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A study to determine the thermal energy and last heat storage's techno-economic felizability for maintaining the indoor comfort level

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Abstract

When it comes to embedding storage technologies into the physical environment, the design phase is essential to establishing a stable and functioning system in order to meet the requirements. In most cases, engineers determine the size of storage units based on their previous experiences "and sanctioned methods, supposing that the storage unit's characteristics and load profiles have been accurately recorded. The outcomes of created systems, however, usually exhibit inconsistencies between the projected outcome and the actual performance of the system when they are put into practise. Insufficient design analysis is commonly cited as the root cause of the problem. In point of fact, a flawed comprehension of latent heat-based thermal energy storage systems (LHTES) is frequently the root cause of designs that are flawed. A more in-depth understanding of PCM is necessary, since accurate phase change process prediction still has to be improved by the use of improved modelling approaches and the input of more exact material data. In order to provide reliable PCM characteristics, engineers need to be able to employ straightforward yet exacting measurement techniques. It is necessary to do research on the optimal method for employing phase change modelling in the LHTES component design process. After the predesign requirements have been satisfied, the next step is the "It is possible to evaluate the system's transient behaviour. In conclusion, the enhancement of the entire system as well as the decrease of its impact on the environment may be assessed.

Keyword: PCM, Latent Technology, Ambient Temperature

INTRODUCTION

Humans benefit from technological advancement. "The demand for energy rises in tandem with rising living standards. In fewer than 40 years, the world total primary energy supply doubled to 150 PWh1 in 2010. Coal and nuclear power supply is a significant contributor to CO2 emissions, with nuclear power generating just 5% of global energy demand (IEA, 2012). Since the industrial revolution, human-caused greenhouse gas (GHG) emissions have increased dramatically, increasing the likelihood of severe climate change. There will be a 2°C to 6°C increase in global temperature by the end of the century if no action is done if CO2 emissions are allowed to stay at 450 ppm (IEA, 2012). Energy storage is a climate change mitigation technology that is gaining popularity. One of the first methods of energy storage was the collection of ice for the purpose of preserving food (London Canal Museum, 2013). A new era is here when 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 proving control over energy demand management at peak times. Storage also helps with load reduction by reducing the amount of fossil fuel-based marginal peak power output, which reduces GHG emissions. During Sweden's peak energy demand seasons, the country produced over 1 TWh/month of fossil fuel-based marginal electric power and imported 1.5 TWh/month" of electricity to fulfil the growing demand.

LITERATURE REVIEW

As the general public becomes "more familiar with the Smart System idea, the attention has shifted to using Electric Energy Storage to control the power grid. While heating and cooling are more basic energy sources, they account for a significant portion of total energy use in the Nordic nations. Over half (45%) of the energy used in the Swedish residential and service sectors comes from this source (SEA, 2011). A large proportion of marginal fossil fuel-based production methods may be minimised if heating and cooling loads are effectively controlled (Hasnain, 2000). With load shift and peak shaving, production units can run at nominal power and thus achieve optimal efficiency; better operating conditions can be achieved with more suitable ambient conditions, such as running chillers at night and heat pumps during the day; increased grid capacity without additional expenditure; and a greater reliance on renewable energy sources are all benefits. Yet another topic that has received little attention, thermal energy storage (TES) and management will be the subject of this study. The design of TES that goes beyond hot/cold water storage tanks is particularly important in this context. Phase change materials (PCMs) or so-called latent heat thermal energy storage are used" to obtain high energy density and the power characteristics required for reliable operation.

STATEMENT OF THE PROBLEM

A number of factors must be taken into consideration when selecting a TES system for a specific application, including: "low thermal loss during storage, high energy extraction efficien- cy, an appropriate temperature, non-hazardousness to the environ- mental, commercial availability, and cost efficacy. In 2003, Zalba et al. published Dincer and Rosen (2011) state this.

Recent years have seen a significant increase in the amount of TES literature available. This chapter summarises PCM classification reviews and gives an outline of PCM benefits and drawbacks. In this field, several reviews have" been cited, including (Hasnain, 1998), (Dincer, 2002), (Tyagi & Buddhi., 2007), (Agyenim et al., 2010), and (Oró et al., 2012).

OBJECTIVE OF THE STUDY

This thesis seeks to establish a robust process in order to design, integrate, and assess PCM-based thermal energy storage for interior comfort control. The method will be built in this thesis. By accomplishing the goals outlined below, we will be able to provide answers to the research questions.

- To determine the environmental advantages" of peak shaving and load shifting through TES.

Research Questions

This argument is based on the premise that TES has the potential to be utilised for the advancement of society as a whole. The following is a list of significant study questions that are raised by a strategy that works from the top down to evaluate the statement:

- What contribution can TES provide to sustainable development and climate change mitigation?

With a particular focus on hidden potentials "This thesis analyses the study subjects of thermal energy storage for interior comfort management from the very beginning of the research process. Therefore, technologies will be investigated throughout their entire stages of development, from material analysis to component modelling, and a techno-economic analysis will be carried out as well "at each and every stage of development, beginning with the analysis of the system and continuing with the evaluation of the national climate change mitigation.

RESEARCH METHODOLOGY

On the material level, it is demonstrated that thermophysical property describing techniques such as differential scanning "calorimetry (DSC) and conventional calorimetry have limits. As a result, the T-History method's resilience in describing non-homogeneous materials has been evaluated. On the component design level, storage performance modelling will be carried out using numerical simulation methods in conjunction with a heat transfer analysis. Conduction and convection are the heat transmission processes included in the modelling, whereas radiation has a minor influence due to the tiny temperature difference. In terms of system integration, a case study of an office building connected to Stockholm's district cooling network will be conducted, as well as an optimization" of the LHTES integrated seminar room. To shed light on the environmental benefits of TES when integrated into the built environment, the marginal CO2 emission reduction from fossil fuels is assessed in the Swedish energy system.

Research Design

The approach is based on the Lumped Capacitance model, which assumes a modest internal temperature gradient in the observed sample. In other words, the non-dimensional Biot number, which is the ratio of internal to exterior thermal resistance, should be minimal. Existing approaches are basically temperature averaged models in which samples are kept constant in relation to the external ambient temperature. The T-History technique is improved in this section.

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. Each technique was repeated three times. In order to properly charge and discharge cold, the temperature of the input HTF will be maintained at 11 degrees Celsius while charging and 32 degrees Celsius when discharging. The temperature values that have been given here are those that were obtained from the central part of the testing rig. In addition, results obtained using a PCM phase transition temperature that was held constant are shown for comparison.

Temperature readings are going to be obtained at several points along the finned pipe, on the fins, within the PCM, as well as at the point where the heat transfer fluid is entering and leaving the system (HTF). The fin temperature sensors will be positioned 20 millimetres out from the centre of the fin, and the PCM temperature sensors will be positioned in the centre of the fins that are spaced 30 millimetres apart at the same radial distance as the fin temperature sensors. A water bath, designated as Lauda RA8, is incorporated into the apparatus used in the experiment "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 are all included in this device. It also performs the functions of 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, experience less subcooling issues, and do not experience phase segregation "Consequently, they are well suited for installation in structures. In active TES systems with high load demand, PCMs' low thermal conductivity limits the thermal power rate for charge and discharge; the technology's widespread adoption is hampered by the relatively high cost of the materials used; and the lack of reproducible PCM thermal property data adds to the uncertainty of system design.

It is shown that, under certain conditions, the specific heat capacity of PCMs may be accurately described by a reduced version of the Dirac delta function "utilising only two independent variables as inputs to the function. Here, we show that it successfully captures the phase change properties, allowing the model to reflect experimental data with an exact specific heat capacity.

LIMITATIONS OF THE STUDY

One significant disadvantage of "utilising PCMs in active storage is their poor heat transfer capability. While inorganic PCMs have a higher thermal conductivity, it is rarely more than 0.7 W/m.K. (Zalba et al., 2003) (2005) (Hauer et al.). Numerous techniques have been developed to increase the heat transfer rate in LHTES. Typical methods include expanding the heat transfer surface and increasing the thermal conductivity of the material. The surface extension is accomplished by the addition of fins (Ismail et al., 2001) (Castell et al., 2008) (Agyenim & Hewitt, 2010) (Tay et al., 2013), impregnation of PCM into highly conductive matrices (Mesalhy et al., 2006) (Yin et al., 2008) (Siahpush e The improvement of material properties is accomplished by the dispersion of highly conductive particles (Wang et al., 2009; Pincemin et al., 2008). (Oya et al., 2012). The highest" heat transfer enhancement will be observed with impregnation techniques, which achieved 130–180 times greater thermal conductivity (Mills et al., 2006). (Zhong et al., 2010). On the other hand, heat exchanger surface extension is a well-established and commercially viable technology for heat transfer enhancement (Medrano et al., 2009), and will be the subject of this thesis.

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.
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.