High-performance Stellio heliostat for high temperature application

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1. Introduction

Stellio is one of the most precise heliostats on the market, characterized by innovative kinematics and drives, an effective structural system, highly precise assembly and sophisticated controls.

For the upcoming generation of high-temperature solar tower systems, high quality heliostats are even more required than for state-of-the-art molten salt receivers and power blocks.

One such advanced high-temperature system has been developed in the Horizon 2020 project next-CSP [1]. A high-performance version of the Stellio heliostat was studied in this framework. Promising components and solutions for improvement have been identified and were analyzed. A techno-economic valuation was applied to define which of these measures should be actually brought into use.

2. Heliostat quality parameters

Heliostat quality is determined by two main components: slope error and tracking error. Definition of these is given.

3. Slope error improvements

Mirror contour accuracy and thus slope error depends primarily on stiffness of the supporting steel structure, stiffness of mirror panels and accuracy of connection between mirror and support structure (canting, jig accuracy).

The principles applied to assemble standard Stellio heliostats already provide very good optical quality of 1.5 mrad (2D standard deviation at low wind speed). A highly precise mirror jig ensures that mirrors are in close to perfect geometry before being glued to the support structure. This allows for compensation of steel structure imperfections without any kind of adjustment and with very good repeatability.

Thus the main contributors to slope error are support structure and mirror deformations. Comparing several reinforcement measures, it was found that additional mirror supports are the most effective one. A study was carried out to determine the best number of supports and the exact positions of all supports were defined in a multi-parameter optimization. A clear reduction of slope errors to 1.3 mrad could be achieved with relatively low additional steel mass and increase in assembly effort.

4. Tracking error improvements

Several measures for tracking error reduction were looked at. Important parameters of the linear actuators to bi-axially move the heliostat's reflector are their stiffness and backlash. Standard Stellio heliostats are driven by an ACME (trapezoid) spindle/nut with brushless motors. These provide good performance at moderate cost. For the high-performance heliostat, ball screw actuators were investigated, having higher stiffness and considerably lower backlash which furthermore increases less over lifetime.

One specific feature of Stellio is the unbalanced reflector which results in pull loads on the drive in the very most positions. While increasing the maximum normal force for the actuator, this avoid stability problems under push load and substantially reduced the situations where wind induced forces can overcome the preload and activate the backlash. Nevertheless, calculating the annualized effect of backlash shows that its reduction reduces tracking error noticeably.

Deadweight and wind deformation of the upper pylon part was identified to be relatively high. While dead weight effect is compensated by calibration, wind induced deformations remain. A quite simple modification increases stiffness while keeping steel mass constant.

Correct combination of tracking error components to total error must be done under consideration of the intermittent effect of backlash. Reduction of the already low Stellio tracking error (1D standard deviation at low wind speed) from 0.6 to 0.4 mrad can be achieved.

5. Techno-economic analysis

To valuate performance improvements vs. cost, the impact of slope and tracking errors on annual receiver net power was simulated. A next-CSP cavity receiver version with 43 MW_{therm} and a corresponding heliostat field [1] were used to calculate net power for a series of cases.

All enhancement measures described above were costed and a simplified LCoE analysis was performed to identify which ones of the anticipated improvements pay out. Resulting total decrease of LCoE is more than 6 %.

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References

[1] next-CSP - High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage, project 727762, http://next-csp.eu/