European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'11)
Las Palmas de Gran Canaria (Spain), 13th to 15th April, 2010

Advances in phase change materials for thermal solar power plants Quality

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Abstract. Thermal solar energy offers a huge opportunity to reduce fuel dependency and environmental impact created by fossil fuel consumption. One of the main disadvantages of this renewable energy is its intermittence which decreases thermal solar power plants performance. In order to reduce cost electricity is necessary to create thermal solar plants which include thermal storage. There are different options of thermal storage: sensible, latent and chemical heat. It has been demonstrated that latent heat could store large amount of energy per unit mass. Moreover, latent heat storage could store fusion heat at a constant temperature which is the phase transition temperature of the phase change materials (PCM). However, these materials have a critical limitation that needs to be resolved in order to reduce operation cost of solar plants. This limitation is their low heat conductivity. This paper gathers the main solutions that are being analyzed in order to increase the possibilities to use PCMs in a high temperature thermal storage that is essential to develop optimum thermal solar power plants.

Key words

Phase change materials, thermal conductivity, thermal solar power plants

1. Introduction

Reducing worldwide fuel dependency and environmental impact requires the development of renewable energies such as wind, hydropower biomass or solar. Thermal solar power plants represent a huge opportunity in areas where solar irradiation is of at least 2,000 kWh/m^2/year [1]. However, this technology has a critical limitation which is its intermittence. This inhibits the regular electricity generation that decreases plant performance. For this reason, it is essential the development of an economical and effective energy storage system to reduce electricity cost.

In solar thermal generation, thermal storage is the suitable storage mode. There are three methods to storage thermal energy: sensible, latent and chemical heat. Latent heat storage systems have the potential of storing a large amount of energy per unit mass. Moreover, latent heat storage could store fusion heat at a constant temperature which is the phase transition temperature of the phase change materials (PCMs). Unfortunately, most of the PCMs possess a low thermal conductivity (around 1W/mK) which limits their deployment in large scale applications like thermal solar power plants [2]. This is the reason that has enhanced the development of different solutions whose target is improving the heat transfer from PCMs. This work collects the main solutions that are being developed to make possible the implementation of PCMs in real solar power plants.

2. Thermal storage

A solar thermal power plant could have four elements: solar field, heat transfer fluid (HTF), thermal storage system and finally power generation system (Fig. 1). The thermal storage system allows use the excess of energy at night and/or cloudy days to increase plant performance. In sensible heat storage, the temperature of the storage material varies with the amount of energy stored. The amount of thermal energy that is stored depends on its specific heat and on the temperature variation. It has been implemented in thermal solar power plants through thermocline or two tanks systems using molten salt as storage medium [2].

Latent heat thermal energy storage is attractive due to its high energy storage density. When compared to conventional sensible heat energy storage systems, latent heat energy storage system requires a smaller weight and volume of material for a given amount of energy [3]. Furthermore, latent heat storage stores fusion heat at a constant or near constant temperature which correspond to the phase transition temperature of the PCMs. In practice, solid-liquid phase change is preferred because of simultaneous slight volume variation and high enthalpy variation.

The last approach for thermal storage is based on thermochemical reactions. This storage method could allow long-term storage but its technical complexity and