Modifying a pyrheliometer to measure direct normal and circumsolar irradiance

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1. Introduction

Direct normal irradiance (DNI) is key to concentrating solar power (CSP) systems energy generation. However, pyrheliometric measurements of DNI also include a circumsolar normal irradiance (CSNI) component because the aperture angle of the instrument is larger than the sun disk. CSNI is due to the scattering of the sun rays by molecules, aerosols and some cloud types such as cirrus clouds [1]. As a result, energy is transferred from the direct solar beam to the circumsolar region, i.e., the region in the vicinity of the sun disk [2]. Typically, CSP systems have a lower aperture angle than that of pyrheliometers, which means that these systems are not able to absorb the same amount of CSNI as the amount that is present in the DNI measurements, leading to an inaccurate forecast of energy generation of CSP systems if DNI measurements are directly used in its sizing and operation. In this way, measuring CSNI for different aperture angles is important to better size, operate and optimize the energy generation of CSP systems.

In this work, a conventional pyrheliometer field-of-view is modified through the variation of its collimator length and diameter in order to gather information on the circumsolar irradiance [3]. The modified pyrheliometer is composed by a revolver with four possible combinations of tube lengths and diameters and a stepper motor, which automatically enable varying the field-of-view of the pyrheliometer.

2. 3D mechanical model

A 3D model of all components was drawn in a 3D software to study the best fit of the revolver, stepper motor and motor enclosure on the pyrheliometer and sun tracker, considering all the constraints to this system to function properly. The 3D model is shown in Fig. 1.

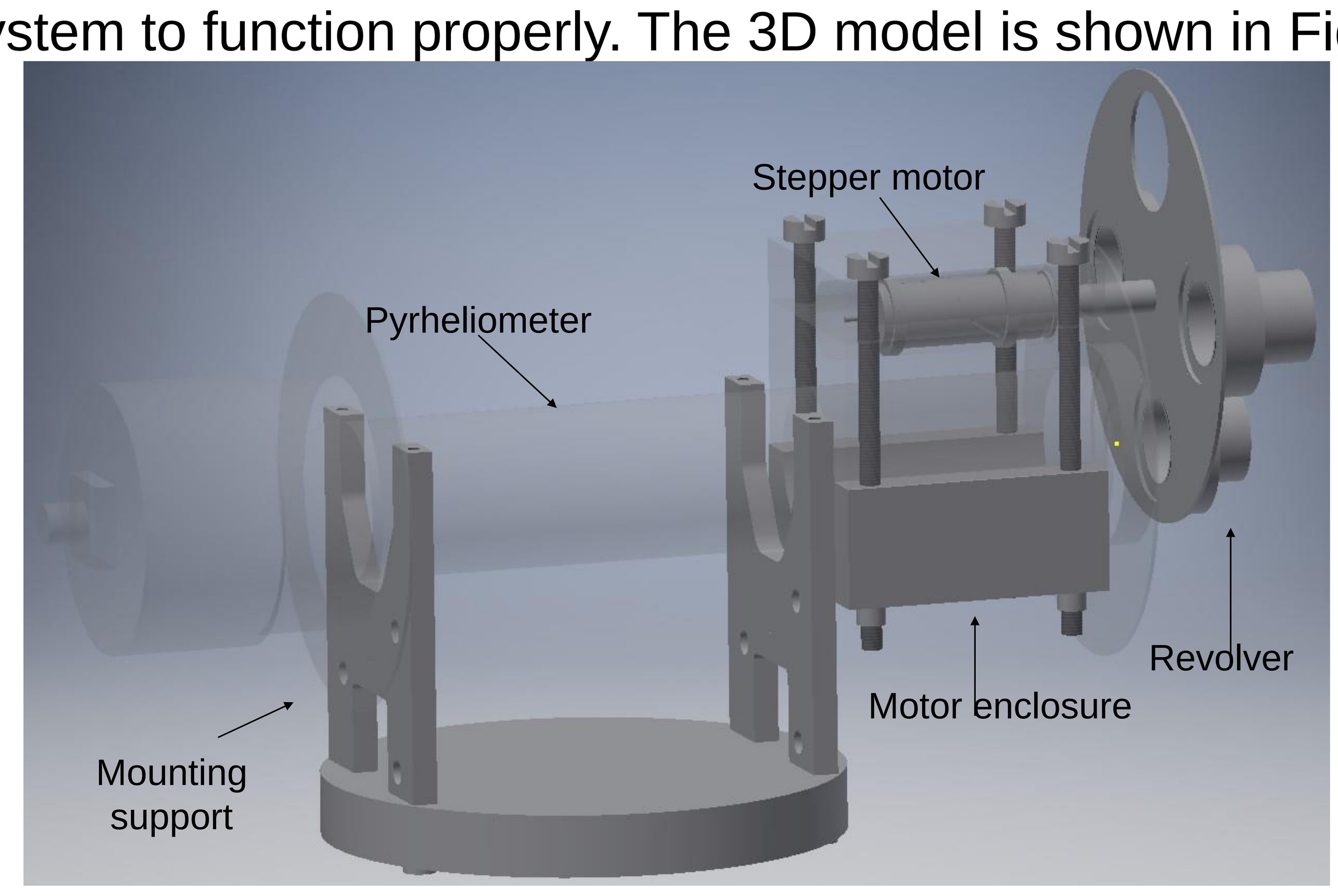

Figure 1 – 3D model of the all components.

3. System assembly

The revolver was printed using a 3D printer. The motor shaft and enclosure were built at the workshop of the University of Évora. The system is controlled using an Arduino board. The pyrheliometer with the motor and revolver attached is shown in Fig. 2.

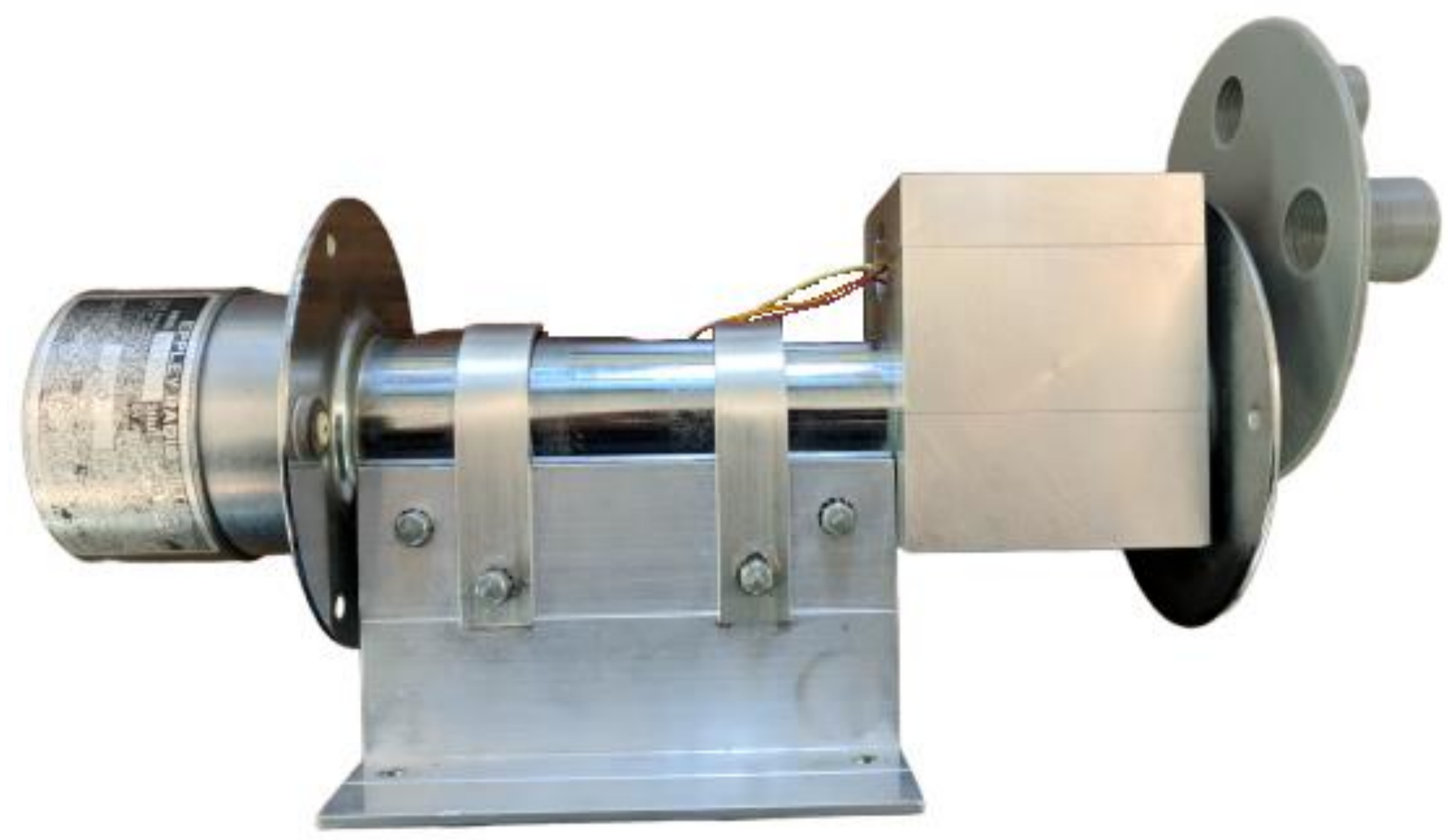

Figure 2 – Field pyrheliometer (Eppley NIP) with motor and revolver attached.

4. Indoor calibration

The pyrheliometer indoor calibration is going to be performed using the optic fibber illuminator Fiber-Lite DC-950 and a reference pyrheliometer. The indoor calibration experimental setup is shown in Fig. 3.

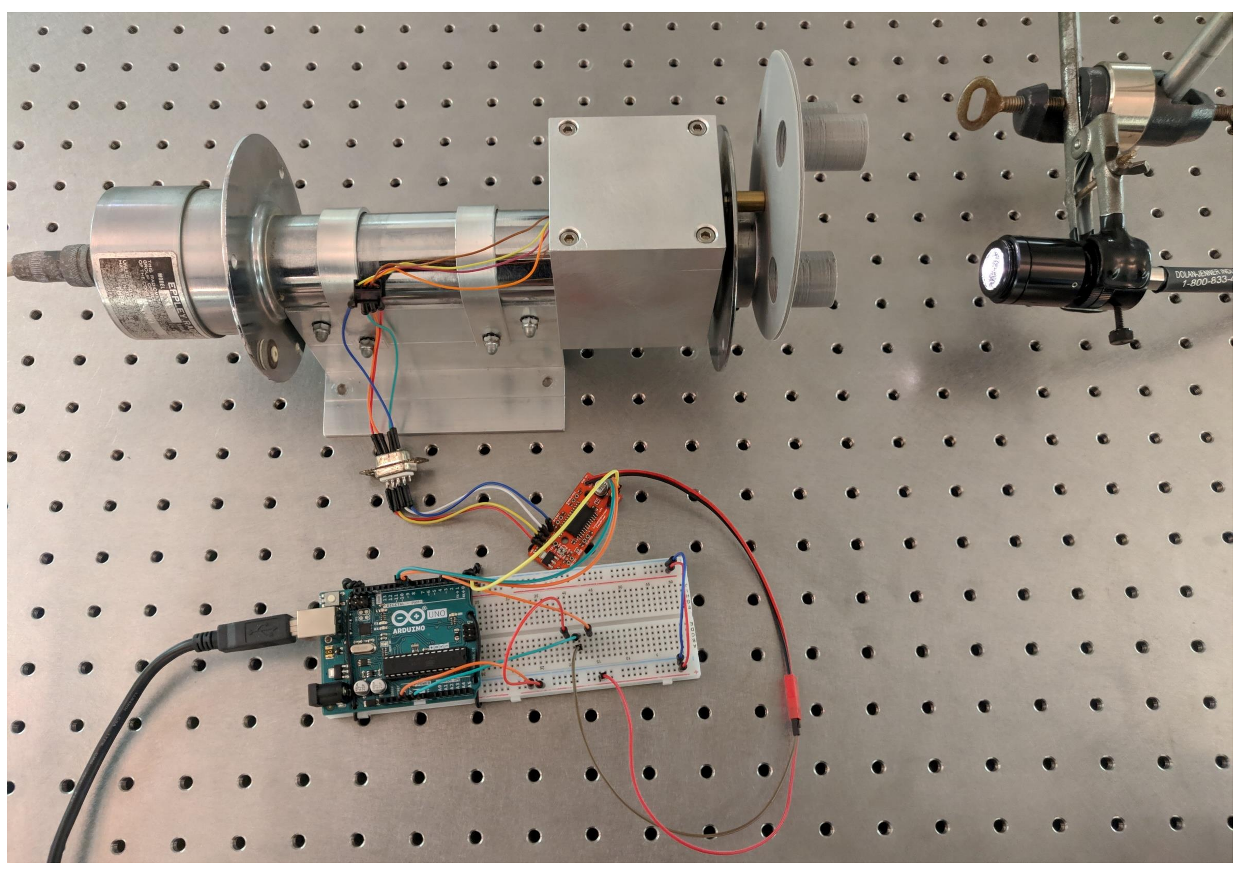

Figure 3 – Indoor calibration experimental setup.

5. Conclusions and Future work

This work aims to improve the capabilities of a pyrheliometer through the variation of its aperture angle, which is achieved by changing the length and diameter of its collimator. To that end, a system was designed to automatically change the position of a revolver which allows for measuring DNI with different aperture angles and, with that, to obtain the CSNI profile. A 3D model of the system was constructed and a 3D printer was used to print the revolver. Both motor shaft and enclosure were built at the workshop of the University of Évora.

Currently, the system is installed in the field pyrheliometer and indoor calibration procedures were initiated. The indoor calibration procedure is performed using an optic fibber illuminator and collimator and a reference pyrheliometer.

The development of a post-processing algorithm is underway. Outdoor calibration and installation have yet to be performed. The measurements recorded with this system will be useful for model development and performance assessment, as well as CSP systems design and operation.

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