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Technologies and Design Considerations for Low Cost Small Heliostats

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Introduction

Small heliostats concepts can in theory deliver higher optical efficiency and should be lower costs due to reduced windloads, resulting in higher material efficiency. However the "per heliostat" costs such as assembly, actuation, control, installation and commissioning have must be addressed to acheive a competitive design. Coventry and Pye (2013) argue that not only cost reductions, but performance improvements must be pursued to reduce levelised costs of energy from solar towers.

The CSIRO heliostat system was designed to enable the testing of research scale high temperature receivers in the solar fields at the National Solar Energy Center at Newcastle, Australia. The version 3 heliostat technology has since been deployed in other research facilities in Pentakomo, Cyprus, Yokohama, Japan, and Northern Adelaide, Australia (Figure 1a).

With support from the Australian Renewable Energy Agency, CSIRO Energy has developed a suite of heliostat components and technologies to unlock the potential cost and performance improvements of small heliostat systems. These can be used together as a complete CSIRO heliostat system, or used in conjunction with other heliostat components. An example of the latter is an 8.2m^2 prototype heliostat using two commercially available heliostat facets, with the CSIRO actuation and control system, which has been built and tested in Newcastle, and is shown in Figure 1c.

(a) (b) (c)

Figure 1. (a) CSIRO Version 3 Heliostat (b) CSIRO Version 4 Heliostat (Center), CSIRO Actuation system with Two Rioglass Solar Sandwich Panel Facets (Right)

Facet and Structure

CSIRO Energy has been working with Australian automotive component manufacturers to develop a heliostat mechanical design suitable for mass manufacture, by reducing operation count, eliminating pre formed tubular sections, removal of redundant material, reducing part count, to result in cost reductions in high volumes. Importantly, cost of freight and assembly in the field was also considered in the mechanical design. Figure 1b shows the improved version 4 design which is being commercialised with CSIRO's technology licensees.

Actuation System

Although some small heliostat systems are using slewing drives for both axes (Ricklin et al., 2014), CSIRO found the unit cost of on-axis drives of sufficient precision and rigidity prohibitive. Linear drives can acheive very good mechanical advantage and are used for elevation actuation in many commercial heliostats. A pair of linear drives is needed for use in azimuthal drives to acheive the required range of motion for surround heliostat fields. Heliostats with pitch-roll actuation such as CSIRO and Stellio are able to use a linear actuator in both axes. CSIRO has developed proprietary encoders and controllers to allow low cost linear drives to operature with the accuracy required for heliostat fields. CSIRO has completed accelerated life testing on linear actuators with prices as low as $20 USD per actuator.

Field Wiring and Communications

Small heliostats result in long path lengths for cabling, CSIRO aggregates 200-500 heliostats into hubs for power and communications, depending on the field density. The hub-heliostat connection is in low voltage DC power with serial communications, which can be direct buried or left on the surface, to reduce trenching costs, and allows all heliostat terminations to be completed by unskilled labour. A preliminary assessment has shown this wiring system is cost competitive against wireless heliostats, and avoids issues associated with running tens or hundreds of thousands of wireless clients.

Commissioning and Calibration

CSIRO is currently developing a calibration system suited to fields with large numbers of small heliostats. This technology will enable long range, small heliostats to be calibrated, and the simultaneous calibration of multiple heliostats (Collins et al, 2017). This is a key step to enabling small heliostats to be used for large fields.

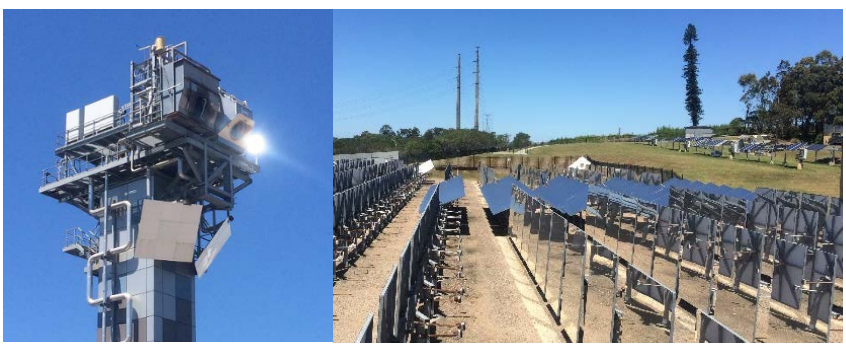

Figure 2. Camera Array Calibration System measuring reflected images of 30 heliostats simultaneously

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