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A pilot power plant based on concentrating solar and energy storage technologies for improving electricity dispatch

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Abstract

This paper presents the main features and the expected performance of the pilot solar power plant under construction in Ottana (Sardinia-Italy). The facility is based on a 600 kWe concentrating solar power (CSP) plant with thermal energy storage, and a 400 kWe concentrating photovoltaic (CPV) plant with electrochemical storage. The CSP plant uses linear Fresnel collectors, thermal oil as heat transfer fluid, a two-tank direct storage system and an ORC module. The CPV plant consists of 37 dual-axis trackers integrated with Sodium-Nickel batteries. The facility is characterised by the integration of different concentrating solar and storage technologies. The pilot power plant has been designed in order to produce electricity with scheduled profiles according to weather forecast.

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Keywords: CSP plants; Linear Fresnel Collectors; Thermal energy storage, Concentrated photovoltaics; Electrochemical storage

1. Introduction

The increasingly widespread use of renewable energy sources (RES), supported by economic subsidies and environmental policies, is changing the structure of the electric power system and is contributing to the spreading of

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the distributed generation (DG). The variability, intermittency and poor predictability of the electricity production from RES and the decentralization of power generation raises serious challenges related to the reliability, control and power quality of the electrical power grid. Coping to these challenges requires the development of active distribution power systems and, in some countries such as Italy, to reinforce the balancing service at distribution level. Currently, a unique and comprehensive operational strategy to overcome these issues has not been assessed yet and intensive research is worldwide devoted to the development of new models, structures and control algorithms [1-3].

For these reasons, the Regional Government of Sardinia (Italy), in the framework of the POR FESR 2007-2013 Program, is supporting the realization of three pilot facilities based on small scale concentrating solar power (CSP) plants integrated with other RES technologies and energy storage systems. This paper focuses on the first pilot facility which will be installed in the industrial district of Ottana. Its design has been developed with the scientific support of Sardegna Ricerche and the University of Cagliari with the aim to effectively integrate solar concentrating technologies and energy storage systems and therefore enhance the dispatch of solar power plants. Overall, the Ottana pilot plant will be able to produce electricity with scheduled profiles according to weather forecast as well as to provide ancillary services at distribution level. In particular, the facility consists of a Fresnel-based CSP plant (600 kWe), a two-tank thermal energy storage (TES) system (capacity of about 15 MWht), a concentrator photovoltaic (CPV) power plant (400 kWe) and an electrochemical storage system with a capacity of 430 kWhe. The plant control system has been designed with the aim to manage the predictable and unpredictable daily power fluctuations that occur in solar power plants in order to ensure the accomplishment of scheduled profile in accordance with the weather forecasting and the planned electricity ancillary services at distribution level.

2. Main design specifications

The main design specifications of the integrated power plant were represented by an overall power output of about 1 MWe, 600 kWe for the CSP section and 400 kWe for the CPV section. Moreover, since the power plant will be able to produce electrical energy with scheduled profiles, suitable thermal and electrical storage devices were included.

The site selected for the construction of the experimental facility is Ottana (40°25’00’’N, 9°00’00’’E), in the center of the Sardinia island, at about 160 m asl. The design was carried out by using a data set for a typical meteorological year obtained from the Meteonorm® software [4]. Figure 1a-b shows the monthly values of air temperature and Direct Normal Irradiation (DNI). Overall, the annual DNI is about 1685 kWh/(m^2·yr).

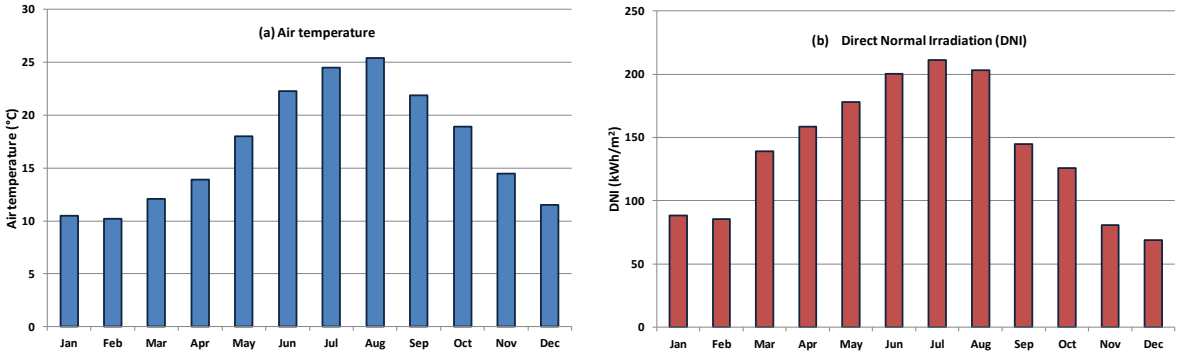

Fig. 1. Monthly values of air temperature (a) and DNI (b).

3. Concentrating solar power plant

Currently, for the design of CSP plants, different options are available for solar field, power block, heat transfer fluid and thermal energy storage [5-6]. For the power output here considered (600 kWe), the most interesting alternative is represented by Organic Rankine Cycles (ORC), that require thermal energy inputs with temperature levels in the range of 250-350 °C [7-8]. For such temperature levels, Linear Fresnel Collectors (LFC) may be a