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State-of-the-art of heliostat field layout algorithms and their comparison

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Abstract

In this paper a complete review of the most relevant algorithms for the generation of heliostat field layouts is presented. For each of the reviewed algorithms, a description of the layout generation approach, all the input parameters required and the main formulation is provided. The algorithms have been compared for different scenarios covering a range of tower heights, heliostat sizes and acceptance angles (defining to what extent the resulting field is North configuration or surrounding). A robust methodology has been developed, which ensures a fair comparison of the algorithms by analysing the performance of optimized solar fields according to each layout generation method. For this, all the input parameters of each layout generation algorithm are optimized for each scenario prior to comparing the solar field performances. The main conclusion of the present study is that all the analysed layout generation algorithms lead to similar solar field efficiencies when compared for the considered scenarios once they are optimized. Further work is required to check if the algorithms also show similar efficiencies, or to what extent they are similar, when wider scenarios are considered (larger solar field powers, locations, etc.).

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1. Introduction

As one of the main drivers of the energy costs (around 50 % [1] of the total plant), much work is being spent nowadays in the design of low cost or more cost-effective heliostats and good progress towards costs savings is

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envisaged. One of the main trends that are currently being investigated for achieving substantial cost savings in the heliostat field is the development of small and single facet (or small number of facets) heliostats [2,3,4,5].
However, these developments require also the adaptation and/or improvement of the heliostat field layout to reach optimum optical efficiencies and larger associated savings. Up to now, several algorithms and methods for placing the heliostats in the solar field have been developed and some of them have been applied to real solar fields based on large, multi-facet heliostats, but their applicability to small heliostat is not known. A first step for adapting or improving the heliostat layout is to perform a review and comparison of existing layout generation methodologies when applied to small heliostats in order to assess their behaviour and characteristics. In this work, the different algorithms found in the literature for the heliostat field layout generation are reviewed. In this review the inputs parameters that defines each of the algorithms are specified along with the process for the layout generation. After this review, a robust methodology used for comparing the identified algorithms when applied to small heliostats is presented. Finally, the results obtained for each of the analysed algorithms and their comparison is shown.

1.1. State-of-art of the heliostat field generation algorithms

In the literature, several algorithms have been proposed to improve heliostat solar layouts efficiencies. The Radial Staggered algorithms are the most common but in the last years some other algorithms have been proposed for improving the results obtained with the classical ones. In this study the classical Radial Staggered algorithms and the more recently proposed biomimetic algorithms and other proposed methods are presented and described.

The Radial Staggered configurations were originally proposed by the University of Houston for the RCELL code [8,9]. Lipps et al. present four field configurations that are generated using two spacing values: Radial Oriented Cornfields, Radial Oriented Staggers, North-South Oriented Cornfields, and North-South Oriented Staggers. After the simulation and optimization of a 100 MWe plant case, Stagger configurations (Radial Oriented Staggers and North-South Oriented Staggers) performances were better. Thus, in the following, only these staggered configurations are considered.

The DELSOL/WinDELSOL algorithm described in [7] is a type of radial staggered configuration where the heliostats are placed using a growing procedure. In this procedure the field is divided in different zones and performance for each zone is calculated. The growth method places heliostats starting with the best zones. The input parameters used by DELSOL are: heliostat dimensions, heliostat mirror ratio to total heliostat area, receiver elevation, No. of zones in azimuth direction, No. of zones in radial direction, radius of the nearest heliostat to tower, radius of the farthest heliostat, extra distance factor to the radial spacing, and a min. gap between two rows of different zones. DELSOL creates a surrounding field from the minimum to the maximum radii and divides it in the specified No. of zones. The procedure starts by calculating the values of the parameters that define each of the zones. Using these values, the spacing between centre points of two adjacent radial zones can be calculated as well as the radius for each radial zone centre. The main parameters to define the zone mirror density are the radial spacing between heliostat rows and the azimuth spacing between two heliostats in the same row. Once the density of the heliostat field zones is obtained, the No. of heliostats in the zone can obtained. Using this information, the number of heliostats per zone row, the No. of rows in each zone and the No. of heliostats in each row are calculated.

The Heliostat Minimum Radial Spacing presented in [9] has as main goal generation of heliostat field layouts that minimizes the shadowing and blocking losses in order to use the heliostat total reflective area and therefore collect the maximum solar radiation in the receiver. The radial spacing is defined as the critical value in the definition of the heliostats position because the azimuth spacing values does not vary too much in the field. The azimuth spacing, which is constant for the complete field, has to be provided in advance. This algorithm unlike the previous ones, takes into account the latitude of the plant location to calculate the value of the radial spacing. The input parameters for the algorithm are the location latitude, the list of heliostat cell centre position angles; the list of heliostat cells centre position radius, the heliostat dimensions a list of year days to calculate the radial spacing and the daily operation time. This algorithm calculates specific radial spacing for a number of different cells defined by the user via the list of heliostat cell centre positions.

The main objective of the MUUEN algorithm, a radial staggered algorithm presented in [4], is the generation of fields avoiding blocking between heliostats. This algorithm divides the field in different zones, with different angular and radial spacing to increase the efficiency of land use. The input parameters of the algorithm are: heliostat