STORAGE OF LATENT HEAT AND THERMAL ENERGY FOR INDOOR COMFORT CONTROL: AN INVESTIGATION INTO TECHNO-ECONOMIC VIABILITY.

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ABSTRACT

The last four seconds of the previous day saw the debut of Homo sapiens, which many people think is one of the most important moments in history. People think this incident is one of the most important in history. During the Industrial Revolution, which happened more than 200 years ago, fossil fuels were found for the first time. A lot of these fuels were taken from the ground during this time. The Intergovernmental Panel on Climate Change (IPCC) says that the world's temperature will rise by two to six degrees Celsius by the year 2100 because people are using too much fossil fuels. This is a direct consequence of human activities that are altering the climate. This is driving the demand for therapies with lower energy consumption. With the goal of lowering GHG emissions, increasing the use of renewable energy sources, and improving system energy efficiency without compromising quality of life, this research investigates load shifting and peak shaving uses of energy storage technology. These goals are reached without lowering the quality of life. High-level thermal energy storage (TES) systems use latent heat (LH) as the main way to store thermal energy. Phase transition materials give these technologies their power. The goal of the research is to create accurate numerical models of the LHTES element to solve the challenges that have been found. These versions are made up of both shaped-stabilized and free-flowing PCM mechanisms. Researchers have reported positive outcomes from an investigation into the practicability of using multistage multi-PCM to enhance thermal power efficiency, which validated these models via tests. Temporary TES combined systems were also the subject of the study, with the goal of reducing the excess energy derived from fossil fuels alongside alternative resources for a cleaner environment. This is why renewable energy was created.

Keywords: Latent Heat, Thermal Energy, Indoor, Techno, Economic Viability.

INTRODUCTION

Technological advancements have contributed to the expansion of the human population, which is also referred to as Sapiens. As the standard of living continues to improve, there is a corresponding increase in the need for energy. After expanding in a period of less than forty years, it became the dominant source of energy for the globe in the year 2010. Fissile fuels produce 30 gigatonnes of carbon dioxide and account for roughly fifty percent of the world's yearly energy use. It is projected that global temperatures will rise by two to six Celsius degrees by the conclusion of the century unless action is taken to address the issue. In an effort to combat climate change, an increasing number of individuals are calling for energy "storage" systems. The practice of collecting ice for the purpose of preserving food is one of the first applications of technology that stores energy. These technologies are necessary in order to accommodate daily periods of over generation and peak loads from these sources (Zahir et al., 2019). Within the scope of this chapter, the requirements for energy storage during the day are classified as short-duration. These requirements cover time spans ranging from seconds to hours and have capacities that range from kilowatts to gigawatts. There have been previous studies that have claimed that the dropping costs of batteries and associated technologies may make it possible for battery systems to meet the short-duration needs of the grid with high penetrations of intermittent renewable energy systems. Recent research, on the other hand, has demonstrated that in order to accommodate the creation of energy that is entirely derived from renewable sources (or carbon-free), long-term energy storage (ranging from days to months) will be required. Additionally, in order to improve the safety and resilience of the electrical system in the face of an increase in the number of natural disasters and purposeful threats, long-term energy storage will be required. TES, also known as TES, is a technology that can help eliminate the gap that exists between the amount of renewable resources that are available and the amount of energy that is really required. TES is a method that involves modifying the internal energy of a material in order to store thermal energy. The energy that has been stored can then be utilised at a later time for a variety of functions, including heating and cooling. When included into an energy system, TES provides a number of advantages, including an increase in overall efficiency and an increase in reliability. As a consequence of this integration, both investment and operational expenses are reduced, and there is also a reduction in greenhouse gas emissions. TES technologies are often divided into three groups, which are called sensible, latent, and thermochemical technologies (Yang et al., 2021).

BACKGROUND OF THE STUDY

By reducing the impact of fluctuations in the flow of energy, energy storage has the potential to enhance the dependability and efficiency of the energy systems that are in use today. As a result, renewable energy sources, particularly those with a "intermittent" characteristic, might be better used, and peak energy demand could be better controlled. The usage of storage for energy has the ability to help reduce greenhouse gas emissions by facilitating the efficient generation of electricity from fossil fuels. In order to satisfy the spike in demand that happens during the winter months, Sweden imports 1.5 TWh of energy every month from other nations. Also around this time, the nation's marginal energy production from fossil fuels hit a new monthly high of almost 1 TWh. It is possible to decrease marginal peak power production "through" power storage usage. As more and more people learn about the idea of a "smart grid," electric "energy" storage plays a crucial role in power grid management. While heating and cooling are two of the most important sources of energy, the Nordic countries rely heavily on both of these energy sources simultaneously (Cabeza et al., 2020). This one source accounts for more than 45% of the energy used by Swedish families and companies. The use of fossil fuels in marginal production methods may be reduced with proper management of heating and cooling loads. Transferring load and peak shaving both have their benefits. Among these benefits are enhanced operational efficiency due to production units running at nominal power, more utilisation of energy from renewable sources, better environmental conditions, and increased grid capacity at no extra cost. This work aims to provide valuable insights into the underappreciated topic of thermal energy TES. The fundamental purpose of this work is to improve the design of TES water storage systems beyond the conventional hot-and-cold water tanks. For the purpose of sensible heat storage, thermal energy is stored by adjusting the temperature of the medium that is being used for storage (Beust et al., 2021). During phase transitions that occur inside the storage medium, heat may either be released or absorbed in a system that is designed to store latent heat. The last kind of storage is known as thermochemical storage, and it involves the reversible breaking and reformation of molecular bonds in chemical processes. This allows thermal energy to be stored and restored. Every single technology that is used for TES comes with its own individual set of benefits and drawbacks. The relatively low energy storage density of sensible TES is a limitation, despite the fact that it is straightforward and has been proved extensively. TES, on the other hand, is capable of achieving a high energy storage density; but, owing to the complex nature of the technology, it is still in the process of being developed (Brütting et al., 2019).

PURPOSE OF THE STUDY

When integrating storage technology into the built environment, meticulous design is required in order to develop a system that is both stable and functional. Engineers often determine the size of the storage unit based on allowed procedures and their own personal experience, provided that the parameters and load profiles of the storage unit are well recorded. In spite of this, planned systems might exhibit discrepancies between the results that were anticipated and those that were actually obtained in real-world applications. When attempting to explain the causes, it is usual practice to blame inadequate design analysis. In point of fact, false designs are often the consequence of incorrect interpretations of LHTES. In order to continue increasing the accuracy of phase change process prediction via enhanced modelling approaches and more precise material data input, it is vital to have a better knowledge of PCM. For engineers to be able to get accurate PCM parameters, measuring approaches that are simple yet precise are required. For the purpose of determining the most effective approach to the development of LHTES components via the use of phase change modelling, more study is necessary. "Transient behaviour of a system may be assessed once predesign requirements have been met." Last but not least, it is possible to undertake an evaluation of the system's overall improvement and the reduction of its negative effects on the environment.

LITERATURE REVIEW

Among these features are low heat loss during storage, high efficiency in extracting energy, suitable operating temperature, and friendliness to the environment, industrial availability, and economic value. There has been a deluge of literature about TES in the past many years. The purpose of this study is to present an overview of the assessments of PCM courses as well as an inventory of the advantages and disadvantages of using PCM. There is an improvement in load control that occurs when TES systems are introduced. What are the advantages of storing thermal energy? Additionally, it may employ all of the load capacity by boosting production and moving high demand times during peak periods to off-peak periods when demand is lower in order to improve overall system performance. This is done in order to operate energy systems, full storage, load levelling, and demand limiting. Lower energy costs could be an outcome of load-shifting during off-peak hours. Using a range of management tactics, it demonstrates how full and partial load changes alter between peak to off-peak times. When it comes to controlling the amount of load that is transported, there are two methods: load levelling and demand limiting (Xu et al., 2020). The energy distribution system employs a load-balancing approach in order to preserve stability, and the storage facility is able to satisfy peak demand for the load that is not optimally evenly distributed. The demand limitation mechanism decreases the amount of energy that is available during peak hours while charging the storage at a higher energy rating during off-peak hours. Under an unequal "tariffing" system, the objective of this regulatory method is to bring about a reduction in peak energy use and, therefore, prices. By reducing the amount of thermal and electricity-producing resources, as well as by ensuring that power plants and thermal equipment are operating at their bare minimum capacity, TES has the potential to provide advantages to both the economy and the environment. Heat pumps are a significant user of home electricity, despite the fact that they take a relatively little amount of power to transfer a greater quantity of heat from a heat source. Heat pumps are also necessary for the operation of heat pumps. The costs of power have dramatically risen as a result of current energy constraints as well as inflation. The trading prices of power are subject to significant fluctuations. There are many instances in which the costs of energy are very cheap. This is because wind power production has an influence. This reveals that the overall costs of electricity trading have increased. The use of TES in domestic heating systems has garnered interest due to its involvement in peak load shifting, which is a means of lowering the costs associated with heating (Thölix, 2021).

RESEARCH QUESTION

What is the effect of latent heat storage on indoor comfort regulation?

RESEARCH METHODOLOGY

Research Design: Quantitative data was analysed using SPSS version 25. The statistical association's strength and direction were assessed using the odds ratio and 95% confidence interval. A criterion of $p < 0.05$ was set by the researchers as being statistically significant. The primary characteristics of the data were identified by a descriptive analysis. Data processed using computer statistical tools, as well as data collected via surveys, polls, and enquiries, are often evaluated using quantitative methods.

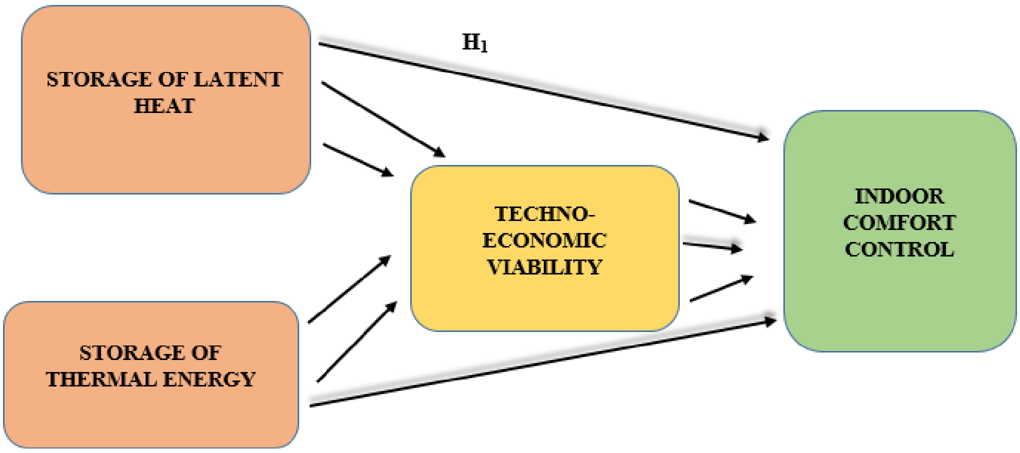
Sampling: Participants in the study filled out questionnaires to provide data for the research. Employing the Rao-soft program, researchers identified a study population of 1,386 persons, leading to the distribution of 1,512 questionnaires. The researchers obtained 1456 replies, removing 47 due to insufficient participation, yielding a final sample size of 1409.

Data and Measurement: A questionnaire served as the primary instrument for data collection in this study. Part A of the survey solicited fundamental demographic information, while Part B used a 5-point Likert scale to gather responses about attributes associated with online and offline channels. A multitude of sources, particularly internet databases, supplied additional data.

Statistical Software: The statistical analysis was conducted using SPSS 25 and Excel from Microsoft.

Statistical Tools: The technique of descriptive analysis was used to comprehend the essential properties of the data. The investigator must analyse the information with ANOVA.

CONCEPTUAL FRAMEWORK



RESULT

Factor Analysis: A common use of Factor Analysis (FA) is to uncover latent variables within visible data. Standard procedure mandates the use of correlation coefficients for evaluation when diagnostic or visually discernible indicators are absent. Models are essential for success in FA. Modelling fundamentally involves errors, intrusions, and evident linkages. The Kaiser-Meyer-Olkin (KMO) Test is a method for evaluating datasets generated by multiple regression analyses. This demonstrates that the variables in the model and the sample are really representative. The statistics indicate the presence of data duplication. Data becomes more comprehensible when proportions are minimised. The outcome of executing KMO yields a value ranging from 0 to 1. An adequate sample size is characterised by a KMO value ranging from 0.8 to 1. Kaiser delineates the acceptable parameters: Kaiser has established the accompanying supplementary entrance prerequisites:

Unsatisfactory: 0.60 to 0.69; inadequate: 0.050 to 0.059

The interval of 0.70 to 0.79 is common in middle grades.

Exhibiting an excellent point score between 0.80 and 0.89.

The range from 0.90 to 1.00 astonishes them. Kaiser-Meyer-Olkin Statistic: .865 The findings of Bartlett's test of sphericity are as follows: The chi-square test has approximately 190 degrees of freedom, with a level of significance of 0.000. This substantiates the validity of the assertions about sampling. Researchers assessed the significance of the correlation matrices using Bartlett's Test of Sphericity. The Kaiser-Meyer-Olkin measure indicates an adequate sample with a value of 0.865. The p-value from Bartlett's sphericity test is 0.00. The association matrices may be indistinguishable if Bartlett's circularity test yields a good outcome.

Table 1. Assessment of Sampling Adequacy using KMO and Bartlett's Test.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.865
Bartlett's Test of Sphericity	**Approx. Chi-Square**	3252.968
	df	190
	Sig.	.000

The significance of the correlation matrix was validated using the Bartlett Test of Sphericity. A sufficient sample size of 0.865 is determined using the Kaiser-Meyer-Olkin metric. Researchers used the Bartlett circularity test to get a p-value of 0.00. Given the significant outcome from Bartlett's eccentricity test, the researcher acknowledges the invalidity of the correlation matrix.

INDEPENDENT VARIABLE

Storage of Latent Heat: Latent heat storage, also known as LHS, is a technique for storing thermal energy that makes use of phase change materials (PCMs). also known as PCMs, to store and release energy during the phase transition of the material, which may include melting and freezing conditions. This technology makes use of the high energy absorption and release that is associated with phase transitions. As a result, it is able to store and retrieve energy in an effective manner. Because of their high energy density and ability to maintain a consistent temperature, LHS systems are used in a broad variety of applications, including the regulation of the climate in buildings, industrial operations, and power generation systems that utilise renewable energy. When a solid is melted into a liquid, the process of latent heat storage includes storing heat in a phase-change material that makes use of the significant latent heat that is generated during the phase shift. It is possible to understand latent heat as a kind of hidden energy that may be provided or removed in order to alter the condition of a material without change in the temperature or pressure of the substance. Latent heat of fusion, which converts solids into liquids, latent heat of vaporisation, which converts liquids into gases, and latent heat of sublimation, which converts solids into gases are all included in this category. The heat that is emitted or absorbed by a body or a thermodynamic system during a process that takes place at a constant temperature is referred to as latent heat. A change in the state of matter, also known as the phase transition process, is a classic example. During this process, the temperature of the system does not change, despite the fact that the system is absorbing (or releasing) heat. In the process of melting a solid or freezing a liquid, the latent heat that is linked with these processes is referred to as the heat of fusion. In the process of vaporising a liquid or solid, or condensing a vapour, the latent heat that is connected with these processes is referred to as the heat of vaporisation (Schüppler et al., 2019).

DEPENDENT VARIABLE

Indoor Comfort Control: Thermal, visual, and auditory comfort, as well as air quality, are all aspects of indoor comfort. Every one of these problems has been solved. The dictionary defines comfort as "a relaxing sensation of feeling at ease and liberated from pain." The Cambridge Dictionary defines comfort as an emotional or mental condition. Assuming moderate humidity and appropriate attire, most people find a room temperature between 20 and 25 Celsius (68- and 77-degrees Fahrenheit) to be comfortable. This range, however, may change substantially for some groups, such infants and the elderly, as well as for individuals based on their level of activity and personal preferences. The typical recommendation for a comfortable sleeping temperature is from 65 to 68 degrees Fahrenheit, or 18 to 20 degrees Celsius. Air circulation, human metabolism, and humidity are all factors that play a significant effect in the overall level of comfort that an individual experiences. Indoor comfort solutions are solutions that aid persons in keeping safe and pleasant air, lighting, and acoustics inside their home or work spaces. There are a variety of solutions available to meet the needs of individuals. Appliances such as air conditioners, heaters, humidifiers, smart thermostats, and soundproofing panels are included in this category. These alternatives are relied on by a significant number of us to ensure that researcher's rooms remain cool during the summer, comfortable during the winter, and free of dust and excess moisture. The temperature is not the only factor that has to be considered when it comes to indoor comfort; it is also possible to use intelligent lighting or curtains in order to decrease glare and improve mood. Using the latest technology, smart systems now allow researcher to adjust the level of comfort inside researcher's home with only a touch or a voice command. Researcher will find a list of the basic categories, as well as tips and tricks for enhancing comfort, and instructions on how to choose what is appropriate for researcher's specific requirements below (Nilsson, 2020).

Relationship between Storage of Latent Heat and Indoor Comfort Control: It is crucial to bear in mind that the process of strengthening the management of interior comfort involves the storage of latent heat, which is a key component. This is an important aspect to keep in mind. This may be accomplished by ensuring that temperatures inside the building are maintained and by lowering the amount of traditional heating, ventilation, and air conditioning systems that are required. During the process of phase transitions, such as melting or solidification, latent heat storage systems, particularly those that make use of PCMs, are able to absorb and release thermal energy. This is especially true for systems that possess the ability to store latent heat. The fact that this is the case is particularly true for systems that use PCMs. It is possible for the interior environment to stay within a range that is comfortable for extended periods of time since this technique does not entail a major movement in temperature. Not only does this thermal buffering make the people who live there more comfortably, but it also decreases the amount of energy that is pulled from the structure. This is accomplished by reducing the variations in temperature. In addition, the incorporation of latent heat storage into building systems produces passive heating and cooling solutions, which makes it a sustainable option for the architecture that is now in use. This contributes to the achievement of the goal of making the building ecologically friendly. When it comes to examining the link between latent heat storage and the degree of comfort that is experienced within a building, the most crucial component is the possibility to simultaneously supply thermal stability and energy efficiency (Ali et al., 2021). In response to the above discussion, the researcher has offered the following hypothesis to examine the correlation between Storage of Latent Heat and Indoor Comfort Control.

“H_{01}: There is no significant relationship between Storage of Latent Heat and Indoor Comfort Control”

“H_1: There is a significant relationship between Storage of Latent Heat and Indoor Comfort Control”

Table 2. H1 ANOVA Test.

ANOVA					
Sum					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	39588.620	587	5653.517	1057.522	.000
Within Groups	492.770	821	5.346		
Total	40081.390	1408			

This investigation will yield substantial results. The F statistic is 1057.522, achieving significance with a p-value of .000, which is below the .05 alpha threshold. The hypothesis posits that “H_1: There is a significant relationship between Storage of Latent Heat and Indoor Comfort Control.” The alternative hypothesis is validated, while the null hypothesis is rejected.

DISCUSSION

The storage of thermal energy is one example of a technology that has the potential to contribute to improvements in energy conservation. In addition to facilitating the shifting of energy demand and the decrease of peak energy load, this technology also makes it possible to make use of waste heat or free cooling. One of the ways that heat can be stored within the temperature range that is deemed to be thermally acceptable is through the utilisation of a hot water storage unit that is split into layers. There is, however, a requirement for a greater storage capacity in the event that sensible storage of thermal energy is employed (for instance, layered chilled water). This is as a result of the fact that the temperature range that is allowed to be tolerated during operations for cold storage is lower. A number of benefits can be derived from the utilisation of PCMs as storage media in LHTES. One of these benefits is the capacity of PCMs to store substantial quantities of thermal energy with minimum variations in temperature. Ice and water are two of the most common phase change materials (PCMs), however their low phase transition temperatures render them unsuitable for producing comfortable indoor cooling. Researchers and scientists have studied and tested a wide range of materials that phase change with "a variety of phase change energies" in recent years. Many studies and investigations have focused on these materials.

CONCLUSION

The TES system benefits greatly from PCMs, which may be either organic or inorganic, depending on their classification. Among these benefits is the reality that they are not phase segregating, are less affected by sub cooling, and work well in containers made of metal. Some of the disadvantages of these materials include their high cost, restricted heat conductivity, and an absence of repeatable data on thermal properties. The high cost of these materials is another factor. By comparing an unidentified substance to a previously known reference sample, the T-History method—a ground-breaking way to evaluating the characteristics of materials—can be used to calculate the entropy variation in an unknown material. To ensure the accuracy of this method, many prerequisites must be met: a low Biot number; a repeatable heat flux; a very sensitive temperature sensor; and familiarity with the reference material. This work adds to the development of a cutting-edge computation method by studying the position of the T- History setup and determining the thermophysical properties of different materials. The particular thermal capacity of PCMs will be shown using a basic modified Dirac delta function. The findings of the experiment will be reflected in this function. However, there are very clear limits that everyone must follow. A conductivity model using finite-difference enthalpy was shown to be within a time difference of 5% when it came to the discharge/charge performance assessment of gelled salt-hydrated PCM-based LHTES. Contrasting the model to the facts obtained via testing showed this. To accomplish the goal of assessing the efficacy of non-gelled storage, a conduction/convection model was built with "material stiffness above and below the phase shift temperatures" taking centre stage. The results of the study, including experimental and numerical studies, show that when PCM is present in both the solid and liquid phases, a "15% delay in the mushy" zone develops. This disagreement stems from the fact that nobody can agree on when exactly the convective transfer of heat process starts to die out.

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