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State of the art on high-temperature thermal energy storage for power generation. Part 2—Case studies

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ABSTRACT

Power generation systems are attracting a lot of interest from researchers and companies. Storage is becoming a component with high importance to ensure system reliability and economic profitability. A few experiences of storage components have taken place until the moment in solar power plants, most of them as research initiatives. In this paper, real experiences with active storage systems and passive storage systems are compiled, giving detailed information of advantages and disadvantages of each one. Also, a summary of different technologies and materials used in solar power plants with thermal storage systems existing in the world is presented.

Contents

1. Introduction

Solar thermal power plants produce electricity in the same way as other conventional power plants, but using solar radiation as energy input. This energy can be transformed to high-temperature steam, to drive a turbine or a motor engine. Among other system

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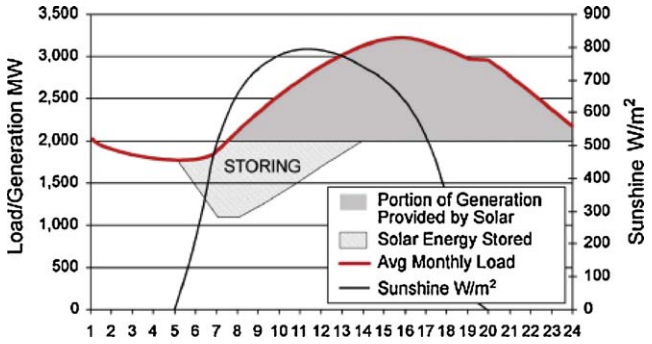

Fig. 1. Sunshine and demand for power [2].

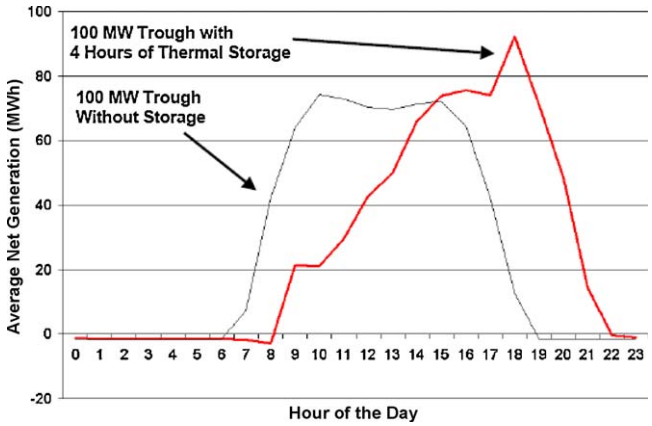

Fig. 2. Results of energy dispatched with and without thermal storge system [2].

parts, storage is a system component which has been neglected, but nowadays its importance within the whole system has attracted the interest of many researchers and companies.

Although thermal energy storage (TES) is used in a wide variety of applications, all the systems are designed to operate on a cyclical basis (usually daily, occasionally seasonally). The systems achieve benefits by fulfilling one or more of the following purposes:

- Increase system reliability, the possibility to reduce the peaks of energy generation means the power plants can work under more stable limits, reducing at same time the probabilities of breakdowns.
- Increase generation capacity [1]: Probably, the most important benefit of the thermal solar energy is the increasing of generation capacity. That means the demand for power is seldom constant over time, and the excess generation available during low demand periods can be used to charge a TES in order to increase the effective generation capacity during high-demand periods. The result is a higher load factor for the plants, helping to generate energy in a stable way.
- Reduction of costs of generation: Energy demands in the commercial, industrial and residential sectors vary on daily, weekly and seasonal bases. These demands can be matched with the help of TES systems that operate synergistically. Energy may be stored in many ways. But in the economy of almost all countries, energy is produced and transferred as heat, the potential for thermal energy storage warrants study in detail, in order to be applied to high-temperature solar power plants.

TES has always been associated closely with solar installations because solar energy availability is limited, and do not coincide with energy demand periods. TES systems have two characteristics of big importance for this application:

- Round-trip efficiency: ratio of the useful energy recovered from the storage system to the amount of energy initially extracted from the heat source.
- They are affected by the laws of thermodynamics and by heat losses in tank, piping and heat exchangers, and by the cost per unit of thermal energy delivery (€/kWh$_{th}$).

Daily, the peak energy consumption takes place after the sunset, as seen in Fig. 1. Storage systems can help to solve part of this problem, dispatching the energy stored during the day in cloudy or night periods (Fig. 2).

Several experiences of TES systems have taken place until the moment in solar power plants. The experiences gathered in these projects were the start point to a new pre-commercial and commercial generation of solar power plants with TES. This paper presents these experiences and compiles the data available in the literature. A previous paper presented the basics of high-temperature thermal energy storage for power generation: concepts, materials, and modelization [3].

2. Thermal energy storage applied to solar power plants

2.1. Experiences of TES in solar power plants

2.1.1. Active direct storage system: direct steam generation

One option for active direct thermal storage is the possibility of generating steam directly in the solar field (Fig. 3), and to use it as heat transfer fluid (HTF) and as storage media. These storage systems are used in process industry to balance demand and generation of steam [4].

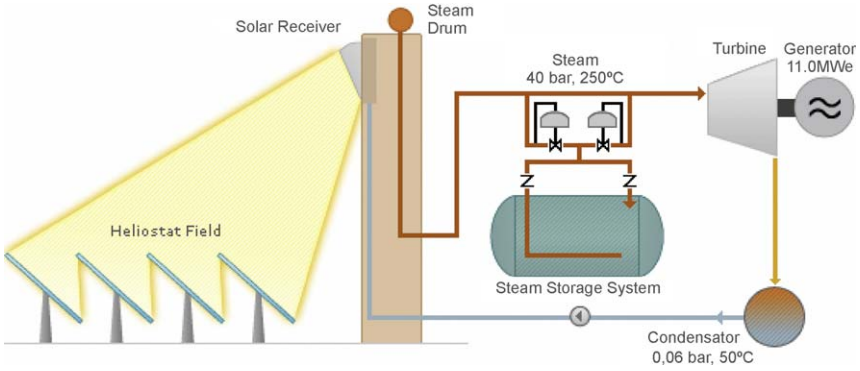

Fig. 3. Scheme of DSG plant installed in PSA [4].