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PCM-based High-density Thermal Storage Systems for Residential and Small Commercial Retrofit Applications

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Abstract

Environmental cooling loads comprise 11% of overall electric usage in the United States, and during peak cooling months in hot/humid climates these cooling loads can comprise more than 50% of peak electric energy loads. Thermal storage systems can shift these environmental cooling loads to non-peak hours, making better use of baseload generation capacity as well as reducing the need for expensive and environmentally inefficient peak power plants. Residential and small commercial buildings generate much of the cooling responsible for peak electric load, but these structures may not have the space or facilities to support conventional sensible energy thermal storage systems, such a chilled water thermal storage tanks. For these applications a compact, high-density, retrofittable thermal storage system is needed. This paper investigates the development, testing, and modeling of a compact, scalable PCM (phase change material) based latent thermal storage system for these applications. The results show that a simple tube-encapsulated, tetradecane PCM-based thermal storage system can reduce the size of a thermal store by at a factor of between 2 and 4 while providing acceptable energy recovery rates.

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Keywords: Thermal storage; PCM (Phase Change Material); retrofit; tetradecane

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1. Introduction

Electric energy, without any utility-scale or distributed energy storage system, must be generated exactly as it is needed. To meet this requirement, electric utilities dispatch generation capacity in stages. These stages consist of baseload, intermediate, and peak generation power plants [1]. Baseload power plants are generally inexpensive to operate, but have long ramp-up periods and cannot respond quickly to changes in demand; these are typically run continually at their rated capacity. Intermediate power plants have moderate start-up periods, but their dispatch can be predicted and they can be brought on-line over the course of a day in anticipation of demand. Peak power plants are fast-response systems capable of mediating the uncertainty between generation and demand; these are generally more costly to operate, less efficient, and higher polluting that baseload or intermediate power plants.

Intermittent renewable energy resources, such as wind and solar, add uncertainty to generation capacity. Solar and wind power generation is expected to provide 20% of all U.S. electrical power by 2040 [2]. As the use of these intermittent resources increases, the added uncertainty in generation requires an increased use of less-efficient and costly fast-response peak power plants. Shifting peak electric energy loads to non-peak hours or periods when intermittent renewable resources are available can make better use of intermittent renewable resources, as well as baseline generation capacity, while reducing the need for inefficient, costly, and polluting peak power plants [3].

Environmental cooling loads comprise 11% of overall electric usage in the United States, and during peak cooling months in hot/humid climates these cooling loads can comprise more than 50% of peak electric energy loads. Data from the Electric Reliability Council of Texas [4] confirms this claim, as shown in Figure 1. This figure also shows that the largest contributors to weather sensitive load are residential and small commercial users.

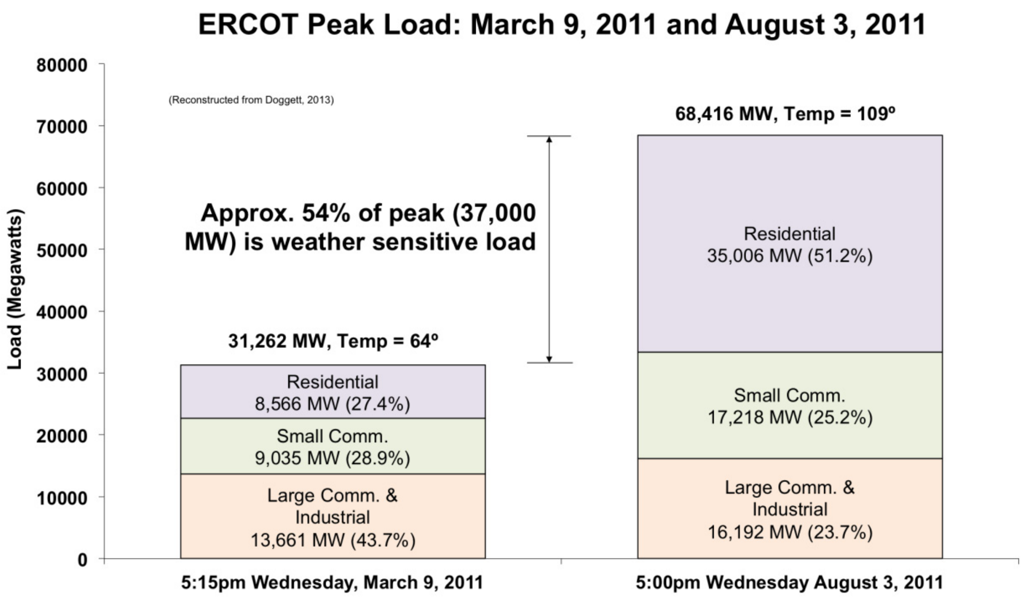

Fig. 1. ERCOT Peak loads for March 3 and August 3 of 2011. This figure demonstrates that the weather-sensitive portion of peak summer electric load is primarily due to residential and small commercial users, ostensibly as HVAC demand. Recreated from [4].

Thermal storage systems can shift these environmental cooling loads to non-peak hours. While residential and small commercial buildings generate much of the cooling responsible for peak electric load, these buildings may not have the space or facilities to support conventional sensible energy thermal storage systems, such as chilled water tanks. In addition, residential and small commercial structures have long service lifespans that can average 37 and 28