Chapter 74

Solar Energy Storage:
An Approach for Terrestrial and Space Applications

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ABSTRACT

With the urgent need to harvest and store solar energy, especially with the dramatic unexpected changes in oil prices, the design of new generation of solar energy storage systems has grown in importance. Besides diminishing the role of the oil, these systems provide green energy which would help reducing air pollution. Solar energy would be stored in different forms of energy; thermal, electric, hybrid thermal/electric, thermochemical, photochemical, and photocapacitors. The nature of solar energy, radiant thermal energy, magnifies the role and usage of thermal energy storage (TES) techniques. In this chapter, different techniques/technologies for solar thermal energy storage are introduced for both terrestrial and space applications. Enhancing the performance of these techniques using nanotechnology is introduced as well as using of advanced materials and structures. The chapter also introduces the main features of the other techniques for solar energy storage along with recent conducted research work. Economic and environment feasibility studies are also introduced.

INTRODUCTION

This book chapter is an effort to provide different techniques/technologies for solar energy storage and to analyze their economic and environment effects. The chapter involves also a pool for recent conducted research work in this vital field. The first section includes storing the solar energy in the form of thermal energy through phase change materials, PCMs. In this context; the deployment of different types of PCMs in terrestrial applications is introduced as well as investigating and predicting their thermal characteristics numerically and experimentally. A negative aspect of PCMs is that most of these materials suffer from inherent low thermal conductivity. Hence, the second section introduces different techniques to enhance the thermal performance of PCMs. On

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the other hand, many studies have been conducted to investigate the enhancement of the thermal conductivity of PCMs using porous matrices. In general, this technique would present several advantages such as achieving high external heat transfer coefficient, very low bulk density, and good mechanical properties. Accordingly, the third section proposes utilizing of PCMs combined with solid porous matrices in thermal energy storage systems. In space applications, solar energy storage is a critical task and using PCMs in energy storage in space applications is very useful due to their higher energy to weight ratio. Consequently, the fourth section includes employment of PCMs in space applications. Nanotechnology and solar energy are being combined by many researchers to establish new generation of solar cells and to develop superior efficient solar energy storage systems based nanocomposites. Therefore, the fifth section introduces the role of nanotechnology in solar energy storage systems. The sixth section aims to present other techniques for solar energy storage. Hybrid Thermal Energy Storage Systems, (HTESS); is proposed to manage simultaneously the storage of heat from solar and electric energy. Another techniques are the Aquifer Thermal Energy Storage (ATES) and Underground Solar Thermal Storage systems. The general objective of these techniques is to provide heating and cooling by storing solar heat underground in summer and cold in winter. Photosensitizer in Photogalvanic cell for storage and conversion of solar energy and the photocapacitors are introduced in the sixth section as well. The seventh section includes economic and feasibility studies for solar energy storage systems. The eighth section incorporates solutions and recommendations for establishing new techniques and enhancing the performance of existing ones for solar energy storage. The ninth section includes, the future research directions and conclusions. The tenth section includes the references.

SOLAR THERMAL ENERGY STORAGE

In many parts of the world, direct solar radiation is considered to be one of the most potential source of energy. However, the large-scale utilization of this form of energy is possible only if the effective technology for its storage can be developed with acceptable capital and running costs (Kenisarin & Mahkamov, 2007). Thermal energy storage (TES), is of great importance in a wide variety of energy applications especially in solar energy storage applications. Thermal energy can be stored as a change in internal energy of a material as sensible heat, latent heat and thermo-chemical or combination of these techniques (Olofsson and Bengtsson, 2008). In his comprehensive study, Dincer (1999) introduced a discussion of the evaluation and the selection of sensible and latent heat storage technologies, systems and applications in the field of solar energy. Several issues relating to energy storage were examined from the current perspective. In addition, some criteria, techniques, recommendations, checklists on the selection, implementation and operation of energy storage systems were provided for the use of energy engineers, scientists and policy makers.

One of prospective techniques of storing solar energy in form of thermal energy is the application of phase change materials, PCMs. The phase change of PCMs falls into the category of moving boundary problems (Crank, 1987) and during their phase change process, both liquid and solid phases are presented and separated by a moving interface, mushy region (Mesalhy et al. 2005). PCMs store energy in both sensible and latent heat forms. Initially, these solid– liquid PCMs perform like conventional storage materials; their temperatures rise as they absorb heat. Unlike conventional (sensible) storage materials, when the PCM reaches the temperature at which they change phase (their melting point) they absorb