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Energy Procedia 105 (2017) 4281 – 4288

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

Selection of Phase Change Material for Thermal Energy Storage in Solar Air Conditioning Systems

Haoxin Xu[a], Jia Yin Sze[a], Alessandro Romagnoli[a] *, Xavier Py[b]

a Nanyang Technological University, 50 Nanyang Ave, Singapore 639798
b PROMES CNRS laboratory UPR 8521, University of Perpignan Via Domitia, Rambla de la Thermodynamique Tecnosud, 66100 Perpignan France.

Abstract

The selection of Phase change materials (PCMs) is crucial in the design of Latent Heat Thermal Energy Storage (LHTES) system in solar air conditioning applications. This study performs a systematic selection procedure of PCMs for LHTES in a typical solar air conditioning system. Comprising prescreening, ranking and objective function examination based on multi-criteria decision making (MCDM) tools, this procedure is able to reflect the system goals of LHTES, as well as to take into account designer's subjectivity. Results indicate the proposed approach to be a highly applicable and efficient tool in the LHTES design process.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.

Keywords: *Phase change material; Thermal storage; Selection methodology; Solar air conditioning; Multi-criteria decision making*

1. Introduction

There is a growing interest in the solar air conditioning systems due to the increasing demand for space cooling in solar abundant areas [1] [2]. However, the intermittency characteristic of solar energy presents a challenge to downstream applications that require a steady energy supply. In recent years, Thermal Energy Storage (TES) has drawn the attention of researchers owing to its capability of resolving the intermittency of renewables [3]. Compared with other types of TES systems, Latent Heat Thermal Energy Storage (LHTES) system charges and discharges the heat power by utilizing phase transformation of Phase Change Materials (PCMs). Being able to provide high storage density and constant temperature output, LHTES is regarded as a very promising energy storage technique [4].

* Corresponding author. Tel.: +65-8389-9657; fax: +65-6791-9690
E-mail address: hxu012@e.ntu.edu.sg.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
doi:10.1016/j.egypro.2017.03.898

Literatures show that incorporating LHTES into the solar air conditioning system was crucial in maximizing the solar harness, and to provide a reliable and steady output of air conditioning system subject to the building's requirements. In 2012, Kantole [5] investigated a numerical model of a LHTES system used in a solar driven ammonia absorption refrigeration system. Agyenim et al. [6] explored the system configuration of a LHTES using erythritol to power a LiBr/H2O absorption chiller. In another study, Noro et al. [7] simulated the effect of using PCM in either hot tank or cold tank of an integrated solar absorption air conditioning system. He pointed out that only when the mean temperature of the storage is around the melting temperature of the PCM that the LHTES can outperform the sensible storage.

Among all the design aspects, selection of the right PCM stands out as the first important step. To select the proper PCM candidates, engineers need to consider a set of criterion. Firstly, the phase change temperature of this material should satisfy the operating temperature range of LHTES. Secondly, the PCM should possess high latent heat of fusion and large specific heat, to ensure high storage density of system. Thirdly, the material is required to have high thermal conductivity, in order to achieve high discharge power. Lastly, material with large density is favored when the volume reduction is considered in the system design. Besides the abovementioned merits, the material is favored if it is at low cost with a high availability. Since none of the PCMs has a perfect property profile, and each application has unique thermal boundaries and operation goals, the good variety of PCMs makes it difficult to select one to match the thermal conditions and requirements in LHTES design.

Regarding selection of PCM in LHTES, only a few papers covered this in detail. Rathod and Kanzaria [8] adopted two Multi-Attribute Decision Making (MADM):Techniques for Order Preference by Similarity to Ideal Solutions (TOPSIS) and Analytical Hierarchy Process (AHP) to evaluate PCMs in solar hot water application. Similarly, another MADM tool VIKOR (acronym from the original Serbian: Vise Kriterijumska Optimizacija I Kompromisno Resenje) was applied to deal with selection of low temperature PCM [9]. In a passive storage case, the authors used MADM method to rank objective functions instead of material properties. This approach was compared with building simulations and received positive compliance [10]. However, the previous two approaches did not attempt to validate the consistency between selected PCMs and their ability to fulfill system requirements. The last approach gave up the design engineer's subjectivity of altering the weights of different properties in the decision making process. Apparently, a more thorough and practical selection procedure should be brought out to overcome the shortcomings discussed above.

Considering the variety of PCMs and the complexity of material selection, this study presents a systematic selection procedure of PCMs for LHTES in typical solar absorption cooling applications. The procedure takes into account both design engineers' preference and also explicitly reflects the system design objectives. Results after performing each step and the final PCM candidate are clearly illustrated, followed by detailed discussion and conclusion.

2. Selection Procedure of PCMs

2.1 Definition of LHTES system scope and goals

A typical solar driving absorption chilling system in building applications is considered here. First of all, the system's goals and requirements are clearly defined and translated into the selection objectives. In the integrated system, LHTES buffers the hot water tank from being overheated, and charges with excess