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Evaluation of variation in optical performance of heliostat according to their position in solar field

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***Abstract*— In the Solar tower power plants, the solar field is composed of several heliostats placed optimally in order to minimize the optical losses due to shadowing and blocking. In this work, we study the optical performance of each heliostat in order to add a new parameter to optimize the solar field, which consists in the effect of distance between heliostats – tower on the concentrated image deformation and thereafter its effect on solar field optical efficiency.**

For this, we used the optical simulation software TracePro to simulate a solar field of 17 heliostats with a tower of 7m height. The simulation present a relation between distances compared to tower and the enlargement of concentrated image. Knowing that, the enlargement of image minimizes the optical efficiency of solar field, for this raison, we must minimize the distance optimally between rings of heliostats.

***Keywords*— Solar tower power plant, shadowing and blocking, optical performance, TracePro software.**

I. INTRODUCTION

Sizing and installing of concentrating solar tower power plants based on several parameters, where it must be respected in order to minimize the optical losses. The heliostats installation lands present a big rat of investment. Minimizing the distance between heliostat seems a good idea to minimizing the installation land, but the installation of heliostats randomly increases the shadowing and blocking between them. A lot of mathematical model was used to calculate the coordinate of each heliostat in order to minimize the two parameters (shadowing and blocking).

In every time of solar tower power plant functioning, the angle between heliostats and the horizon increase from the first ring to the last ring, the irradiance received by each heliostat varied depending on this angle. The far heliostats have a big angle with the horizon. For this reason, we must optimize the distance between heliostats in order to rise the irradiance admissibility.

The paper is organized as follows: Section I mathematical method to calculate heliostats positions, Section II description of optical simulation to improve the irradiation variation in the different heliostats, section III yearly irradiation simulation of solar field.

II. GRAPHICAL METHOD FOR A NO-BLOCKING HELIOSTATS FIELD

From purely geometrical considerations thus rendering the procedure adaptable for computer implementation. To aid this task the following definitions are introduced see Fig. 1.

Essential rings (ER): The rings that have a heliostat on the north axis in the field. Staggered rings (SR): The rings that have no heliostat on the north axis in the field. [1]

The characteristic diameter (DM): This is equal to the diagonal of the heliostat plus the separation distance.

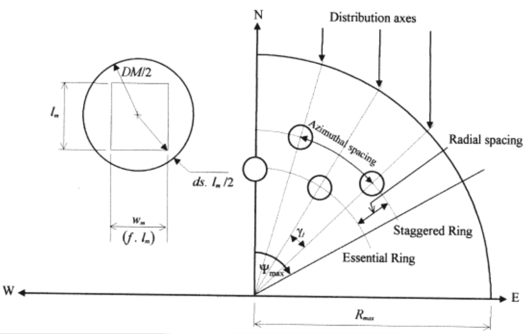


Fig. 1. Fundamental definitions in the heliostat field.

For no blocking, the minimum value of the ratio of separation distance to heliostat length, as given by Collado and Turegano [2], is:

$$dS_{min} = 2f - \sqrt{1 + f^2} \quad (1)$$

Therefore, $DM_{min} = 2w_m$ (2)

Angular direction unit: The angle between the distribution axis. In radians, this is given by

$$\gamma_j = \frac{DM/2}{R_{0j}} \quad (3)$$

The group: The heliostats that have the same angular direction unit can be classified in the same group. The group starts by an essential ring.

Angular direction: The angle between the north axis and distribution axes. It is given by:

$$\psi_m = \pm n\gamma_j \tag{4}$$

Where n=0,2,4,... for essential rings , n=1,3,5,... for staggered rings

(+) For NE half field and (-) for NW half field.

A heliostat is located in the field by defining the co-ordinates of its center. These are known once the angular direction of the heliostat and the radius of the ring to which it belongs are fixed. Hence:

$$X_m = R_{i,j} sin\psi_m \tag{5}$$

$$Y_m = R_{i,j} cos\psi_m \tag{6}$$

$$X_m = R_{i,j} sin\psi_m \tag{7}$$

III. Optical Simulation

In this section, we propose the simulation of the prototype of concentrating solar tower power plant, installed at URAER-CDER Ghardaïa site, using the software of SolidWorks [3] we have realized a CAO design Fig 2. The dimension of this power plant is: 17 heliostats of 1m² with a tower of 7m of height, the file generated is imported in TracePro software. TracePro is an optical engineering software used for designing and analyzing optical systems [4].

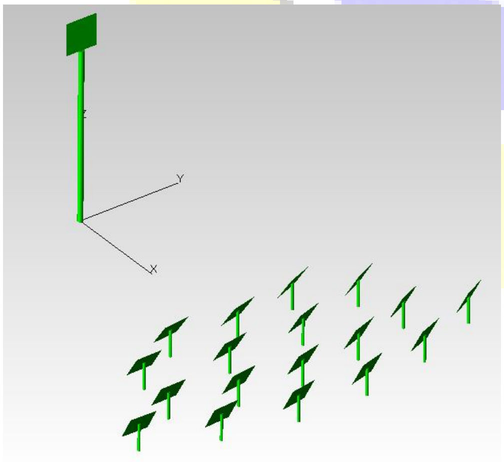


Fig. 2. 3D presentation of Prototype of concentrating solar tower power plant installed at URAER-CDER Ghardaïa.

In order to facilitate the simulation and presentation of results we simulate two heliostats placed in the same plane with the tower and sun, the first heliostat is near to tower (8.491m) and the second is far from tower (12.008m). For time and date of simulation we choice December 21 day at 12h00 because it is a minimum value of sun elevation in the year for Ghardaïa Site. The results is showed as follow:

- The near heliostat (8.491m)

In this case the image of heliostat reflection have a 1m² of area, nearly to heliostat area Fig.3, the irradiance value is less because the heliostat is tilted compared to received rays and the absorber is tilted compared to reflected rays.

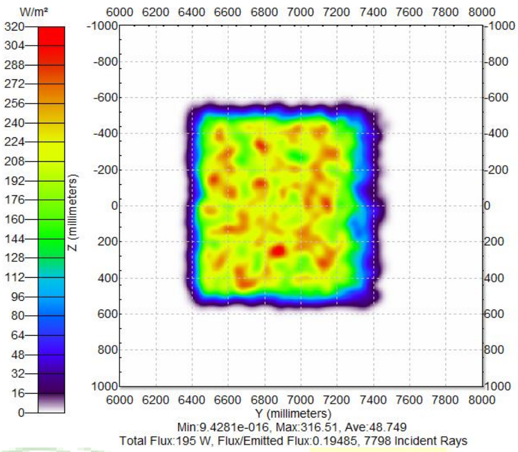


Fig. 3. Reflected irradiance presentation in the absorber from the first heliostat.

- The second heliostat is far from tower (12.008m)

In this case, the area image is almost equal to the heliostat area the irradiance is little big compared to last case Fig.4, this increase due to the difference in incident angle; we can say the angle of incidence increase with increasing of distance between heliostats and tower, for December month.

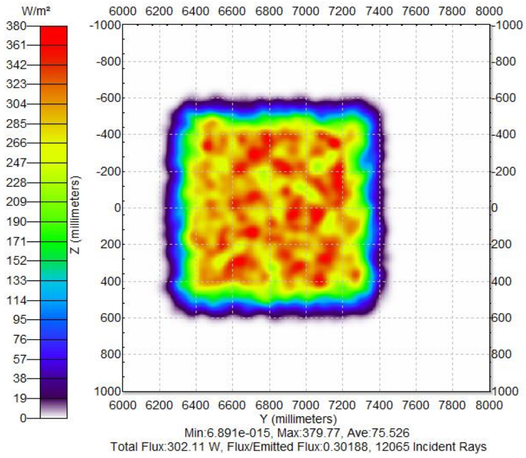
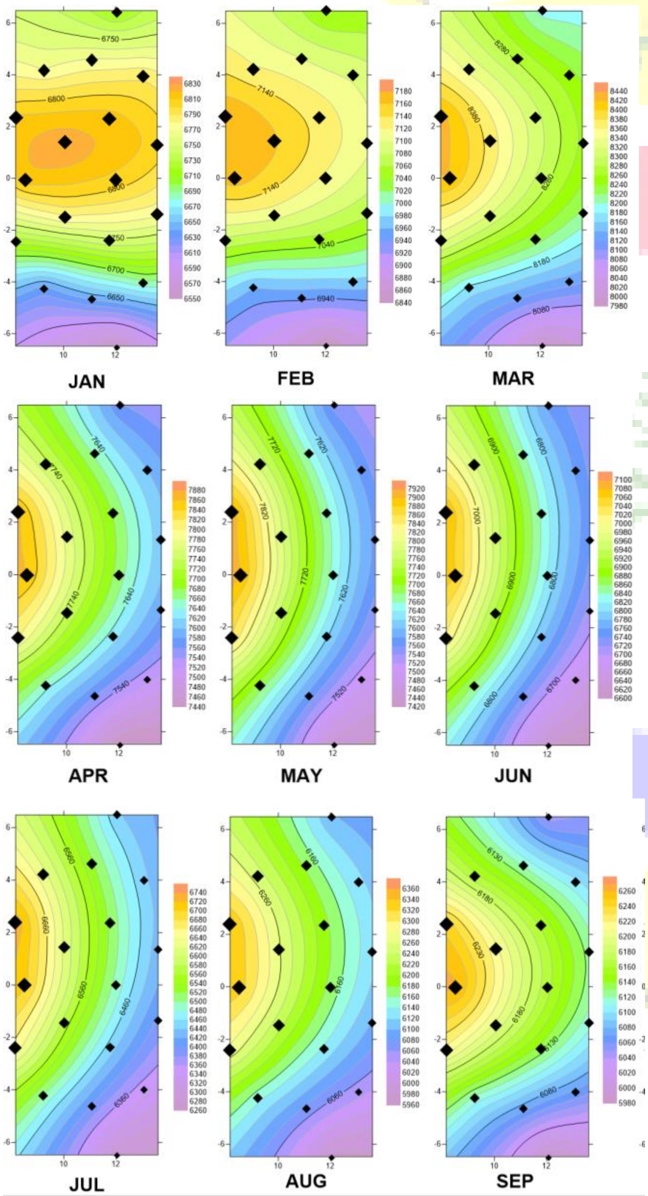


Fig. 4. Reflected irradiance presentation in the absorber from the second heliostat.

IV. Irradiation value simulation

After proving the value change of concentrated irradiance by the optical simulation, using a mathematical model of irradiance calculation (r-sun) [5], by C language we have realized a program calculation of yearly irradiation of each heliostats in the solar field for all moment of their functioning.

The results was very interesting see Fig.5, from the month of March to October the last ring in the solar field have a small value of irradiation compared to other ring and compared to other months.



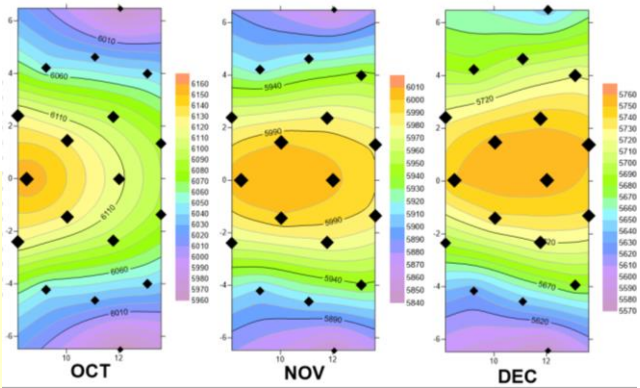


Fig. 5. Yearly irradiation received by each heliostats in the solar field.

V. Conclusions

The optimization of the solar field area seems important due to the land high cost. In this work we have optically simulate two heliostats in order to improve the variation of solar irradiance in the different heliostat according to their position in the solar field. After this improvement, we have used a solar irradiance model r-sun to calculate the yearly irradiation received by each heliostat.

The study present a decreases of incident irradiation in the far rings in 8 months in the year (March to October) we conclude that: We must optimize the distance between heliostats in order to eliminate the shadowing and blocking and to minimize the decreasing of irradiation value in the last rings. In perspective, we work to find a mathematical model to add it to shadowing and blocking model in order to have a full model of solar field optimization.

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