AN ANALYSIS OF THE QUALITY OF THERMAL POWER PLANT OPERATION AND MAINTENANCE STANDARD

AMGBARI CHARLES
Department of Mechanical Engineering Technology,
Federal Polytechnic, Ekowe,
Bayelsa State, Nigeria.

OWUTUAMOR FREDERICK TOUN
Department of Electrical Engineering,
Federal Polytechnic, Ekowe,
Bayelsa State, Nigeria.

ABSTRACT

Maintenance is a preservative technique needed to expand the life span of an equipment. The study viewed analysis of the quality of thermal power plant operation and maintenance standard. The study considered the coal powered thermal power plant. Consideration is made in the maintenance specification of features of thermal plant, planning of O & M system in thermal plant and scope of maintenance of thermal plant. The research work used survey method to gather relevant information from maintenance engineer in the coal thermal plants locations. A total of three different thermal plants were used as a case study to analyze the maintenance procedure adopted. The instrument administered to the experts or maintenance engineers was titled "Maintenance of Thermal Power Questionnaire (MTPQ)". The instrument was administered to 24 maintenance engineers. The data obtained from the questionnaire items was analyzed using simple mean. The result obtained from table 1 revealed that items 1, 2, 3, 4 and 5 were all accepted to the various questions. The result obtained from table 2 revealed that items 1, 2, 3, 4 and 5 were all accepted to the various questions. Coal thermal powered plant is an electrical generated equipment that requires maximum maintenance for it to function optimally. The required specification and expert opinion is needed for it to last for a long time because of cost. Major requirement needed during maintenance service includes features needed for maintenance of thermal plant facility, planning of operation & management in maintenance of thermal plant facility. Finally, it was recommended amongst others that coal thermal power plant system should adopt appropriate maintenance technique before going into servicing such huge plants.

Keywords: ***Thermal Power Plant and Maintenance Standard***

INTRODUCTION

Maintenance is a major activity of the production span since it details for as much as 60 to 70% of its total costs of production of an equipment (Dhilon, 2006). More specifically, industrial research has shown that the cost of fixing worn-out components may be as high as 70% of the total maintenance cost (Venkataraman, 2010). Although the cost of maintenance is extremely high, the existing industrial maintenance solutions are used in isolation without considering the real condition of the power plant and equipment (Efthymiou, et. al, 2012). Failures of the machine tools, easily lead to supplying bottlenecks in the subsequent value-added processes of the company and its customers, due to the interlinked production systems provided.

Real-time inspection of machine based plant and equipment together with conceptualization and data analysis, under the umbrella of collaboration between the two systems, can lead to condition-based maintenance techniques. In addition, condition-based maintenance uses condition evaluation to schedule appropriately maintenance schedule without hindering normal power plant operations (Gao, et. al, 2015). Condition–based preventive maintenance (CBPM) represents the preventive maintenance approach supported by sensor measurements. The collaboration between various information technology tools can be enabled and facilitated through the mobile technology and communication. Thus, manufacturing systems are more and more perceived as social structures, built up of employees that act as social machines that process data and information and distribute it among the different IT tools. Equipment like coal thermal power plant has some level of energy conversion which is used to generate electricity.

The energy conversion in a coal-fired power plant uses and adopts a thermodynamic process. The improvement of energy efficiency in a thermodynamic process generally depends on energy analysis of the process which identifies measures required to be addressed. The conventional method of energy analysis is based on first law of thermodynamics which focuses on conservation of energy. The limitation with this analysis is that it does not take into account properties of the system environment, or degradation of the energy quality through dissipative processes. In other words, it does not characterize the irreversibility of the system. Moreover, the first law analysis often casts misleading impressions about the performance of an energy conversion device [4-6]. Achieving higher efficiency, therefore, warrants a higher order analysis based on the second law of thermodynamics as this enables us to identify the major sources of loss, and shows avenues for performance improvement [7]. Exergy analysis characterizes the work potential of a system with reference to the environment which can be defined as the maximum theoretical work that can be obtained from a system when its state is brought to the reference or ‘‘dead state” (standard atmospheric conditions). The main purpose of exergy analysis is to identify where exergy is destroyed. This destruction of exergy in a process is proportional to the entropy generation in it, which accounts for the inefficiencies due to irreversibility.

This research conducts exergy analysis in one unit of a coal-fired power plant in Central Queensland, Australia as a case study. The exergy analysis identifies where and how much exergy is destroyed in the system and its components. Based on the analysis, it assesses and discusses different options to improve the efficiency of the system.

Process description of a coal-fired power plant

A coal-fired power plant burns coal and uses it as source of fuel to produce electricity. In a typical coal-fired plant, there are pulverizes to mill the coal to a fine powder for burning in a combustion chamber of the boiler. The heat produced from the burning of the coal generates steam at high temperature and pressure. The high-pressure steam from the boiler impinges on a number of sets of blades in the turbine. This produces mechanical shaft rotation resulting in electricity generation in the alternator based on Faraday’s principle of electromagnetic induction. The exhaust steam from the turbine is then condensed and pumped back into the boiler to repeat the cycle. This description is very basic, and in practice, the cycle is much more complex and incorporates many refinements.

A typical coal plant schematic is presented in Figure 1. It shows that the turbine of the power plant has three stages: high-pressure, intermediate-pressure and low-pressure stages. The exhaust steam from the high-pressure turbine is reheated in the boiler and fed to the intermediate-pressure turbine. This increases the temperature of the steam fed to the intermediate pressure turbine and increases the power output of the subsequent stages of the turbine. Steam from different stages of the turbine is extracted and used for boiler feed water heating. This is regenerative feed water heating, typically known as regeneration. The improvement of the thermal performance of the power generation cycle with reheat and regeneration is a trade.

Thermal Power Plants - Advanced Applications off between work output and heat addition [8] and it can be evaluated through the efficiency of the power generation cycle. In a typical pulverized coal power plant, there are three main functional blocks. They are (1) the boiler; (2) the turbo-generator and (3) the flue gas clean up. The boiler burns coal to generate steam. The combustion chamber of the boiler is connected with the coal pulverizes and air supply. The water pre-heater (also known as the economizer), the super heater and the reheated are all included in this block. The steam produced in the boiler is used in the turbine as shown in Figure 1. The generator is coupled with the turbine where mechanical shaft rotation of the turbine is converted into electrical power and supplied to the power distribution grid through a transformer. The purpose of the transformer is to step up the voltage of the generated power to a level suitable for long distance transmission. The steam leaving the turbine is condensed in the condenser as shown in the Figure 1 using cooling water which discharges low temperature heat to the environment. The condensate produced is pumped back to the boiler after heating through the feed water heaters. The feed water heaters use regenerative steam extracted from the turbine.

The burning of coal in the boiler of a power plant produces flue gas. The main constituents the of flue gas are nitrogen (N2), carbon dioxide (CO2) and water (H2O). It carries particulate matter (PM) and other pollutants. There are traces of some oxides such as oxides of sulphur (SOx) and oxides of nitrogen (NOx) depending on the combustion technology and fuel used. The flue gas clean-up block comprises all the equipment needed for treating the flue gas. The power plant shown in Figure 1 includes a DeNOx plant for NOx removal, followed by electrostatic precipitation (ESP) to remove particulate matter (PM), and wet flue gas desulfurisation (FGD) to remove SOx from the flue gas. An air-preheating unit is situated between the DeNOx and the electrostatic precipitator (ESP). There is a significant amount of heat energy leaving through the flue gas, some of which is recovered by using the air preheater. This improves the thermal performance of the process.

The properties of the coal used in the boiler and the environmental legislation and/or environmental management policy of a plant are two major factors that determine the nature of the flue gas treatment process. In some countries, due to stringent environmental regulation, coal-fired power plants need to install denitrification plants (DeNOx) for nitrogen oxide (NOx) and flue gas desulphurisation plants (FGD) for sulphuroxide (SOx) removal [9, 10]. In Australia, the coal used has a very low sulphur content and therefore, the concentration of SOx from the burning of coal in Australia is relatively low. Dave et al. [11] report an absence of stringent regulatory requirements for limiting NOx or SOx in flue gas streams in Australia.

Therefore, Australian coal plants in the past have not been required to have deNOx or deSOx equipment to clean up flue gas. In this research, a pulverized coal-fired power plant in Central Queensland, Australia has been considered as a case study. One of the units of the said plant was used to develop a process model and to perform energy analysis. This unit has Maximum Continuous Rating (MCR) of 280 MW. It spends less than 5% of its operating time at loads greater than 260 MW. Operation of the unit is mostly in the range of 100 to 180 MW range.

ENGINEERING MAINTENANCE

As a result to many factors, it was established in the previous century that "maintenance" must be an integral part of the production strategy for the overall success of an organization. For the effectiveness of the maintenance activity, the 21st century must build on this. It is expected that equipment of this century will be more computerized and reliable, in addition to being vastly more complex. Further computerization of equipment will significantly increase the importance of software maintenance, approaching, if not equal to, hardware maintenance. This century will also see more emphasis on maintenance with respect to such areas as the human factor, quality, safety, and cost effectiveness.

New thinking and new strategies will be required to realize potential benefits and turn them into profitability. All in all, profitable operations will be the ones that have employed modern thinking to evolve an equipment management strategy that takes effective advantage of new information, technology, and methods.

MAINTENANCE TERMS AND DEFINITIONS

This section presents some terms and definitions directly or indirectly used in engineering maintenance:

•*Maintenance:* All actions appropriate for retaining an item/part/equipment in, or restoring it to, a given condition.

•*Maintenance engineering:* The activity of equipment/item maintenance that develops concepts, criteria, and technical requirements in conventional and acquisition phases to be used and maintained in a current status during the operating phase to assure effective maintenance support of equipment.

Preventive maintenance: All actions carried out on a planned, periodic, and specific schedule to keep an item/equipment in stated working condition through the process of checking and reconditioning. These actions are precautionary steps undertaken to forestall or lower the probability of failures or an unacceptable level of degradation in later service, rather than correcting them after they occur.

•*Corrective maintenance:* The unscheduled maintenance or repair to return items/equipment to a defined state and carried out because maintenance persons or users perceived deficiencies or failures.

•*Predictive maintenance:* The use of modern measurement and signal processing methods to accurately diagnose item/equipment condition during operation.

•*Maintenance concept:* A statement of the overall concept of the item/product specification or policy that controls the type of maintenance action to be employed for the item under consideration.

•*Maintenance plan:* A document that outlines the management and technical procedure to be employed to maintain an item; usually describes facilities, tools, schedules, and resources.

•*Reliability:* The probability that an item will perform its stated function satisfactorily for the desired period when used per the specified conditions.

•*Maintainability:* The probability that a failed item will be restored to adequately working condition.

•*Active repair time:* The component of downtime when repair persons are active to effect a repair.

•*Mean time to repair (MTTR):* A figure of merit depending on item maintainability equal to the mean item repair time. In the case of exponentially distributed times to repair, MTTR is the reciprocal of the repair rate.

•*Overhaul:* A comprehensive inspection and restoration of an item or a piece of equipment to an acceptable level at a durability time or usage limit.

•*Quality:* The degree to which an item, function, or process satisfies requirements of customer and user.

•*Maintenance person:* An individual who conducts preventive maintenance and responds to a user’s service call to a repair facility, and performs corrective maintenance on an item. Also called custom engineer, service person, technician, field engineer, mechanic, repair person, etc.

•*Inspection:* The qualitative observation of an item's performance or condition.

Purpose of the study

The study looked at analysis of the quality of thermal power plant operation and maintenance standard. Specifically, the sought to:

1. Find out the features needed for maintenance of thermal plant facility.
2. Find out the Planning of Operation & Management in maintenance of thermal plant facility.
3. Find out scope of Operation & Management in maintenance of thermal plant facility.

Scope of the Study

The research work understudies an analysis of the quality of thermal power plant operation and maintenance standard. The study considered the coal powered thermal power plant. Consideration is made in the maintenance specification of features of thermal plant, planning of O & M system in thermal plant and scope of maintenance of thermal plant.

Method

The research work used survey method to gather relevant information from maintenance engineer in the coal thermal plants locations. A total of three different thermal plants were used as a case study to analyze the maintenance procedure adopted. The instrument administered to the experts or maintenance engineers was titled "Maintenance of Thermal Power Questionnaire (MTPQ)". The instrument was administered to 24 maintenance engineers. The data obtained from the questionnaire items was analyzed using simple mean.

Data Analysis

Table 1: Features Needed for Maintenance of Thermal Plant Facility

S/NO	ITEMS	MEAN	REMARK
1)	Viewpoints from the utility, as an operator of the plant	3.45	Appropriat
2)	A long history of engine operation of coal thermal plant	4.20	Appropriate
3)	Record of experiences of procurement from parts in plant	3.90	Appropriate
4)	Time of thermal power plant operation	4.21	Appropriate
5)	Manufacturers details of the use of components parts of plant	3.20	Appropriate

The result obtained from table 1 revealed that items 1, 2, 3, 4 and 5 were all accepted to the various questions. This shows that viewpoints of operator, history of engine operation, experience from procurement, time of plant of power plant operation and maintenance details of components parts in plant are appropriate features that are needed for coal thermal plant maintenance.

Table 2: Planning of Operation & Management in maintenance of thermal plant facility.

S/NO	ITEMS	MEAN	REMARK
1)	Preparation of planning Management Manual / System Operation	3.75	Appropria
2)	Preparation of planning Management Manual / System Maintenance	4.00	Appropriate
3)	Preparation of planning Management Manual / System Quality Control	3.45	Appropriate
4)	Preparation of planning Management Manual / System Security and Safety	4.15	Appropriate
5)	Preparation of planning Management Manual / System Environment	3.25	Appropriate

The result obtained from table 2 revealed that items 1, 2, 3, 4 and 5 were all accepted to the various questions. This shows that the preparation of planning management manual / system operation, environment, security and safety are appropriate for the maintenance of coal thermal power plant.

Table 3: Scope requirement of maintenance of thermal plant facility.

S/NO	ITEMS	MEAN	REMARK
1)	Scope of Works	3.44	Appropriate
2)	Scope of Guarantee items	3.10	Appropriate
3)	Scope of Evaluation of Contractors	3.22	Appropriate
4)	Scope of Review of O&M Proposal	3.12	Appropriate
5)	Scope of Overall Schedule	4.15	Appropriate
6)	Scope of Suppliers	3.55	Appropriate

The result obtained from table 3 revealed that items 1, 2, 3, 4, 5 and 6 were all accepted to the various questions. This reveals that Scope of works, guarantee items, evaluation of contractors, overall schedule, suppliers and review of O & M are appropriate for the maintenance of coal thermal power plant.

Summary of Findings

The findings of the study can be summarized as follows:

1. The result obtained from table 1 revealed that items 1, 2, 3, 4 and 5 were all accepted to the various questions. This shows that viewpoints of operator, history of engine operation, experience from procurement, time of plant of power plant operation and maintenance details of components parts in plant are appropriate features that are needed for coal thermal plant maintenance.
2. The result obtained from table 2 revealed that items 1, 2, 3, 4 and 5 were all accepted to the various questions. This shows that the preparation of planning management manual / system operation, environment, security and safety are appropriate for the maintenance of coal thermal power plant.

3. The result obtained from table 3 revealed that items 1, 2, 3, 4, 5 and 6 were all accepted to the various questions. This reveals that Scope of works, guarantee items, evaluation of contractors, overall schedule, suppliers and review of O & M are appropriate for the maintenance of coal thermal power plant.

Conclusion

Coal thermal powered plant is an electrical generated equipment that requires maximum maintenance for to function optimally. The required specification and expert opinion is needed for it to last for a long time because of cost. Major requirement needed during maintenance service includes features needed for maintenance of thermal plant facility, planning of operation & management in maintenance of thermal plant facility.

Recommendations

The following recommendations were made:

1. Coal thermal power plant system should adopt appropriate maintenance technique before going into servicing such huge plants.
2. Proper procurement details are needed to ensure replacement of special components.

References

AMCP 706-134, *Engineering Design Handbook: Maintainability Guide for Design,* Department of Defense, Washington, D.C., 1972.

Ankenbrandt, F.L., et al., *Maintainability Design,* Engineering Publishers, Elizabeth, New Jersey, 1963.

Altman, J.W., et al., Guide to Design of Mechanical Equipment for Maintainability, Report No. ASD-TR-61-381, U.S. Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, 1961.

Blanchard, B.S., Verma, D., and Peterson, E.L., *Maintainability,* John Wiley & Sons, New York, 1995.

Dhilon BS. (2006). Maintainability, Maintenance, and Reliability for Engineers. Taylor and Francis,

Efthymiou K, Papakostas N, Mourtzis D, Chryssolouris G. On a Predictive Maintenance Platform for Production Systems. Procedia CMS 2012;250-257.

Denkena B, Bluemel P, Kroening S, Roebbing J.(2012) Condition based maintenance Planning of Highly productive machine tools. Production Engineering Research and Development 2012;6:277–285.

Dorf, R.C., ed., *Technology Management Handbook,* CRC Press, Boca Raton, Florida, 1999.

Gao R, Wang L, Teti R, Dornfeld D, Kumara S, Mori M, Helu M. (2015).Cloud enabled Prognosis for Manufacturing. CIRP Annals – Manufacturing Technology 2015;64/2:749-772.

Grant-Ireson, W. and Coombs, C.F., eds., *Handbook of Reliability Engineering and Management,* McGraw-Hill, New York, 1988.

MIL-STD-721 C, *Definitions of Terms for Reliability and Maintainability,* Department of Defense, Washington, D.C.

Naresky, J.J., Reliability definitions, *IEEE Transac. on Reliability,* 19, 1970, 198–200.

Niebel, B.W., *Engineering Maintenance Management,* Marcel Dekker, New York, 1994.

Niebel, B.W., *Engineering Maintenance Management,* Marcel Dekker, New York, 1994.

Omdahl, T.P., ed., *Reliability, Availability and Maintainability (RAM) Dictionary,* ASQC Quality Press, Milwaukee, Wisconsin, 1988.

Venkataraman V (2010). Maintenance engineering and management. PHI Learning Private Limited

Von Alven, W.H., ed., *Reliability Engineering,* Prentice-Hall, Englewood Cliffs, New Jersey, 1964.