Simulation and Economic Analysis of Coal Based Thermal Power Plant: A Critical Literature Review

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***ABSTRACT*:** *Coal based fired power plant is a very complex unit. Today's electric energy is playing an important role in the industrial and all-round development of every country. It is desired form of energy, because it can be produced easily and transmitted economically. Further, it can be used efficiently and easily to domestic and industrial applications. Performance evaluation of such units is becoming important because of increasing costs, competition and public demand on one way, while the risk of failure on the other. The failure-free operation of production unit seems to be impossible; also the failure occurrence is nearly an unavoidable phenomenon for all repairable industrial units and cannot be prevented completely. So, its impact and probability of occurrence should be minimized as much as possible. To increase the working time or maintain failure free operation of the plant for a long duration, it is necessary to maintain the plant at higher operational availability level. Thus working time can be increased by implementing the stand by systems parallel to active system in the plant. Formulation of the problem is carried out using Markov Birth-Death process using probabilistic approach and a transition diagram represents the operational behavior of the systems. The successful completion of a thermal power plant requires estimation of the fixed and variable costs involved in the project. The economic analysis of the coal based thermal power plant can be done on the basis of initial capital investment or fixed cost, operating cost and annual revenue.*

Keywords: *Availability Modeling, Markov Birth-Death Process, Transition Diagram*

I. INTRODUCTION

With the rising demand of automation in the different industrial parts, the high initial cost is required for installing the production units especially process industries like chemical, sugar, thermal, paper and fertilizer plants etc. It is necessary to have high productivity and maximum profit from process plants for their survival. To achieve this point, availability and reliability of component in process must be maintained at the highest level. Unfortunately, this is not the case because failure is inevitable even though it can be minimized by proper maintenance, inspection, proper training to the operators, motivation and by inculcating positive attitude in the workmen. The performance of any system also affects its design quality and the optimization tools used. Thus the performance of a system may be increased by proper design, optimization at the design stage and by maintaining the same during its service life. Proper maintenance plays a important role in reducing production costs. Increasing availability of manufacturing units and improving the quality also help a lot towards the productivity increment.

Unit performance depends on maintenance, reliability and availability of the system/sub-systems. Reliability, availability and maintenance have become more significant in recent years due to the large number of competitors in services, growing needs and overall operating costs. In order to gain targeted goals at minimum cost-input on reliability/availability improvement programs, it is necessary that each sub-system or component should run failure free and give its excellent performance. In the present scenario, evaluation of optimum values of system availability has become one of the vital ingredients of system design, development and operation of modern thermal power plants. The production systems services on time and meeting the required quality specifications satisfy the customer. Thus, the only reliable system can complete these needs.

On the other hand availability of the system can be improved by improving in its reliability and maintainability. Increasing system complexity decreases its reliability. Organizations such as airlines, the military and public utility are aware of the cost of unreliability. Reliability importance analysis helps in the detection of components which contribute the most to the failure of a system. The optimum reliability level is desirable not only to reduce overall costs of production but also decrease the risk of hazards. Increasing demand of power with a very slow pace of capacity addition requires that the power plants must operate with highest possible power availability and reliability.

II. LITERATURE REVIEW

Ravinder et al. [2015] investigated the impact of various factors affecting coal-fired power plant economics of 210 MW subcritical units for electricity generation. The work presented was an endeavour to study the influence of some of the important parameters on the lifetime costs of a coal-fired power plant. For this purpose, parametric study with and without escalation rates for a period of 35 years plant life was evaluated.

R.Paul and L.Pattanayak [2014] dealt with the possibilities of renovation and modernization (R&M) options in an existing 210 MW pulverized coal fired thermal power plant. Three different options along with its cost implications had been discussed based on the performance and levelised cost of generation. The performance of the unit for all the three options was examined under the consideration of increasing the availability of the unit with continuous capabilities to generate power maintaining normal operating parameters over an extended life of at least 15 years.

Ravinder et al. [2014] presented the thermal and economic performance of a 210 MWe coal-fired power plant situated in North India. The economic analysis included operational activities such as equipment cost, fuel cost, operations and maintenance cost, revenue, and plant net present value. From economic point of view, the effect of condensate extraction pump redundancy on net present value was observed to be sensitive than boiler feed pump redundancy.

D. Panchal and D. Kumar [2014] studied the behaviour of the CHU (Compressor House Unit) of a medium size coal fired thermal power plant using fuzzy approach (quantitative approach). The system had been modelled using PN and various reliability indices viz. failure rate, repair time, MTBF, Availability and reliability are computed at different spread/uncertainty level. The results were helpful to the system analyst to analyse the behaviour of the system and to plan suitable maintenance policy for improving the system availability.

Ravinder et al. [2013] presented the performance (availability) evaluation of a typical coal-fired power plant in a realistic working environment for identifying the critical sub-system and planning the preventive maintenance schedule. For analysis, the entire thermal system is broken down into six sub-systems i.e., turbine, condenser, coal supply, water circulation, air circulation and boiler sub-systems; these are further subdivided into a number of units. Formulation for availability of each sub-system is based on well-known Markov birth-death process.

Aggarwal et al. [2013] dealt with the performance modeling and availability analysis of the serial processes in the skim milk powder production system of a dairy plant. The skim milk powder system consist of six sub-systems namely chiller, cream separator, pasteurizer, evaporator, drying chamber and packaging sub-system. These subsystems were connected either in series or parallel with each other. Two sub-systems namely evaporator and drying chamber are supported by a standby sub-system with perfect switch over devices and by assuming the non-failure of packaging sub-system, the remaining five subsystems are subjected to failure. By considering the exponential distribution of failure and repair rate of sub-systems, the mathematical formulation of the model is developed with the use of mnemonic rule for these five sub-systems and Chapman-Kolmogorov differential equations were derived from the transition diagram. These differential equations were solved by using normalizing conditions to compute the availability under steady state condition. Finally, the performance of each sub-system of the system had been analyzed for selecting the best possible maintenance strategies in the plant.

M.A. El-Damcese and M.S. Shama [2013] investigated reliability and availability of a repairable system with degradation facility. Failure times and repair times of failed units were assumed to be exponentially distributed. There are two types of repair. The first was due to failed state, the second is due to degraded state. The expressions of availability and reliability characteristics such as the system reliability and the mean time to failure are derived.

We used several cases to analyze graphically the effect of various system parameters on the availability system, reliability system and mean time to failure. We also investigated the sensitivity analysis for the system reliability with changes in a specific value of the system parameters.

Liu et al. [2013] introduced the structure of the double 2-out-of-2 system and presents its Markov model for performance analysis. Transient reliability and safety of the system were obtained. In addition, the effects of imperfect diagnostic coverage and common cause failures on the reliability and safety of the system are researched. The results demonstrated that increasing the diagnostic coverage and decreasing the factor of common cause failures could improve the performance of the double 2-out-of-2 system.

Ravinder et al. [2012] proposed a methodology to evaluate the availability simulation model for power generation system (Turbine) in a thermal power plant under realistic working environment. The power generation system consists of five subsystems with four possible states: full working, reduced capacity, reduced efficiency and failed state. The availability simulation model (Av.) had been developed with the help of mathematical formulation based on Markov Birth-Death process using probabilistic approach.

S. Gupta et al. [2011] dealt with development of a simulation model for the performance evaluation of feed water system of a thermal power plant using Markov Birth-Death process and probabilistic approach. In present paper, the feed water system consisted of four subsystems. After drawing transition diagram for feed water system, differential equations were developed and then solved recursively using probabilistic approach. Then to predict the steady state availability i.e. measure of performance of feed water system, normalizing conditions are used. Thus availability simulation model has been developed. After that, the availability matrix and plots of failure/repair rates of all subsystems were prepared to decide the availability trends. Based upon various availability values in the availability matrix, performance of feed water system has been evaluated.

Adhikary et al. [2011] investigated the reliability, availability and maintainability (RAM) characteristics of a 210 MW coal-fired thermal power plant (Unit-2) from a thermal power station in eastern region of India. Critical mechanical subsystems with respect to failure frequency, reliability and maintainability were identified for taking necessary measures for enhancing availability of the power plant and the results are compared with Unit-1 of the same Power Station. Reliability-based preventive maintenance intervals (PMIs) at various reliability levels of the subsystems are estimated also for performing their preventive maintenance (PM)

Adhikary et al. [2010] the availability of a complex power plant system was strongly associated with its component's reliability and maintenance policy. Failure of significant equipment results in adverse consequence on the power generation, productivity and cost of generation. Failure of any component or equipment leads to disruption in power generation and eventually loss of revenue

Gupta and Tewari [2009] dealt with the opportunities for the modeling of flue gas and air system of a thermal power plant by making the performance evaluation using probabilistic approach. The system of thermal plant under study consisted of four subsystems with three possible states: full working, reduced capacity working and failed. Failure and repair rates for all the subsystems are assumed to be constant. Formulation of the problem was carried out using Markov Birth-Death process using probabilistic approach and a transition diagram represented the operational behavior of the system

S. Gupta et al. [2008] discussed the performance modeling and decision support system for a feed water unit of a thermal power plant using the concept of performance analysis and modeling. A feed water unit ensured a proper supply of water for the sound functioning of a thermal power plant. The decision support system for a feed water unit had been developed with the help of performance modeling using a probabilistic approach.

P. Gupta et al. [2007] purposed of this paper is to compute reliability, availability, and mean time before failure of the process of a plastic-pipe manufacturing plant consisting of a (K, N) system for various choices of failure and repair rates of sub-systems. This plant consists of eight sub-systems.

M.J. AlSalamah et al. [2006] examined the reliability of a cooling seawater pumping station which pumps seawater to refineries and petrochemical plants in Kuwait, mainly for cooling purposes, because owing to the harsh operating climate and lack of other alternative sources of water, high reliability of pumping system is crucially important.

Ramirez-Marquez, J.E. and Coit, D.W. [2005] described a Monte-Carlo (MC) simulation methodology for estimating the reliability of a multi-state network. The problem under consideration involves Multi-state Two-Terminal Reliability (MTTR) computation. Issues related to the reliability calculation process based on Multi-state Minimal Cut Vectors (MMCV) have been discussed.

A. Rauzy [2004] has been reported results of an experimental study on six iterative methods to compute the transient probabilities of large Markov models: full matrix exponentiation, forward Euler method, explicit Runge-Kutta methods of order 2 and 4.

Ramirez-Marquez, J.E. and Coit D.W. [2004] studied a Multi-state Series-Parallel System (MSPS) with capacitated binary components that can provide different multi-state system performance levels. They stated that different demand levels, which must be supplied during the system operating period, result in the multi-state nature of the system and the new solution methodology offers several distinct benefits.

N.B. Ebrahimi [2003] developed the techniques for assessing system reliability relies heavily on failure data. Also focused on a method that assesses the reliability of a system, which has extremely high reliable components/systems, for which it is difficult to collect failure data. This method expresses failure time and consequently the reliability of a system as a function of several explanatory variables (covariates).

G.C. Avontur and K.V. Werff [2002] presented a new method based on finite element equations, for systems reliability analysis of mechanical and hydraulic systems.

G. Arulmozhi [2002] proposed an expression and an algorithm for computing reliability of K-out-of-N system. The author states that it is an easy to implement, fast and memory efficient algorithm and helps to improve the computational efficiency considerably.

R.J. Cizelj et al. [2001] developed a new method (based on Bayesian approach) that explicitly includes numerical and linguistic information into the assessment of a specific failure rate. A prior distribution selected from a generic database, whereas likelihood assessed using the principles of fuzzy set theory. The influence of component operating conditions on component failure rate modeled using a fuzzy inference system.

K. Ni and S. Zhang [2000] established a new method of fatigue reliability analysis under two-stage loading on the basis of the two-dimensional probabilistic Miner's rule. Eight large samples of testing data under low–high and high–low two-stage cyclic loading was used in the experimental verification.

J.E. Yang et al. [1999] applied genetic algorithm, to the reliability allocation problem of a typical pressurized water reactor. They state that one of the main problems of reliability allocation is defining realistic objective functions and hence, in order to optimize the reliability of the system, the cost for improving and/or degrading the reliability of the system should be included in the reliability allocation process.

S.K. Khobare et al. [1998] stated that, "Reliability analysis of microcomputer circuit modules and computer based control systems are important for the safety of nuclear power plant. The fault tree model was developed for the integrated programmable digital comparator system. An attempt was made to establish the quantitative reliability values of indigenously developed and standardized microcomputer circuit hardware modules and C&I systems.

B. Ouhbi and N. Limnios [1997] estimated the reliability and the availability of a turbo-generator rotor using a set of data observed in a real engineering situation provided by Electricite De France. The rotor modeled by a semi- Markov process, which further used to estimate the reliability and availability.

T. Aven and K. Opdal [1996] studied the steady state unavailability of standby systems comprising n identical components of which n - 1 are normally operating and one is in standby, with one repair facility. The components are assumed to have constant failure rates, but arbitrary repair time distribution.

M.R.R. Khan and A.B.M.Z. Kabir [1995] described a simulation modeling technique for assessing the availability of an ammonia plant. They have collected field data on failure and down times analyzed it by fitting

Weibull distributions and has been estimated the plant availability using the existing plant configuration and actual failure and repair time distributions.

B.S. Dhillon [1993] stated that, "Reliability and availability analysis of the system with warm standby and common cause failure. The standby and switching mechanisms are subject to failure. He emphasized on the fact that one of the method to increase the reliability of an item is to introduce redundancy. Some of the common cause failure may occur due to operation and maintenance error, external normal environment, design deficiency, functional deficiency, common redundant items, common manufacturer and common external power source.

S. S Eliyas and M. Y Haggag [1992] stated that, "Availability, MTTF and Cost analysis of a three-state parallel redundant multi-component system under common human failure can be done by using supplementary variable technique. Several parameters of interest were obtained on complex system made up of three subsystems.

III. SUMMARY

The rising complexities in advanced technological units have increased the importance of reliability, availability and maintainability. This is mainly true in process industries, characterized by expensive specialized equipment's and rigorous environmental conditions. From the literature review, it is found that no rigid system for maintenance can be applied universally to process industries to control every situation. Therefore a proper maintenance procedure must be designed and develop to suit the requirements of a particular process industry. A detailed behaviors analysis and scientific maintenance planning helps the equipment/ systems be remain available for long duration. In order to express the system availability in quantitative terms, it is necessary to develop mathematical models for the system / sub systems and analyze their behaviors to evaluate the performance in real working conditions. Differential equations associated with the transition diagram are solved recursively in steady state environment for given failure and repair rate. The successful completion of a coal based thermal power plant requires estimation of the fixed and variable costs involved in the project.

IV. CONCLUSION

The plant is divided into several systems. A detailed behaviors analysis and scientific maintenance planning help the systems be remain available for long duration. In order to express the system availability in quantitative terms, it is required to develop mathematical models for the system. The availability of every system is obtained using Markov birth-death process. The thermal and economic analysis of a coal based thermal power plant is carried out to predict the coal consumption rate, overall thermal efficiency, mass flow rate of steam through boiler, and Net present value of thermal power plant for given plant load and redundancy of boiler feed pump and condensate extraction pump. Economic analysis includes equipment cost, fuel cost, operation cost, maintenance cost and annual revenue.

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