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BREAKEVEN ANALYSIS OF THERMAL ENERGY STORAGE SYSTEM UNDER UNCERTAIN OPERATING CONDITIONS

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ABSTRACT

Since thermal energy storage (TES) systems gained momentum in the global energy market, there is a greater demand to enhance their energy efficiency and, more significantly, lower their costs. The purpose of the study is to assist decision-making under uncertainty and risk associated with stochastic increases in cost connected with Thermal Energy Storage System operation. The Thermal Energy Storage System (TSS) at the Gas District Cooling Plant in Perak, Malaysia is the purpose of this research. When fluctuating cooling demands develop, the Thermal Energy Storage System (TSS) is used to transfer energy use from peak to off-peak hours. For TSS and Gas District Cooling (GDC) systems, electric chillers and thermal storage tanks are required. Thermal energy systems (TES) play a role in the ongoing process of increasing integration across diverse energy systems to achieve a cleaner, more flexible, and long-term use of energy resources. Break-even analysis was used in the study, which is a basic tool for analyzing the feasibility of real-world initiatives with uncertainty. The findings reveal that a single-shift operation is not feasible, and the project will require at least two shifts to be viable.

Keywords: breakeven, thermal energy storage system, gas district cooling.

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INTRODUCTION

Today's world is full of uncertainties, many of which are also unpredictable. To operate complex engineering systems, suitable management decisions must be made to deal with these uncertainties. The only certain thing is historical data, whereas investment problems are concerned with the future [1].

It is well acknowledged that uncertainty should be considered while making management decisions, due to the uncertainty and imprecision associated with risk in the oil and gas industries, risk assessment has become a difficult undertaking in today's competitive economic environment [2]. The inability to effectively predict future uncertainty has a significant impact on decision-making. Researchers are sedulous to overcome these problems and have employed several Life Cycle Costing techniques (LCC). Many authors have adopted LCC analysis in the past for various applications such as power systems, railway networks, and heat pumps [3, 4]. A thermal Energy Storage System (TSS) is a method for storing thermal energy through a heating or cooling storage medium, that can be layer-on used for heating, cooling, or power generation. TSS systems have major applications in buildings and industrial processes.

TES usage results in improved efficiency & dependability, lower investment and operating expenses, and reduced pollution of the environment. TES not only lowers the gap between supply and demand by preserving energy, nevertheless it also improves the system's performance and thermal reliability. As a result, designing effective and cost-effective TES systems is necessary.

As industrial countries have been more electrified over the last four or five decades, a variety of TSS approaches have evolved. From an economical perspective, such TSS systems offer a vast potential to increase the usage of thermal energy equipment and permit large-scale energy alternatives. There are mainly two types of TSS systems, i.e., sensible (e.g., water and rock) and latent (e.g., water/ice and salt hydrates). The section depends on the storage period needed, for example, diurnal or seasonal, as well as the economic viability and operating conditions.

The TES Tank and electric chillers are the two primary components of a TSS. The separation of cold/hot water kept in the TES tank from cold/warm water coming from the building's HVAC system is one of the most important aspects of water storage system performance. Various techniques have been utilized, including the usage of two tanks (one for cold and another for warm water), the use of a membrane to separate cold and warm water in that tank, & and natural stratification. Cold and warm water are stored in tanks and separated by natural stratification in the stratification system, which has been reported to perform better or similarly to other approaches.

To address the cooling demand, TES tanks could be used in conjunction with supporting chillers. The cold TES tank stores night-time peak energy for usage throughout the day [5]. The extra electric energy produced by the gas turbines that is accessible throughout the night is used to produce chilled water by using electric chillers to charge the TES tank in the co-generation plant under this study. The cold water is kept in the tank to meet peak demands throughout the day. This is done for better use of electricity. According to studies, the TES system's operation has a significant impact on TES performance.

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LITERATURE REVIEW

Many hypotheses have been suggested that the Thermal Energy Storage (TES) system is among the most advanced energy conversion technologies that have been adopted in recent years. The ability to fulfill electrical cooling demand at low prices during peak periods has been the main attraction in the adoption of TES, which has been able to reduce cost consumption. According to Karim *et al* [6] and Li *et al* [7], TES can temporarily store thermal energy and hold it for later use in cooling down the building.

The phrase "Life-Cycle Cost" (LCC) is used frequently in engineering practice. It's a technique for weighing economic factors when making decisions. LCC is the total of all costs associated with a product's structure, systems, or performance during its lifetime. LCC gives a framework for estimating the entire cost of creating and utilizing a certain item. LCC is a structured way of estimating the cost of an engineering system from the beginning to the end. The present worth (PW) analysis is linked to LCC. In a PW analysis, future costs and revenues are converted into the present value of money using existing formulas to allow determining the economic benefit of respective systems clearer.

The deterministic approach and the probabilistic approach can both be used to estimate LCC. LCC analysis uses fixed and distinctive input variables in its deterministic approach. Only a single value, such as average or median, is identified in this approach, which is usually based on historical data or expert knowledge for every input variable [8].

In comparison to the deterministic technique, the probabilistic approach is more comprehensive. According to Chong [9], probabilistic LCC analysis can handle the uncertainties of input parameters including maintenance cost, downtime, and failure rate. Avoiding variance in input data might cause inaccuracy in the expected result and lead to poor judgment. The probability of all possible outcomes depending on the change of input can be obtained and further examined using a probabilistic technique. The probabilistic life cycle cost (LCC) will be utilized in this study to estimate the total cost of an electric chiller across its whole system life span.

A chiller is a sort of refrigeration machine that uses the refrigeration cycle to remove heat from a liquid through the Vapor Compression Cycle (VCC) or the Absorption Cycle (AC), according to engineering studies. Both cycles could cool the secondary refrigerant, which was commonly water, which was subsequently utilized to chill the area [8].

Manufacturers prefer to estimate LCC using a deterministic technique over a probabilistic approach, according to Chong [9], even though it does not represent the true situation that the systems or equipment have gone through. The authors discovered a need for constructing a probabilistic LCC model to improve LCC estimation. This is comparable to the goal of this research, which aims to create a probabilistic LCC model to help with LCC estimation.

RESEARCH METHOD

Data Acquisition

The Collection of data is gathered using a TSS system installed at the GDC plant in Perak, Malaysia. Figure-1 and Figure-2 offer statistics on daily production and daily power consumption over a year. The tariff rates for peak and off-peak hours are 0.288 RM/kWh for peak hours and 0.173 RM/kWh for off-peak hours, according to Tenaga Nasional Berhad in Malaysia. The chilled water produced by TSS is sold at a rate of 0.606 RM/RTh. The salaries of the employees at the GDC factory are also considered operational expenditure (OPEX) for the study, although they are kept private. Figure-3 shows the Capital Expenditure (CAPEX) for the TSS equipment, which includes a thermal energy storage tank and an electric chiller.

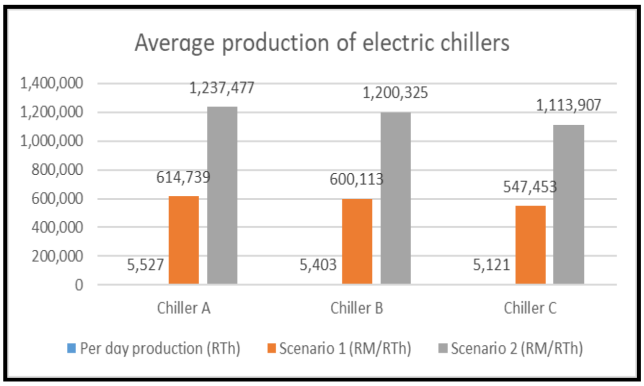

Figure-1. Average production of electric chillers at GDC plant.

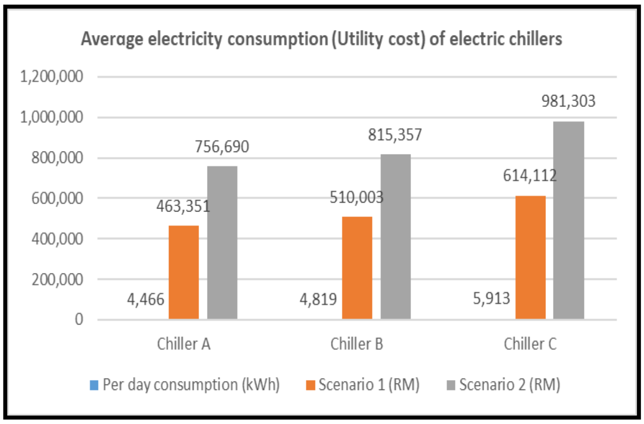

Figure-2. Average electricity consumption (Utility cost) of electric chillers at GDC plant.

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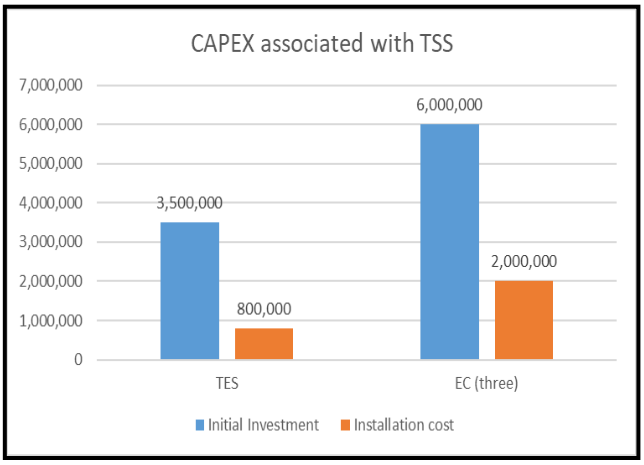

Figure-3. CAPEX associated with TSS.

Break-Even Analysis

Break-even Analysis is a basic and relatively straightforward strategy for analysing difficulties of investment project evaluation under uncertain situations. The break-even point of an investment project is the amount of production and sales at which the project generates neither profits nor losses but generates a positive financial outcome. The break-even point is the point where profits and losses meet. Above this opinion, the project is profitable; lower the value, the project is losing money. Break-even can be defined as the crucial point of production (critical utilisation of production capacity) or the critical sales income (critical sale price per unit). Because it only uses data on one project, break-even is a static method for investment project evaluation in circumstances of uncertainty.

The first stage for breakeven analysis is to convert the data into Net Present Vαlue (NPV). The Net Present Value condition is identified as a sum up of present values of annual net incomes gained at the time of the project development. A mathematical representation of this criterion is given by equation (1) for future value conversion

$$NPV_{Future} = \sum_{j=1}^{n} \frac{I_j}{(1+i)^j} \quad (1)$$

$$NPV_{Annual} = \sum_{j=1}^{n} \frac{A.\,[(1+i)^j-1]}{i.(1+i)^j} \quad (2)$$

Where *I_j* is the net income in *j^th* year of the period of the project; *i* is the interest rate; *n* is the project's period of development; A is the annual arising cost.

The break-even point of an investment project is the point at which it is neither profitable nor losing money. The important point of production or sales is known as the break-even point.

In this project, the costs that are predicted to occur throughout TSS operation are only increasing with time as the breakeven threshold approaches. Annual quantities, such as salary and utilities, are translated using equation (2), while single-occurrence amounts, such as breakdown maintenance costs and so on, are transformed using equation (1).

RESULTS AND DISCUSSIONS

Scenarios for Case Study

In this project, the major objective is to ensure the feasibility of single and two-shift operations for TSS operation based on data gathered from real data. To analysis the uncertainties occurring in the future, a random number is multiplied by the cost as per equation (3).

$$OPEX_{uncertaininty} = OPEX_{normal} \cdot (1+x); \; where, \; 0 \le x \le 0.2 \quad (3)$$

The operating hours are assumed to be 12 hours per day in the first scenario, i.e., single-shift operation, and expenses are estimated. Similarly, the costs for scenario 2, which is a two-shift operation, are estimated. To accommodate for uncertainties, all costs are updated per year by inserting a random multiplier, and a cash flow diagram is created.

The break-even point for both scenarios is evaluated once the cash flow diagrams for costs are created, taking into consideration uncertainties such as fuel price changes and electricity tariff changes that are random. The break-even point calculation for single and two-shift operation scenarios is shown in Figures 1 and 2.

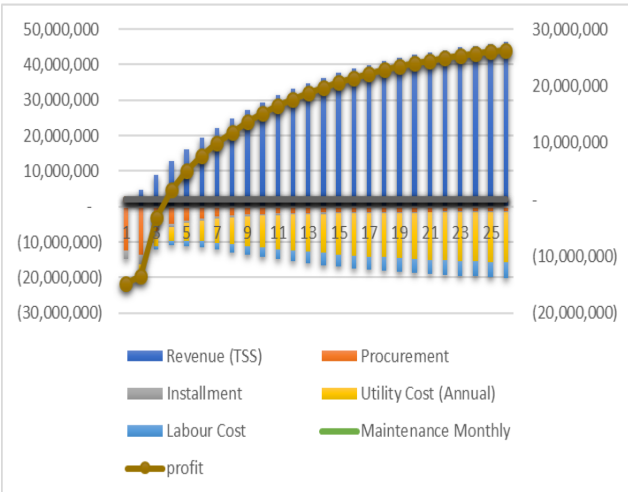

Figure-4. Breakeven analysis for a single-shift operation.

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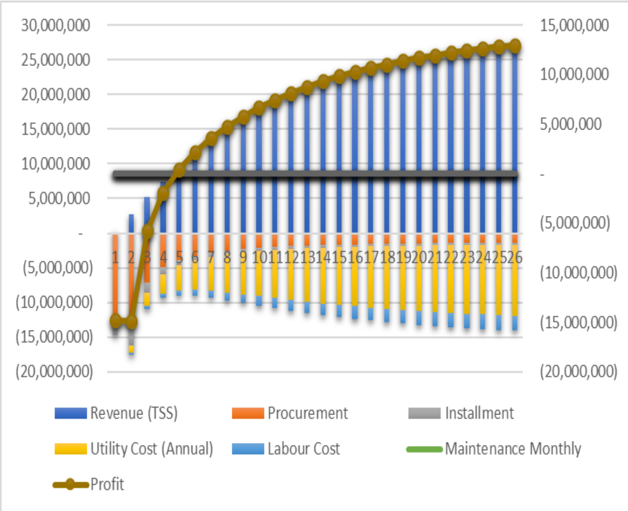

Figure-5. Breakeven analysis for a two-shift operation.

CONCLUSIONS

In our conducted research, a break-even analysis was performed for the Thermal Energy Storage System (TSS) installed at UTP. The uncertainties related to fuel prices & electricity tariff rates by confined authorities are taken into account. The results achieved show that single-shift operation is not feasible however two shifts should be proceeding to make the project feasible. Future work will also be done by considering designated breaks and performing replacement analysis. Another work that can be done is the analysis of three-shift operations (8 hrs. each) as compared to two-shift operations.

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