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Nonlinear MPC for Thermal Balancing of the TCP-100 Parabolic Trough Collectors Solar Plant

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***Abstract*— The efficiency of the solar plants is conditioned by the control strategies applied in their operation. In this paper, an application of a Model Predictive Controller based on nonlinear models of the TCP-100 parabolic trough collector solar plant is presented as one example of the advanced control techniques that can contribute to enhance the efficiency of this type of plants. Both types of nonlinear models of the TCP-100 facility are applied for this application: lumped and distributed parameter ones. The objective of the proposed control strategy is to face a problem that arises in current commercial solar trough plants, with hundreds of loops, where in practice each of those loops get a different outlet temperature of the heat transfer fluid. These temperature differences might cause inefficiency in the operation and/or irreversible damages by overheating, if not properly controlled. The presented control strategy computes the set-points of the control valves of each of the loops to achieve a good thermal balance of the solar plant. The proposed strategy implements also a heuristic based algorithm when strong transients are affecting the field. The simulation results show that the application of the proposed control technique balances the outlet temperatures of the loops, protecting the TCP-100 facility from damages and increasing its efficiency in the operation.**

I. INTRODUCTION

Since the decade of 1980, many solar thermal energy plants of the main commercial technologies (parabolic trough and central receiver) have been constructed [1]. Among the first commissioned parabolic trough collectors (PTCs) solar plant at PSA was the ACUREX research facility. This facility was composed of a field of solar collectors of ACUREX class, a heat storage system, and a 0.5 MW turbine for thermal to electric power conversion. An important amount of research related to the application of advanced control strategies for solar plants has been done in this plant [2], [3], [4], [5].

The ACUREX solar field was a small scale solar trough plant, that has been replaced by the TCP-100 facility, see Figs. 1 and 3. Around the world, since the 2000 onwards, an important number of commercial PTCs solar plants have been commissioned. The size and power production of those plants were increased to fulfill the energy demands of the current society [6], [7]. Some examples are the four plants of 50 MW Solaben and the three plants of 50 MW Helioenergy in Southern Spain, all of them owned by Atlantica Sustainable. Greater solar projects were carried out in the USA: the Solana power plant which uses thermal energy units and the Mojave solar parabolic trough plants each of them 280 MW of electrical power production [8], [9]; with several hundreds of loops each of them.

Fig. 1. North view of the TCP-100 solar field at Plataforma Solar de Almería.

The great size and complexity of current commercial solar trough plants poses new operation difficulties that need to be afforded with advanced control techniques. One of them is the equilibration of the thermal balance in the parabolic trough collector solar field. In general, when dealing with the regulation of the average outlet solar field temperature, it is typical to assume that the irradiance and the optical efficiency are the same for the whole field [10], [11]. However, this may not be the case if several loops have been cleaned or affected by dust. If there are loops that are more efficient than others, the most efficient ones have to be defocused to avoid overheating problems, thus producing energy losses as explained in [12].

To deal with this problem, the control valves of the most efficient loops are opened in order to increase the heat transfer fluid (HTF) flow through them. This action will change the flow of the rest of the loops. Several preliminary works have been published addressing this topic. In [5] an optimization algorithm which manipulated each loop control valves with a sample time of 30 minutes is presented. The algorithm tried to compensate the differences in the optical efficiencies between the loops. In [13] and [14] a similar optimization algorithm was proposed and tested in a large scale solar trough plants of 50 MW.

We present in this paper a nonlinear model based optimization algorithm for improving the thermal balance of the TCP-

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