includes the installation of three solarimetric stations suitable to participate in INPE's National Environmental Data System. Those stations will be responsible for collecting and transmitting data of the direct normal, diffuse, global horizontal and inclined latitude irradiation, in addition to other measures.

The stations will be placed inside the Federal University of Technology –Paraná (UTFPR) in the campuses of Curitiba, Campo Mourão and Medianeira. The location choice was due to their spatial distribution in the state, providing important information about its solar radiation. Certain models are able to estimate the distribution of solar radiation in a region, notwithstanding, in order to measure the accuracy of these models, it will be essential to validate the estimated results with measured surface data [6].

The SONDA data network is the result of a project from the National Institute of Space Research (INPE), whose objective is the implementation of physical infrastructure to increase and improve the database for solar and wind energy resources in Brazil [7].

From the measurements of a SONDA station it is possible to obtain values of direct normal, diffuse and global radiation on a horizontal and inclined surface [4].

## METHODS

To avoid shades over the equipment, present on the SONDA, it is necessary to perform a previous analysis. For this purpose, a qualitative analysis was carried out using software simulation. The shading analysis done with the utilization of the AutoCAD development platform aims to reduce or eliminate shadow over the solar radiation measurement equipment throughout all the days of the year. For this, the study has focused on the critical days: summer and winter solstices.

The sensors used for the SONDA stations that will be installed in the UTFPR campuses are: anemometer, for wind direction and speed measurement; secondary class pyranometer for the measurement of the global horizontal, diffuse and latitude inclined component; first-class pyrheliometer for measurement of direct normal radiation; pyrgeometer, for measurement of long wave radiation; solar tracker; thermohydrometer, for measuring the temperature and air relative humidity; barometer, for atmospheric pressure measurement; rain gauge and photosynthetically active radiation sensor (PAR). A datalogger will be installed for data collection and storage and other accessories.

In order to complement the measured data, it is also possible to incorporate in these stations other sensors such as atmospheric visibility sensor, all-sky camera and spectroradiometer, which allow the development of other studies in the area and also the deepening of current studies.

### Equipment and Accessories Description

Conditioner: device designed to keep the datalogger secure, protected against damage from exposure to water and pollutants. An example of the equipment is shown in Figure 1.



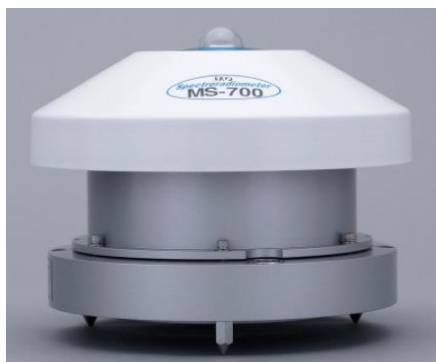
**Figure 1.** Conditioner from *Campbell Scientific*, model 16.

Anemometer: equipment to measure wind speed and direction by sending ultrasonic signals between its electrodes, one pair at a time. Because of its measurement method, this equipment must be far from radiofrequency sources and must be installed at a height of 10 meters from ground level [9]. An example of the equipment is shown in Figure 2.



**Figure 2.** *WindSonic-4* Anemometer, from *Gill Instruments*.

Spectrometer: instrument responsible for estimating values of solar irradiance by frequency spectrum band. An example of the equipment is shown in Figure 3.



**Figure 3.** Spectrometer from *EKO*, model *MS-700N*.

PAR (Photosynthetically Active Radiometer): equipment capable of verifying the incidence of photosynthetically active radiation, which is the type of radiation associated with the process of photosynthesis of plants. An example of the instrument is shown in Figure 4.



**Figure 4.** PAR from *Kipp&Zonen*, Lite model.

Pyranometer: device used for measuring both global and diffuse radiation [9]. Obtaining the global radiation values does not require the use of a solar tracker [13]. However, to measure the diffuse radiation, it is necessary to use a sphere or ring of shading is required to prevent the incidence of direct radiation in the sensor [9]. An example of the described instrument can be viewed in the Figure 5.



**Figure 5.** Pyranometer from *Kipp&Zonen*.

Pyrheliometer: device used to measure the direct irradiance normal to the surface [1]. In order to do the measurements, the equipment must be pointed directly at the sun, so it must be connected to a solar tracker with two axes [14]. An example of the equipment is shown in Figure 6.



**Figure 6.** Pырheliometer from *Kipp&Zonen*, model *CHP1*.

Pyrgeometer: high-quality radiometer whose function is the measurement of long wave irradiation in flat surface, due to the incident radiation of the hemisphere above the equipment. This equipment can be connected parallel to the horizontal surface and can be positioned in the solar tracker [15]. An example of the equipment described is shown in Figure 7.



**Figure 7.** Pyrgeometer from *Kipp&Zonen*, model *CGR4*.

Solar Tracker: platform-like equipment with the purpose to point devices specialized at the sun's movement according to the function of each [16]. In the solar tracker, a pyrheliometer can be installed to measure direct radiation, a pyranometer for diffuse radiation measurement, and a pyrgeometer. In this way, this equipment can measure irradiance variables that depend on the orientation of the Sun throughout the day. An example of the equipment is shown in Figure 8.



**Figure 8.** Solar Tracker from *Kipp&Zonen*, model *Solys2*.

Thermohydrometer: allows the measurement of temperature and the air relative humidity. This device obtains the temperature measurement through a platinum resistance and the humidity measurement through a high precision capacitive sensor. This equipment has a protection to prevent that meteorological factors interfere in its correct operation [9]. The fixture bracket attaches to a vertical post up to 5 cm in diameter [17]. An example of the equipment described is presented in Figure 9.



**Figure 9.** Thermohydrometer from *RM-Young*, model 41372VC.

Barometer: equipment used to measure atmospheric pressure [9]. This device must be installed in an enclosed location. If this is not possible, it would require a special protection. The installation should always be in a vertical position, with the connectors facing downwards to prevent water accumulation [18]. An example of the equipment is shown in Figure 10.



**Figure 10.** Barometer from *Campbell Scientific*, model PTB110 Vaisala.

Atmospheric visibility sensor: is used to measure the extinction of light in a known trajectory [19]. This equipment has a good resistance to background light, however, it is recommended that the sensor is not pointed at a light source or a reflecting surface [20]. An example of the equipment described is shown in Figure 11.



**Figure 11.** Atmospheric visibility sensor from *Campbell Scientific*, model CS-120A.

Rain gauge: device that does the measurement of rainfall [9]. The equipment is 200 mm in diameter and 315 mm high. It should be installed away from large obstructions such as buildings and trees. It has three holes of 10 mm diameter for fixing and level adjustment [21]. An example of the equipment described is shown in the Figure 12.



**Figure 12.** Rain Gauge from *Hydrological Services*, model TB6.

All-Sky Camera: is a camera that captures images of the sky as a way of measuring cloudiness as well as other obstacles to the irradiance incident on the ground [21]. An example of the equipment is presented in Figure 13.



**Figure 13.** All-Sky Camera from *EKO*, model ASI-16.

### **Stations Geographical Layout**

In order to map the microclimates in a more comprehensive way, three campuses of UTFPR were chosen: Curitiba, Medianeira and Campo Mourão; all of them in different parts of the Paraná state.

### **Equipment Selection and Allocation**

For this project, it was decided that the station will be placed over the ground and, in order to protect and adequate arrangement of the constituent equipment, it was decided to use a platform to set the sensors.

The measuring instruments can be positioned in different spots of the platform, however, it is of utmost importance for the efficiency of the majority of the equipment, that there is no shadowing during the day all over the year [9]. For this to be possible, it would be necessary to avoid the shading by external sources and others equipment.

### **Platform Sizing**

To meet these demands, a digital prototype of a platform for the installation of the equipment was made e, referenced in the station's models for the SONDA standard installed throughout the national territory[7]. The front, side, top, three-dimensional perspective and a three-dimensional model of the station were elaborated using the AutoCAD development platform [23].

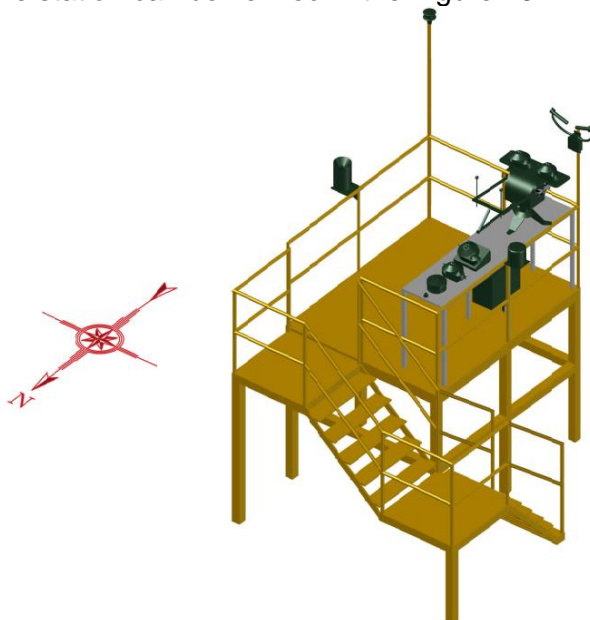
## RESULTS AND DISCUSSION

The equipment labeling, in the schematic of the project, was carried out in numerical order. The association between the equipment and their respective identifications can be seen in Table 1.

**Table 1.** Equipment identification for the station

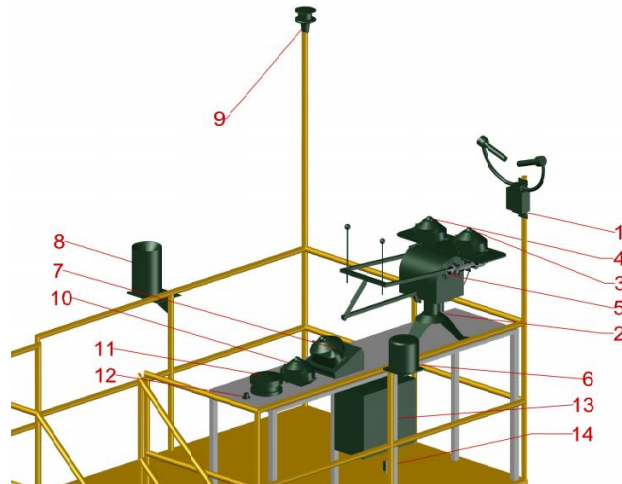
Item	Equipment
1	Atmospheric visibility sensor
2	Solar Tracker
3	Diffuse Radiation Pyranometer
4	Pyrgometer
5	Pyrheliometer
6	All-Sky Camera
7	Inclined Surface Radiation Pyranometer
8	Rain gauge
9	Anemometer
10	Global Horizontal Pyranometer
11	Spectrometer
12	PAR
13	Conditioner
14	Barometer
15	Thermohydrometer

The station perspective view is displayed in the Figure 14. The indication of the equipment present in the station can be verified in the Figure 15.



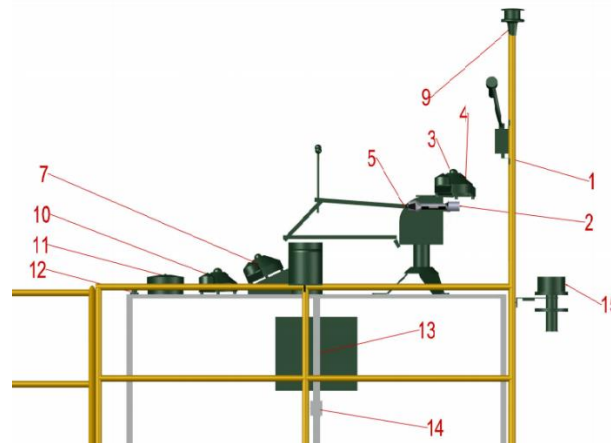
**Figure 14.** Solarimetric Station, in perspective.





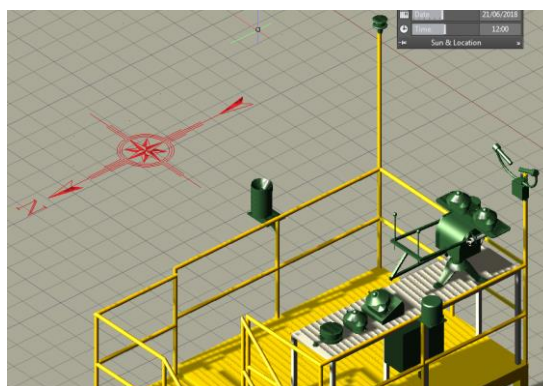
**Figure 15.** Equipment presents in the station.

The side view of the station is present in Figure 16, indicating the equipment whose visualization is not possible in the three-dimensional perspective.



**Figure 16.** Station's side view with indication of the equipment.

The Figure 17 presents the result of the computational simulation of shading generated by the station components to the radiation with solar height characteristic of the winter solstice period in the city of Curitiba, Paraná, as an approximation to the locations of other cities where the seasons will be implemented.



**Figure 17.** Three-dimensional view of the station, in simulation of shading effect under sunlight at the winter solstice for the city of Curitiba, Paraná.

The winter solstice solar height was used as a reference, because it is the worst operating situation of the equipment.

The instruments that will compose the stations must be tested before implantation, and the radiometers must be very well leveled. Another point of attention should be regarding the assembly of the metal structure, which must be positioned on a solid platform, and the material used in its manufacture must not suffer deformations caused by the temperature variations throughout the day, as not to compromise the sensors measurements. It is also necessary to carry out the previous planning of the equipment allocation in order to avoid any shading over the sensors.

## CONCLUSION

As a result of the increasing participation of solar energy in the generation of electric energy, the mapping of solar radiation and other magnitudes has become increasingly important, it is of great importance the correct planning of equipment, structures and measurement places.

Therefore, the structure of the SONDA station was designed to adapt the equipment that measures the solar radiation components in order to avoid shading from both the solarimetric station structure and adjacent equipment. The other equipment were also allocated according to the manufacturer's recommendations and positioned in the lateral regions and to the south of the solarimetric station, with the purpose of avoiding shades over the equipment allocated in the table.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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