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JOURNAL OF MANAGEMENT AND ARCHITECTURE RESEARCH
E ISSN: 2689 3541; P ISSN 2689 355X
Volume:06; Issue:02 (2024)

A study to estimate the techno-economic felizability of last heat storage and thermal energy to maintain the indoor comfort level

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Abstract
When it comes to integrating storage technologies into the physical environment, the design phase is critical to creating a stable and functional system that meets the requirements. In most cases, engineers determine the size of storage units based on their previous experiences and approved methods, assuming that the storage unit's characteristics and load profiles have been accurately recorded. However, the outcomes of created systems frequently show inconsistencies between the projected outcome and the system's actual performance when it is implemented. Insufficient design analysis is frequently cited as the underlying cause of the problem. In fact, a poor understanding of latent heat-based thermal energy storage systems (LHTES) is frequently the underlying cause of flawed designs. A More in-depth understanding of PCM is required, as accurate phase change process prediction remains to be improved through the use of improved modelling approaches and the input of more precise material data. To provide reliable PCM characteristics, engineers must be able to use simple yet precise measurement techniques. It is necessary to conduct research into the best method for using phase change modelling in the LHTES component design process. After the predesign requirements have been met, the next step is "It is possible to evaluate the system's transient behavior." Finally, the overall system can be improved while also reducing its environmental impact.

Keyword: PCM, Latent Technology, Ambient Temperature

INTRODUCTION

Technological advancement benefits humans. "The demand for energy rises in tandem with rising living standards." In less than 40 years, the world's total primary energy supply had doubled to 150 PWh1 by 2010. Coal and nuclear power generation contribute significantly to CO2 emissions, with nuclear power accounting for only 5% of global energy demand (IEA 2012). Human-caused greenhouse gas (GHG) emissions have skyrocketed since the industrial revolution, raising the risk of severe climate change. If CO2 emissions remain at 450 ppm, global temperatures will rise by 2°C to 6°C by the end of the century (IEA, 2012). Energy storage is a rapidly growing climate

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change mitigation technology. One of The first method of energy storage was the collection of ice to preserve food (London Canal Museum, 2013). A new era has begun in which energy storage holds great promise for improving overall system efficiency and dependability by smoothing out fluctuations in the flow of energy, particularly intermittent renewable resources, and providing control over energy demand management during peak times. Storage also aids in load reduction by lowering the amount of fossil fuel-based marginal peak power output, resulting in lower GHG emissions. During Sweden's peak energy demand seasons, the country produced more than 1 TWh/month of fossil fuel-based marginal electric power and imported 1.5 TWh/month of electricity to meet rising demand.

LITERATURE REVIEW

As the general public becomes "more familiar with the Smart System." The focus has shifted to using electric energy storage to control the power grid. Heating and cooling are more basic energy sources, but they account for a large portion of total energy consumption in the Nordic countries. This source accounts for more than half (45%) of the energy used in Sweden's residential and service sectors. A significant portion of marginal fossil fuel-based production methods can be reduced if heating and cooling loads are effectively controlled (Hasnain, 2000). With load shifting and peak shaving, production units can run at nominal power and thus achieve optimal efficiency; better operating conditions can be achieved by running chillers at night and heat pumps during the day; increased grid capacity without The benefits include increased expenditure and a greater reliance on renewable energy sources. This study will focus on thermal energy storage (TES) and management, another understudied topic. The design of TES that extends beyond hot/cold water storage tanks is especially important in this context. Phase change materials (PCMs), also known as "latent heat thermal energy storage," are used to achieve high energy density and the power characteristics required for reliable operation

STATEMENT OF THE PROBLEM

When choosing a TES system for a specific application, several factors must be considered, including "low thermal loss during storage, high energy extraction efficiency, an appropriate temperature, environmental safety, commercial availability, and cost efficacy. In Zalba et al. published this in 2003, as stated by Dincer and Rosen in 2011.
In recent years, there has been a significant increase in the availability of TES literature. This chapter summarizes PCM classification reviews and provides an overview of PCM advantages and disadvantages. Several reviews in this field have been cited, including (Hasnain, 1998), (Dincer, 2002), (Tyagi & Buddhi, 2007), (Agyenim et al., 2010), and (Oró et al., 2012).

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OBJECTIVE OF THE STUDY

This thesis aims to develop a robust process for designing, integrating, and evaluating PCM-based thermal energy storage for interior comfort control. The method will be developed in this thesis. We will be able to answer the research questions if we complete the objectives listed below.

- To assess the environmental benefits of peak shaving. and load shifting via TES.

Research Questions

This argument is based on the premise that TES has the potential to benefit society as a whole. The following is a list of significant research questions raised by a top-down approach to evaluating the statement:

- How can TES contribute to sustainable development and climate change mitigation? With a special focus on hidden potentials. "This thesis examines the study subjects of thermal energy storage for interior comfort management from the outset of the research process. As a result, technologies will be investigated throughout their entire development stages, from material analysis to component modeling, and a techno-economic analysis will also be carried out "at each and at all stages of development, from system analysis to national climate change mitigation evaluation.

Research Methodology

On the material level, it is shown that thermophysical property-describing techniques such as differential scanning calorimetry (DSC) and conventional calorimetry have limitations. As a result, the T-History method's ability to describe non-homogeneous materials has been evaluated. On the component design level, storage performance modeling will be done using numerical simulation methods in conjunction with a heat transfer analysis. The heat transmission processes included in the modelling are conduction and convection, with radiation having only a minor influence due to the small temperature difference. In terms of system integration, a case study of an office building linked to Stockholm's district cooling network will be conducted, as well as "optimization" of the LHTES integrated seminar room. To shed light on the ecological benefits When TES is integrated into the built environment, the marginal CO_2 emission reduction from fossil fuels is measured in the Swedish energy system.

Research Design

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The approach is based on the Lumped Capacitance model, which assumes a small internal temperature gradient in the observed sample. In other words, the non-dimensional Biot number, or the ratio of internal to external thermal resistance, should be low. Existing approaches are essentially temperature averaged models in which samples remain constant in relation to the external ambient temperature. This section focuses on improving the T-History technique.

Data Analysis

"The empirical validation that was performed consisted of charging cold by freezing PCM from 29 to 15 degrees Celsius and discharging cold by heating PCM from 15 to 29 degrees." Celsius, three times. Every technique was repeated three times. To properly charge and discharge cold, the input HTF temperature will be kept at 11 degrees Celsius while charging and 32 degrees Celsius when discharging. The temperature values provided here were obtained from the central part of the testing rig. In addition, results obtained with a PCM phase transition temperature that was kept constant are shown for comparison.

Temperature readings will be taken at several points along the finned pipe, including the fins, the PCM, and the point where the heat transfer fluid enters and exits the system (HTF). The fin temperature sensors will be positioned 20 millimetres away. The PCM temperature sensors will be located in the center of fins that are 30 millimetres apart and have the same radial distance as the fin temperature sensors. The apparatus used in the experiment includes a water bath (Lauda RA8), a pump that delivers HTF at a flow rate of 4.5 l/min (0.1 l/min), a data logger (Keithley 2701, Multiplexer 7706), and a 32-bit computer. It also functions as both a heat source and a heat sink.

CONCLUSION

Inorganic PCMs have a higher volumetric storage density and are non-flammable, whereas organic PCMs are more compatible with metallic storage containers, have fewer subcooling issues, Do not experience phase segregation.As a result, they are ideal for structural applications. In active TES systems with high load demand, PCMs' low thermal conductivity limits the thermal power rate for charge and discharge; the relatively high cost of the materials used impedes widespread adoption; and a lack of reproducible PCM thermal property data adds to system design uncertainty. It is demonstrated that, under certain conditions, the specific heat capacity of PCMs can be accurately described by a reduced version of the Dirac delta function that takes only two independent variables as inputs. We demonstrate that it successfully captures phase change properties, allowing the model to reflect experimental data with an exact specific heat. capacity.

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Limitations of the Study

One significant disadvantage of "using PCMs in active storage is their low heat transfer capability. While inorganic PCMs have higher thermal conductivity, it rarely exceeds 0.7 W/m.K. (Zalba et al., 2003); (2005) (Hauer et al.). Several techniques have been developed to improve the heat transfer rate in LHTES. Typical methods include increasing the heat transfer surface and the material's thermal conductivity. Surface extension is accomplished by the addition of fins (Ismail et al., 2001), (Castell et al., 2008), (Agyenim & Hewitt, 2010), (Tay et al., 2013), and the impregnation of PCM into highly conductive matrices (Mesalhy et al., 2006). (Yin et al., 2008.) Siahpush e Material properties are improved through the dispersion of Wang et al. (2009) and Pincemin et al. (2008) describe highly conductive particles. (Oya et al. 2012). Impregnation techniques provide the greatest" heat transfer enhancement, achieving 130-180 times greater thermal conductivity (Mills et al., 2006). (Zhong et al. 2010). Heat exchanger surface extension, on the other hand, is a well-established and commercially viable heat transfer enhancement technology (Medrano et al., 2009), and this thesis will focus on it.

REFERENCES

1. Abhat, A., 1983. Low temperature latent heat thermal energy storage: heat storage materials. Solar Energy, p. 313–332.
2. Al-Dabbas, M. & Al-Rousan, A., 2013. Energy extracted from underground rock area by using a horizontal closed loop system in Mutah University/Jordan. Energy Conversion and Management, pp. 744-750.
3. Almajali, M., Lafdi, K. &Prodhomme, P., 2013. Effect of copper coating on infiltrated PCM/foam. Energy Conversion and Management, pp. 336-342.
4. Anisur, M. et al., 2013. Curbing global warming with phase change materials for energy storage. Renewable and Sustainable Energy Reviews, pp. 23-30.
5. Arce, P. et al., 2011. Overview of thermal energy storage (TES) potential energy savings and climate change mitigation in Spain and Europe. Applied Energy, pp. 2764-2774.
6. Cabeza, L. et al., 2011. Materials used as PCM in thermal energy storage in buildings: A review. Renewable and Sustainable Energy Reviews, pp. 1675- 1695.
7. Cabeza, L., Svensson, G., Hiebler, S. &Mehling, H., 2003. Thermal performance of sodium acetate trihydrate thickened with different materials as phase change energy storage material. Appl. Therm. Eng., p. 1697–1704.
8. Geneva, I. 8., 1989. Ergonomics of Thermal Environments – Determination of Metabolic Heat Production, s.l.: s.n.

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JOURNAL OF MANAGEMENT AND ARCHITECTURE RESEARCH
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9. Gong, Z. &Mujumdar, A., 1996. Cyclic heat transfer in a novel storage unit of multiple phase change materials. ApplThermEng, p. 807–815.
10. Grozdek, M., 2009. Shifting and Storage of Cooling Energy through Ice Bank or Ice Slurry Systems - modelling and experimental analysis.. PhD Thesis, Royal Insitute of Technology ed. Stockholm, Sweden: s.n.
11. Herrick, C. S., 1982. Melt-freeze-cycle life-testing of Glauber's salt in a rolling cylinder heat store. Sol. Energy, pp. 99-104.
12. Hinze, M. &Ziegenbalg, S., 2007. Optimal control of the free boundary in a two-phase Stefan problem. Journal of Computational Physics, pp. 657- 684.
13. Javierre, E., Vuik, C., Vermolen, F. &Zwaag, S. v., 2006. A comparison of numerical models for one-dimensional Stefan problems. Journal of Computational and Applied Mathematics, pp. 445-459.
14. Kuznik, F., David, D., Johannes, K. & Roux, J.-J., 2011. A review on phase change materials integrated in building walls. Renewable and Sustainable Energy Reviews, p. 379–391.
15. Li, D., Cheung, K., Wong, S. & Lam, T., 2010. An analysis of energy- efficient light fittings and lighting controls.. Applied Energy, pp. 558-567.
16. Li, G., Hwang, Y. &Radermacher, R., 2012. Review of cold storage materials for air conditioning application. International Journal of Refrigeration, pp. 2053-2077.
17. Mesalhy, O., Lafdi, K. &Elgafy, A., 2006. Carbon foam matrices saturated with PCM for thermal protection purposes. Carbon, pp. 2080- 2088.
18. Mlakar, J. &Strancar, J., 2011. Overheating in residential passive house: Solution strategies revealed and confirmed through data analysis and simulations.. Energy and Buildings, pp. 1443-1451.
19. Oró, E. et al., 2012. Review on phase change materials (PCMs) for cold thermal energy storage applications. Applied Energy, pp. 513-533.
20. Oya, T. et al., 2012. Thermal conductivity enhancement of erythritol as PCM by using graphite and nickel particles. Applied Thermal Engineering,p. dx.doi.org/10.1016/j.applthermaleng.2012.05.033.
21. Peck, J., Kim, J., Kang, C. & Hong, H., 2006. A study of accurate latent heat measurement for a PCM with a low melting temperature using T- history method. International Journal of Refrigeration, pp. 1225-1232.
22. Persson M.L, R. A. W. M., 2006. Influence of window size on the energy balance of low energy houses.. Energy and Buildings, pp. 181-188.

23. Ryu, H. W., Woo, S. W., Shin, B. C. & Kim, S. D., 1992. Prevention of supercooling and stabilization of inorganic salt hydrates as latent heat storage materials. Sol. Energy Mater. Sol. Cells, Volume 27, pp. 161-172.
24. Salunkhe, P. &Shembekar, P., 2012. A review on effect of phase change material encapsulation on the thermal performance of a system. Renewable and Sustainable Energy Reviews, pp. 5603-5616.
25. Salunkhe, P. &Shembekar, P., 2012. A review on effect of phase change material encapsulation on the thermal performance of a system. Renewable and Sustainable Energy Reviews, pp. 5603-5616.
26. Sharma, A., Tyagi, V., Chen, C. &Buddhi, D., 2009. Review on thermal energy storage with phase change materials and applications. Renewable and Sustainable Energy Reviews, Volume 13, pp. 318-345.
27. Teng, Y., 1994. An effective capacity approach to stefan problems using simple isoparametric elements. International Communications in Heat and Mass Transfer, p. 179–188.
28. Tyagi, V. V. &Buddhi., D., 2007. PCM thermal storage in buildings: A state of art.. Renew. Sust. Energy Rev., Volume 11, p. 1146–1166.
29. Verma, N. &Mewes, D., 2009. Lattice Boltzmann methods for simulation of micro and macrotransport in a packed bed of porousadsorbents under non-isothermal condition. Computers & Mathematics with Applications, pp. 1003-1014.
30. Voller, V., 1990. Fast implicit finite difference method for the analysis of phase change problems. Numer Heat Transfer, pp. 155-169.
31. Voller, V. & Cross, M., 1981. Accurate Solutions of Moving Boundary Problems Using the Enthalpy Method. Int. J. Heat Mass Transfer, p. 545– 556.
32. Zalba, B., Marín, J. M., Cabeza, L. F. &Mehling, H., 2003. Review on thermal energy storage with phase change: materials, heat transfer analysis and Applications. Appl. Therm. Eng., pp. 251-283.
33. Zhang, Y., Jiang, Y. & Jiang, Y., 1999. A simple method , the T -history method , of determining the heat of fusion , specific heat and thermal conductivity of phase-change materials.. Meas. Sci. Technol., Issue 10, pp. 201-205.
34. Zhao, C., Zhou, D. & Wu, Z., 2011. Heat transfer of phase change materials (PCMs) in porous materials. Frontiers in Energy, pp. 174-180.