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RESEARCH ARTICLE

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On- and off-design thermodynamic analysis of a hybrid polar solar thermal tower power plant

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Summary

Concentrated solar power (CSP) is one challenging renewable technology for the production of electricity. Within this concept central receiver solar plants combined with gas turbines are being investigated because of their promising efficiencies and reduced water consumption. Hybrid plants incorporate a combustion chamber in such a way that in periods of low solar irradiance power output can be kept approximately constant and so, electricity production is predictable. An integrated, non-complex solar thermodynamic model of a hybrid gas turbine solar plant is developed employing a reduced number of parameters with a clear physical meaning. The solar subsystem is modeled in detail, taking into account the main heliostats field losses factors as cosine effect, blocking and shadowing, or attenuation. An heliostat field with polar symmetry together with a cavity receiver are considered. The model is implemented in our own software, developed in Mathematica language, considering as reference SOLUGAS solar field (Seville, Spain). Heliostats field configuration is determined for the design point and its associated efficiency is computed. First, an on-design analysis is performed for two different working fluids (dry air and carbon dioxide), for recuperative and non-recuperative modes. A pre-optimization process is carried out regarding the pressure ratio of the gas turbine for different configurations. Some significant efficiency and power rises can be obtained when pressure ratio is adapted for each specific configuration and working fluid. Maximum achievable plant overall efficiency is 0.302 for both fluids in the recuperative mode, taking a pressure ratio of 7 for dry air and 16 for carbon dioxide. In non-recuperative configurations maximum overall efficiency is obtained for dry air, about 0.246. Moreover, a dynamic study is performed for four representative days of each season. Then, efficiencies and solar share are plotted against time. In addition, fuel consumption and greenhouse emissions are computed for all seasons.

KEYWORDS

concentrated solar power, dynamic analysis, gas turbines, overall plant efficiency, solar field efficiency, tower power plants

