Design and Demonstration of a 10-meter Metallic Reflectors Based Fresnel Lens, with Lower Focal Point Fixed to the Ground

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1. Introduction

The main drawback of conventional Dish-Stirling concentrated solar power (CSP) systems is that the solar receiver is attached to the parabolic dish and is moving during sun tracking. Therefore it is very complicated, or even impossible, to integrate a thermal energy storage (TES) system. Without TES option, Dish-Stirling technology loses the main advantage of CSP when competing against very inexpensive photovoltaic type solar farms. Wahaj Solar proposed an innovative design of metallic reflectors based Fresnel lens, called ASC, that allows the system having a lower focal point fixed to the ground [1, 2]. A 40 cm in diameter prototype was successfully demonstrated in 2016 in Jordan (see Fig. 1). Based on this laboratory-scale proof of concept and an optical model, a new design of a 10 meter in diameter pre-commercial scale unit was developed (see Fig. 2) and is currently under construction at the Masdar Institute Solar Platform in the UAE (see Fig. 5).

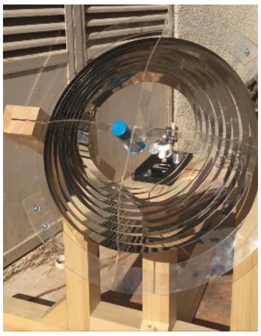

Fig. 1. ASC system at laboratory Scale.

Fig. 2. 3-D rendering image of the up-scaled ASC system.

Fig. 3. Construction of 1/16 of the ASC dome.

2. Concept and Design

There are two basic innovations in the ASC current design. The first one is a tracking system which is based on the mathematical geometric simulation of a lower focusing solar concentrator (both reflective and refractive) included in a hemisphere, such that the focal point of this concentrator coincides with the center of the hemisphere. Consequently, as the hemisphere rotates around its fixed center to track the sun, the included concentrator will focus the incoming radiation onto a fixed focal point. Based on this concept it was conceived that the hemisphere can be imaginary, and this motion can be achieved by holding the concentrator between two arms with the right length as shown in Figures 1 and 2. The second part of the innovation is the design of the concentrator itself. It is a non-imaging concentrator composed of a set of nested conical rings designed and distributed in a way to maximize the efficiency of the concentrator by evenly concentrate solar radiation to a fixed focal area. This area can be of various shapes according to the future application. The concentrator is designed to stand wind speed up to 120 km/h and the optical performance is simulated for many different conditions using TracePro®.

3. Optical Model & Construction

Many situations and conditions were simulated, including various shape of receivers and deviation from the solar position. Moreover, sections of the receiver and deflections of the reflectors are also simulated. To compare with some preliminary experimental results, one section of the concentrator (1/16th of the full concentrator) is also simulated.

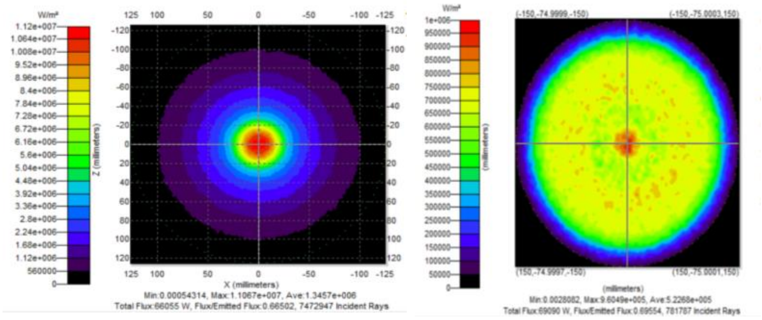

Fig. 4. Simulated solar flux on a flat receiver (left) & a cavity receiver (right).

Fig. 5. ASC system turn table operational.

As it can be seen in Fig. 4, the solar flux at the surface of a flat receiver of 25 cm in diameter can reach more than 11,000 kW/m^2 at the center, with a total flux of 66 kW. On the other hand, the solar flux on a cavity receiver with 30 cm in diameter opening is more evenly distributed with 750 kW/m^2 on most of the receiver while at the center it reaches around 1,000 kW/m^2. The total flux is in this case 69 kW. Simulations of other receiver shapes and conditions are conducted and will be shown in the full paper. Construction of the ASC system is ongoing as shown in Figures 3 & 5 and it should be fully operational in June 2019.

5. Preliminary Experimental Results.

The concentrator dome is composed out of 16 sections each looking like that of Fig. 3. The first section was manufactured, simulated in TracePro® and tested by laser and on-sun to be compared with the model. A laser beam (simulating the solar ray) is used to confirm the reflectivity angle of each conical ring. As expected, the laser beam was reflected on the same point. Next the first section was positioned to face noon during several days and a flat piece of wood was then placed at the location of the focal area. Within seconds the wood burned in a certain rectangular pattern with rounded edge as shown in Fig. 8 with 25 cm wide rounded rectangle. The simulated results of the solar flux of 1/16 section is shown in Fig. 7 showing the same pattern of the real burn demonstrating the high flux area. The temperature was measured at this burned are via an industrial thermocouple to be 180 °C. When 16 similar section concentrate the solar beam on the same area a temperature exceeding 1000 °C can be expected. System commissioning will be presented in the full paper.

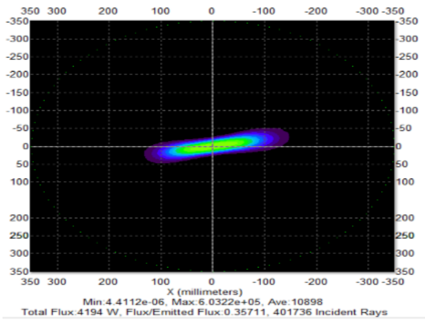

Fig. 7. Solar flux simulation of 1/16 section**.**

Fig. 8. Real burning of the 1/16 section**.**

References: **[1]** A. A. Al-Maaitah, "Method and apparatus for tracking and concentrating electromagnetic waves coming from a moving source to a fixed focal point ", US patent #9,772,121 B1. **[2]** A. A. Al-Maaitah "System for collecting radiant energy with a non-imaging solar concentrator". US Patent # 15/796,030.