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A Case Study on the Implementation of Maintenance Strategies at an Energy Generation Facility

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ABSTRACT

This paper examines a case study involving the implementation of preventative maintenance strategies gleaned from a coal power plant's turbo generator. Turbo generators are an essential and fundamental part of the power generation process. Applying the right maintenance strategies and following the right operational procedures are crucial. This is done so that the machinery can be reliable. The research was conducted at a coal-fired power plant with an eye toward the eventual switch to cleaner forms of energy production. This research is essential because it will help inform plans and operational models when renewable energy sources like solar and wind power replace coal-powered turbines. Firstly, this paper describes various approaches to turbo generator module maintenance. Secondly, recommendations for future actions are presented after discussing the effects of human factors on a coal power station.

Keywords: Human factor, Maintenance strategies, Turbo generator, Operational error

INTRODUCTION

Human factors are significant components considered and cannot be isolated when implementing maintenance strategies in power-generating stations. In this research, the maintenance strategies adopted in a coal power generating station were considered. Coal-fired power plants have witnessed continuous improvement (Laseinde and Ramere, 2019) over the years with a significant effort to optimize their energy generation capacity and thermal efficiency. This is because increasing their efficiency can yield a drop in the total cost of electricity production while also mitigating the environmental impact of coal combustion (Wróblewski et al., 2013). Coal is the primary source of energy in South Africa and is abundant and less expensive than nuclear and fuel. This makes South Africa's energy costs one of the lowest among nations globally. While coal accounts for around 59% of the country's total primary energy supply (Ratshomo and Nembahe, 2018), other sources like crude oil, natural gas, wind, solar, and hydropower are also used. However, overreliance on coal has raised environmental concerns such as air pollution and greenhouse gas emissions, emphasizing the need to diversify the energy mix and invest in cleaner energy technologies for a sustainable energy future in South Africa.

Observations from the coal-power stations visited during the research showed that well-maintained systems generate lower carbon emissions than poorly maintained systems with incomplete pulverized coal combustion. Effective maintenance strategies guarantee good working conditions. Any system that produces electricity should have as its primary goals the provision of the necessary amount of energy to satisfy consumer demand and the accomplishment of regulatory compliance. For power stations to accomplish this performance level, it is essential to ensure that it is both available and reliable. If either of these were to become compromised, it would have a negative impact on the availability, and beyond availability, it will also affect the reliability of the electric generation system.

Additionally, availability is seen when equipment is not experiencing any failure mode where it can no longer perform its operations. Reliability is defined as the probability that equipment will operate in a prescribed manner, for a specified amount of time, and a prescribed set of operating conditions without suffering any event pre-defined as a failure. The possibility that some system element or the system as a whole will perform below the functions that they have been designed to fulfill is termed "failure" (Al, 2016). This concept is readily applicable to components of a thermal power station or when referring to the thermal power station in its entirety. The nature of the actual or potential failure, as well as the consequences of the failure on both the equipment and the entire system, will determine the kinds of maintenance activities that will need to be performed (Laseinde and Ramere, 2019).

Monitoring the condition over a predetermined amount of time, also known as continuous monitoring, is a process that involves conducting consistent inspections or supervisions of the operation of the equipment (Kuzle et al., 2010). It ensures the device functions appropriately and identifies any abnormalities that may signal an impending breakdown.

OVERVIEW OF MAINTENANCE STRATEGIES

Maintenance strategies in power stations refer to the various approaches used to ensure the optimal functioning and longevity of equipment and systems in power generation plants. In this case study, six alternate maintenance strategies are evaluated. Each maintenance strategy has its benefits and drawbacks. The choice of strategy largely depends on factors such as the type of equipment, cost considerations, and the criticality of the equipment to the power generation process. A combination of these strategies is often used to ensure efficient and effective maintenance of power station equipment. The strategies explored in the energy-generating facility include corrective, preventative, Predictive, opportunistic, condition-based, and Total Productive Maintenance (TPM).

Corrective Maintenance

The key aspect of corrective maintenance is that interventions are only carried out after the equipment has failed. There is no interference until there has been a breakdown. In corrective maintenance the equipment is ran to failure. The aims only to correct faults and return the equipment to its full operation

(Melani et al., 2019), It is also referred to as run-to-failure or no scheduled maintenance (Kombe, 2009). The "Run-to-failure" technique is acceptable in situations where it is necessary if, firstly, maintenance personnel are unable to prevent failure through predictive maintenance. Secondly, failure has minimal implications on safety and production costs; the expense of replacing the failed component is cost-effective. Thirdly, failure is difficult to be eliminated by simply replacement. Lastly, predictive maintenance cannot anticipate failure, such as when failure happens too soon to be controlled by a monitoring system.

In the energy generation industries, corrective or breakdown maintenance are classified as an unplanned capacity load factor (UCLF). It determines the amount of energy wasted due to incidental energy losses caused by malfunctioning equipment and unstable conditions in plants. Kombe (2009) further shares the view that the advantages of corrective maintenance are that the maintenance strategy requires fewer maintenance personnel and less initial investment. When working with new equipment, failures should be rare until the equipment breaks or stops working (Ramere and Laseinde, 2021). Since there are no maintenance costs during this time, it could be seen as a way to save money. But this method increases future capital costs because while waiting for the equipment to break down, the equipment's life is cut short. This results in more frequent equipment replacement and higher capital equipment costs. Also, there may be extra costs if the failure of the primary equipment causes failures in the secondary equipment connected to it. The overall repair costs of the correction strategy can potentially exceed those suffered in the event of a more proactive solution. Unexpected repairs could drive up the cost of maintenance because fixing broken machinery often necessitates more work than would have been necessary if it had been closely monitored and not pushed until it reached a point of sudden failure.

Preventive Maintenance

The term "preventive maintenance" refers to activities planned ahead of time and performed to lower the likelihood of operating equipment breaking down (Kombe, 2009). It is based on the reliability of components. This data makes it possible to analyse the component's behaviour and enables the maintenance personnel to define a routine maintenance program for the machine. A preventive maintenance strategy is designed to define a sequence of inspections, repairs, or component replacements with a frequency associated with the failure rate. Preventive maintenance requires a scheduled scope of work, time forecasts, equipment forecasts, and other components. It is important because preventative maintenance practices are not focused on a single defined failure mode but on the assumption that routine maintenance can mitigate or prevent the occurrence of failure.

The preventive maintenance approach aims to define a sequence of reviews, repairs, or equipment modifications with a frequency relevant to the failure rate. This means that preventive maintenance is successful in resolving component wear problems. Clearly, after a check, component replacement is not always necessary, as maintenance is often sufficient. The advancement of preventive maintenance technology is important in terms of economy as well as reliability (Shimomura et al., 2002). Preventive maintenance practices mostly focus on previous malfunction information, system specifications, and the original equipment manufacturer's (OEM) initial product guidelines. Intervals may be based on OEM recommendations, sometimes supplemented by experience with some level of safety factor (Smalley & Mauney, 1997). Preventing previous failure modes from recurrence depends on various preventive maintenance procedures. If catastrophic failures are not prevented, the number of losses tends to increase. Preventive maintenance is advantageous by active routine participation in equipment and by a reactive mode, where maintenance can only fix interruptions quickly following a failure. A concern is that inadequate or unwanted maintenance has a potential for accidental harm to parts due to the reassembling fault inherent in the reassembling equipment,

Opportunistic Maintenance

Opportunistic maintenance is a maintenance approach in which maintenance procedures are performed on equipment or plants whenever possible rather than waiting for a planned maintenance period. This strategy is based on the premise that addressing maintenance issues as they arise is more efficient and cost-effective rather than waiting until they become critical and necessitate extensive labor or downtime. The maintenance means that the entire power plant must be shut down to facilitate the required maintenance concurrently.

Opportunistic maintenance often includes routine equipment and machinery inspections to detect any issues, such as worn or damaged components, leaks, or other symptoms of wear and tear. When these issues are discovered, maintenance professionals can immediately repair or replace the broken pieces. This kind of maintenance can assist in preventing equipment breakdowns and downtime. It can also improve the equipment's reliability and overall performance (Laseinde and Ramere, 2019). Businesses may save money on repair and replacement expenses and avoid costly production losses caused by equipment failure by taking care of maintenance issues as soon as they arise (Juneja & Wadhwa, 2016). The competitive advantage of the control or replacement time intervals for the different components of the same machine or plant must define the potential of adopting opportunistic maintenance.

Condition-Based Maintenance

Condition-based maintenance (CBM) approach involves continuously or regularly monitoring the state of equipment or machinery and utilizing that information to determine when maintenance operations should be conducted.

CBM is frequently employed in complicated, essential systems like power plants and machinery manufacturing. CBM collects data on equipment status using sensors and other monitoring devices, such as vibration, temperature, pressure, humidity, air quality, and other signs of wear and tear. This data is then evaluated using modern algorithms and Artificial Intelligence (AI) to spot trends or abnormalities that might suggest a problem. The availability of a set of measurements and data-collecting devices to monitor the machine's performance in real-time is required for condition-based maintenance. Continuous monitoring of working circumstances can simply and clearly identify an abnormal scenario (for example, surpassing a specified parameter threshold level). As a result, the operator can perform the essential controls on time and, if necessary, stop the machine before it fails.

Predictive Maintenance

Predictive maintenance involves comparing physical parameter trends with known engineering limits to detect, analyse, and correct problems before failure. It involves monitoring rotational machinery to detect growing problems and avert catastrophic failures in electrical components such as motors and other devices to identify emerging faults. Frequent monitoring of the ideal mechanical status, operational efficiencies, and many other metrics of the process conditions of machine trains and process systems will yield the statistics needed to guarantee the maximum duration between repair and replacement. Furthermore, it will also reduce the frequency and cost of unscheduled shutdowns caused by the equipment breakdown. Compared to the condition-based maintenance approach, controlled parameter data are analysed in predictive maintenance to determine a potential time trend. It makes it easy to predict whether the output should meet or surpass the control parameters. Maintenance employees will subsequently be capable of determining when, according to performance conditions, component replacement or revision is truly necessary.

In a predictive maintenance approach, determining the appropriate number of maintenance staff needed in an industry requires a comprehensive understanding of the production demands, equipment requirements, staff experience and training, and available budget, among other factors. This process can be challenging and complex, requiring careful analysis and ongoing monitoring and adjustment to ensure optimal staffing levels. Finding the optimal quantity of maintenance workers is difficult, particularly for managing large, multifaceted, complex machinery like thermal energy facilities (Melani et al., 2019).

Total Productive Maintenance

Total Productive Maintenance (TPM) is described as maintenance activities carried out or implemented by all employees. TPM is an approach to equipment and machinery maintenance that stresses the participation of all personnel. TPM aims to enhance equipment efficiency and prevent losses caused by breakdowns, faults, or other difficulties due to isolated activities working in silos. TPM is a comprehensive approach that includes all levels of the organization, from technicians to management, and all departments, such as maintenance, operations, inventory, accounting and finance, and production management (Wireman, 2004). TPM's five primary goals are to increase equipment reliability (performance), optimize maintenance efficacy, avoid maintenance challenges, offer training to improve the skills of all concerned personnel, and involve technicians in regular maintenance operations (Laseinde and Ramere, 2019).

HUMAN FACTORS: OPTIMIZING MAINTENANCE STRATEGIES

Many human factors influence maintenance strategies in industries. Of these, three categories of dynamic facets have been found as effective in power generation stations.

Training to Improve the Skills of All People Involved

Training is an essential aspect of Total Productive Maintenance (TPM) because it ensures that all workers involved in equipment maintenance have the requisite knowledge and abilities to perform their duties successfully and efficiently. By investing in training, businesses may increase the efficiency of their equipment, decrease their maintenance costs, and foster a culture of continual development. Such training requirements include technical training, emergency preparation training, equipment safety training, and others based on departmental requirements. Workers must possess the appropriate skills and expertise to contribute to a TPM setting. This obligation applies to the maintenance and production divisions, inventory, accounts, and operating divisions. Equipment efficacy will not be compromised by demonstrating the correct degree of training.

Participation of Operators in Preventive Maintenance

The importance of this aspect of maintenance is the need to include the operators of the equipment so that they may assume ownership of the plant and be responsible for the first-line maintenance execution. The purpose of the engagement of operations is not to reduce the size of the maintenance organization; rather, it is to merge the resources of operations and maintenance in order effectively integrate the technical elements of TPM in the organization.

Improving Equipment Effectiveness, Maintenance Efficiency, and Early Detection of Equipment Faults

The purpose of equipment effectiveness guarantees that the equipment functions in accordance with design requirements. The machinery must function at its intended speed, generate output at its intended rate, and deliver high-quality results at these speeds and rates. Similarly, increasing maintenance effectiveness strives to guarantee that equipment maintenance is carried out and done affordably. This objective's major aim is to reduce maintenance costs. Also, it is to ensure that maintenance tasks are completed in a way that has little bearing on the equipment's availability or uptime. Lastly, early defect detection and equipment maintenance are intended to minimize the amount of maintenance that the equipment needs. The design engineers meticulously examine engineering and maintenance data, enabling modifications to the car to lower maintenance.

THE IMPACT OF HUMAN FACTORS IN A COAL POWER STATION

Coal-fired power stations are increasingly operating in cycling modes; many are confronted by the potential of higher levels of component damage, reduced equipment reliabilities, and increased maintenance costs. A review of previous studies revealed process utilization, fatigue, knowledge, expertise, and time constraint are the main factors contributing to production risk. (Sheikhalishahi et al. 2017). Human and organizational performance instability may contribute to loss of productivity, inadequate maintenance, and major disasters. According to Sheikhalishahi et al. (2017), three classes of elements influence maintenance activities. The elements are personnel, environmental factors, and other provisional factors. Human error can occur in any organization during the maintenance or operational process. Safety precautions should be put in place to investigate the possible human error and eliminate it from arising or have a plan in place for recovery functionality. Human factors have an influence on operating processes, maintenance plans, and safety measures in power plants (Orme et al. 2011). To enable the organization to develop an elimination strategy of unwanted disruptors, a methodology is needed to identify potential human errors and other risk factors.

CONCLUSION

This paper proposes an approach to applying adequate maintenance strategies on a turbo generator at a coal power plant and analyzing human factors in maintenance and operational tasks. Preventative and recovery risk measures must be established to choose the best way to lower human errors. In addition to this recommendation, research may be conducted to offer more accurate models to calculate the failure probability of equipment and the humans managing them.

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