ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

Optimising Maintenance Staffing for a CSP plant

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Background

Operation and Maintenance (O&M) is important to the competitiveness of Concentrating Solar Power (CSP). In high labour cost countries (e.g. Australia), determining the appropriate staffing level for maintenance activities can strongly influence O&M costs. This study aims to develop a methodology to determine the optimal maintenance staff to strike the optimal balance between labour costs and impact on CSP plant productivity and availability improvements. For the solar field, a key issue in the plant productivity is the optimal cleaning of the mirrors, but this issues has already been addressed in previous work (Truong Ba et al., 2017). However, the occurrence of "hard" failures in the heliostat (e.g. broken mirrors, tracking drive failures) and power block equipment significantly reduce the productivity of the plant and must be repaired by maintenance staff. Yet there is a basic trade-off: more staff means more responsive maintenance (and more electricity generation), but incurs larger labour costs.

In this paper, methodologies are developed for optimising the maintenance staff levels for the solar field and power block in a CSP plant. Firstly, heliostat failures are modelled as a Markov process and a cost model is developed to compute the probability distribution of the total maintenance cost, i.e. the sum of labour costs revenue loss due to unavailable heliostats. This models is then used to determine the optimal number of staff for the solar field. For the power block, reliability models of the key equipment are taken from literature and coupled to an economic model to determine the cost of downtime (resulting from lost revenue). The optimal staffing level is determined by minimising the total cost of maintenance using a Monte-Carlo simulation approach.

Methodology

CSP heliostats fail due to a variety of phenomena including the breakage of mirrors, and failures in the tracking system, causing a drop in the radiant energy on the receiver and a corresponding production decrease. Predicting the occurrence of these failures a priori remains a challenging task, due to high variability of environmental factors and the large number of heliostats in a typical plant. Thus, in this work, the average rate of failures of heliostats is considered constant as is the (average) rate of repair of heliostats per person. These assumptions enable the development of a Markov model for the number of heliostats available at a given time. The state diagram for the model is shown in Figure 1. The probabilities of each of these states may be determined using well-established techniques (Ross, 2014) and the total maintenance cost may be computed. The optimal number of staff can then be determined via a grid search on the number of staff.

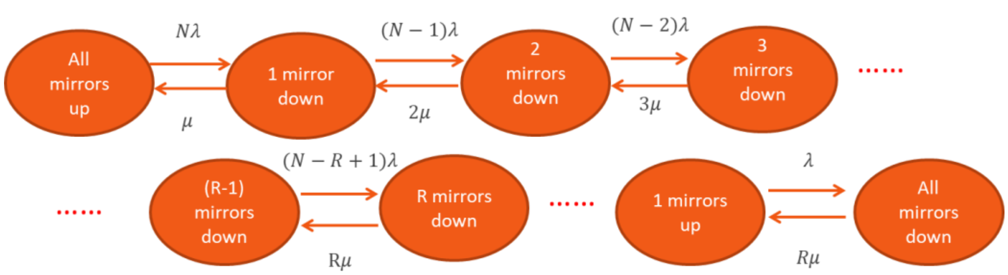

Figure 1. Markov process for failure and repair of mirror field

A similar methodology is pursued for the power block. However, the reliability models for the power block equipment are more complex (i.e. non-constant failure rates) and the repair rates are non-constant, so a Monte Carlo simulation approach is pursued to determine the total maintenance cost. A grid search on the number of staff is conducted in a similar manner to the solar field to produce the optimal number of power block staff.

Results

The solar field methodology was applied to a case study on the base plant available in the System Advisor Model (SAM) from the National Renewable Energy Laboratory (NREL) (Blair et al., 2014), along with their staffing cost data. The probability distribution for the number of failed heliostats at for different staff levels is shown in Figure 2. For the parameters used in the case study, the optimal number of staff is 5.

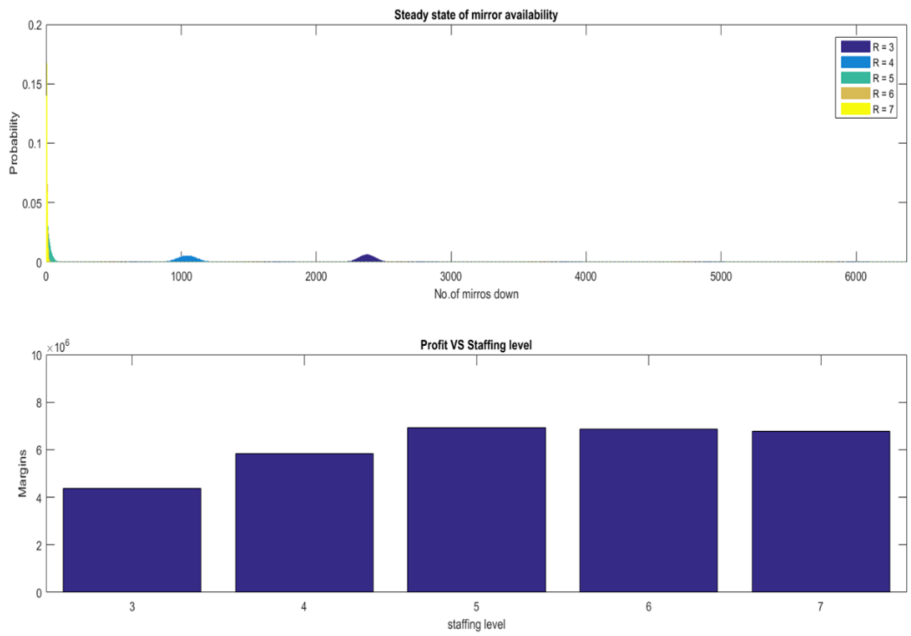

Figure 2. The distribution of failed mirrors and profit with different staff level

In the full paper, a sensitivity study will be pursued to determine optimal staffing levels for high-labour-cost locations and the results for the power block will be presented.

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