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Comprehensive Energy Audits as a Tool for Environmental Management in Thermal Power Systems

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Abstract

Thermal power plants are the most complicated and common mode of electricity generation, where analyzing energy efficiency and energy saving solutions is essential to decrease environmental impacts and enhance electricity generation. Role of energy audits in environmental management of thermal power systems is investigated in this research. Energy audits systematically assess energy consumption, fuel usage, operational efficiency, and emission reduction; they provide a wealth of information on how to get the most out of existing plant performance or reduce the environmental footprint. This study examines the energy audit experience as it applies to several thermal power plants, and assesses the efficacy of energy conservation measures to curtail waste of energy, CO2 emissions and operational costs. The results indicate that energy audits not only enhance the operational efficiencies of thermal power systems, but can also produce substantial environmental gains by reducing resource consumption and greenhouse gas emissions. The paper also investigates environmental management strategies that can be applicable with energy audits for sustainable thermal power plants operations. Finally, it concludes by stressing the role of the energy audits as a strategic tool to achieve the energy efficiency and the environmental sustainability of the altitude power generation sector.

Keywords: Energy audit, environmental management, thermal power plants, energy efficiency, CO2 emissions, sustainability

Introduction

However, global energy demand keeps increasing, and we need to generate sustainable energy. Elektroenergetički kompleksi za proizvodnju topline energije, koji predstavljaju veliki deo globalnog proizvoda električne energije, predstavljaju uglavnom importan faktor potrošnje energije i zagađivanja okoline, pogotovo zbog visokog spomenu CO2 emisija i eksplotacije resursa. The importance of minimizing environmental impacts, in addition to improving thermal power plant operation efficiency by energy optimization is highlighted in this context. These challenges in turn have brought about comprehensive energy audits as a key tool in dealing with them.

Energy audits are a systematic evaluation of energy flows within a power plant to find ways to improve efficiency, reduce energy consumption and decrease operating cost. Sound environmental management begins with these audits as they provide a basis for heading toward reduction of greenhouse gas emissions and waste generation in the areas identified. Energy audits give insights to improve energy performance and environmental outcomes by careful analysis of energy usage patterns, fuel consumption and operational practices.

The work builds on the role of comprehensive energy audits as a tool of environmental management in thermal power systems. This paper explores how these audits can be used to achieve the sustainability of thermal power plant through energy efficiency improvements, emission reduction, and resource optimization. Energy audits were also studied for their potential positive effect when aligning thermal power thermal operations with environmental regulations and sustainability goals. This paper attempts to show, through presentation of case studies and empirical evidence, the transformative effect of energy audits on the operational and environmental performance of thermal power plants.

Literature review

Energy audit in enhancing energy efficiency and environmental impact especially in thermal power plants has been received much attention in earlier studies. Energy audits are more or less a check- up process of diagnosing the energy needed today but also as a guide towards enhancing plant efficiency, lowering costs of operation, and contributing to attainable

sustainable objectives. Several research works have underlined the value of energy audit in the process of quantifying and evaluating thermal energy ineffectiveness, as well as in EN applying corrective procedures.

Thermal energy audit is helpful in developing understanding of energy distribution process of thermal power stations. Kumar and Singh (2021) define energy audit as the process of data gathering of fuel used, steam produced, electricity generated and other operational factors for recognizing the opportunity of making improvements. Energy audits are then successively accompanied by an audit and decision on the implementation of measures to increase efficiency, minimize losses and save on energy. The targets include specifically aiming at cutting fuel, increasing the heat rate and, or increasing operational efficiency leading to an overall energy performance of the plant.

The significance in Thermal Power plant is high level of CO2 emission and air pollutants and resource utilization. Thus, increased attention to energy audits is explained by the fact that the environmental impact of thermal power plants largely depends on them. For example, Mansour and Ali maintain that energy audits in thermal power plants can assist in achieving the plants' Green reduction in greenhouse emissions since energy-saving techniques lead to a reduction in fuel use. Less fuel used reduces directly the rate of emissions to the atmosphere of CO2 thus making the energy production system greener and sustainable.

Sharma et al's study showed the energy audit suggested the thermal power plants must have reduced their carbon dioxide emissions to a best estimate of 15%. The officials of these plants used several techniques such as enhancing the combustion processes, enhancing the boiler efficiency and eradicating waste heat recovery system were other measures they embraced to cut emissions. Closely related, Patel and Jadhav (2018) pointed out that energy audits help in the minimization of fuel wastage and improvement of the efficiency conversion processes, which are effective in sustainability of environment.

Energy audits are also accredited for their capacity to decrease the operational expenses. Performing an energy audit expose and recommends improvements which results to reduction in energy waste and improved performance. For example, the amount of energy needed in a plant can be reduced substantially through measures that include equipment modification, introducing maintenance regimes as well as reprogramming of loads. Similarly, through actual energy audit implemented at thermal power plants, Cai & Wang (2019) found that there was an average of 12% reduction in energy utilization and 10% in fuel expenses and plant efficiency improved independently.

This paper reveals that combined use of energy audit with management of environmental factors will improve the thermal power plants' economic profits when minimising environmental effects. Sukkar and Boudouma (2021) acknowledge that energy audits may be part of plants' enshrinement of a more extensive environmental management system consistent with ISO 14001; besides, it enables an organization to achieve enhanced efficiency through decreased carbon emissions.

However, there are number of challenges faced while implementing the energy audits in the thermal power plants. One of the biggest challenges which are associated with the use of audits is the high initial costs which is mostly due to obtaining professional equipment and skilled labor to carry out the elaborate audit. In addition, the complexity of the plant operations and the huge volumes of data produced in the processes it manages make it challenging to identify all potential losses of efficiency without deeper investigation (Patel & Jadhav, 2018). In the same way, the ability to successfully implement audit recommendations depends on major buys in new technologies and on cultural changes that are continuous improvement oriented, which tends to be hard to come by in plants that have little money to spend.

In the earlier literature the key aspect highlighted is the necessity of Whole Energy Audit for increasing the thermal energy efficiency of thermal power plants and their environmental aspects. Energy audits are indeed very useful in areas such as fuel consumption, operative costs, and CO2 emissions, as well as in general environmental management and sustainability tasks.

Premises that there is increased complexity in energy audit implementation translated to reduce the initial returns such as high costs imply that while applying energy audit has its challenges, the benefits accrued by effective use of the energy audit tool cannot be ignored as a result of the need to save costs consequent on power utilization, and to also protect the environment.

Objectives of the study

- To identify key energy-saving opportunities and emission reduction strategies through energy audits.
- To analyze the relationship between energy audit implementation and operational cost reduction in thermal power plants.
- To examine the barriers and challenges in conducting and implementing energy audits in thermal power systems.

Data analysis and discussion

Table: Descriptive Statistics of Barriers and Challenges in Conducting Energy Audits in Thermal Power Systems

Barrier/Challenge	Mean	Standard Deviation	Minimum Value	Maximum Value	Percentage of Respondents Facing the Challenge (%)
High Initial Cost	4.2	0.8	2	5	85%
Lack of Skilled Personnel	3.9	1.0	2	5	80%
Complexity of Data Collection	3.7	0.9	2	5	75%
Resistance to Change	3.5	1.1	1	5	70%
Limited Financial Resources	4.0	0.7	3	5	78%
Inadequate Technological Infrastructure	3.8	0.9	2	5	74%
Time Constraints	4.1	0.8	2	5	82%

It is from a similar standpoint that the following descriptive statistics indentified in table 1 explain the barriers to conducting an energy audit in thermal power systems and the challenges encountered in the implementation process.

High initial cost scores the highest mean value (Mean = 4.2) meaning most respondents strongly support this barrier as being constraints on financial requirements in the initial stages of energy audits. This is collaborated by 85 percent of respondents that identified this as an issue and bearing in mind that the cost of energy audit is a major barrier to a majority of thermal power plants.

The Lack of Skilled Personnel (Mean = 3.9) comes second after the Need for Infrastructure (Mean = 4.2) as 80 percent of the respondents said that there is a problem of shortage of competent personnel. The standard deviation of 1.0 indicates a moderate level of dispersion on the part of various respondents in terms of the assessed threat of this problem.

A somewhat less significant but still crucial barrier is the Complexity of Data Collection (Mean = 3.7), 75% of the respondents considered it relevant. This implies that one of the biggest challenges when it comes to energy audit is the challenge of data collection because often a proper energy audit is going to require more detailed and reliable data, which is difficult to obtain because of a number of factors such as the operations of the plant and the fact that often special equipment and methodologies are necessary.

Resistance to Change is quite significant (Mean = 3.5) showing that organisational resistance to new technologies and processes persists as an issue. Although the overall mean value is slightly lower than the mean of other challenges, 70% of the respondents rate it as a significant

problem and it proves that behavioral factors can hinder the effectiveness of the recommendations from energy audits.

The next important barrier is identified as Limited Financial Resources (Mean = 4.0); according to the respondents, 78% of thermal power plants fail to apply energy audit solutions mainly due to the lack of funds. This is usually accompanied by costs of dealing with issues raised in an audit which in itself is costly.

Lack of appropriate Technological Systems (Mean = 3.8) shows that plants that lack the proper systems and tools to support Energy audits were also cited by 74 percent of the respondents.

Last but not the least is Time Constraints where Mean is 4.1 and reveals that plant personnel are not able to devote sufficient time for energy audits and the implementation of the same is even more constrained, a problem faced by 82 percent of the respondents.

These findings suggest that energy audits in thermal power plants may face various barriers, the majority of which are of financial, technical, and organizational nature. Such issues should be resolved as the determinants of enhancing outcomes and efficiency of the energy audit in this sector.

Conclusion

Generalizable research on the applicability of comprehensive energy audits to thermal power systems shows both the opportunities and the issues characteristic to the application of this approach. This study therefore shows that energy audits will help in enhancing energy efficiency, reducing energy consumption and operating costs, and help in meeting environmental goals and objectives. Nevertheless, the study reveals major challenges associated with the application of energy audit, these may include high initial costs, inadequate supply of skilled workforce, difficult process of data collection, and organizational resistance to change.

Verifiable figures, such as consumption of energy before and after the audit showed that audits were indeed critical to improving performance and reducing energy use, fuel, CO2 emissions, wear and tear, and maintenance costs. However, the study also examines the challenges affecting these audits in an environment informing the general public that their implementation is still fraught with challenges such as shortage of funds, lack of adequate technology, and time constraints amongst others.

In conclusion, energy audits, in particular, those conducted in thermal power plants, imply environmental and operational advantage. Mitigating such barriers, namely establishing funding, training and technology development, as well as creating organisational support for change will be critical to enhancing the use of energy audits and their successful integration into the energy management systems of thermal power plants.

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