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Application of Markov Process to Improve Production of Power Plant

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Abstract: Due to the fast paced growth of world economy the energy demand is increasing very rapidly. To maintain the quality of power, economical production and long run performance of the plants should be kept failure free (as far as possible). So, these industries invest much more for up-gradation, high level of automation and use sophisticated machineries to get the desire level of results. But, still these industries are lagging in dependable and reliable supplies of electricity. Today most of the power plants are operating with low efficiency. In most of the cases it is less than 30%. There are a few plants in which efficiency is more than 60%.

To prevent such mishaps a detailed system behavioral analysis along with maintenance planning is important. For which a mathematical model is necessary which exhibit the system upstate in quantitative form and analyze system performance in actual operating conditions. It is also helpful to process design department for modification in design and to maintenance department to in monitoring the system performance and planning in advance to keep system failure free for longer duration.

The work presented here is mainly concerned with reliability centered maintenance of thermal power plant. The study is conducted in a Thermal Power Plant situated in Rajasthan.

Keywords – MTBF, MTTF

I. INTRODUCTION

1.1 Introduction

Due to the fast paced growth of world economy the energy demand is increasing very rapidly. To maintain the quality of power, economical production and long run performance of the plants should be kept failure free (as far as possible). So, these industries invest much more for up-gradation, high level of automation and use sophisticated machineries to get the desire level of results. But, still these industries are lagging in dependable and reliable supplies of electricity. Today most of the power plants are operating with low efficiency. In most of the cases it is less than 30%. There are a few plants in which efficiency is more than 60%.

To prevent such mishaps a detailed system behavioral analysis along with maintenance planning is important. For which a mathematical model is necessary which exhibit the system upstate in quantitative form and analyze system performance in actual operating conditions. It is also helpful to process design department for modification in design and to maintenance department to in monitoring the system performance and planning in advance to keep system failure free for longer duration.

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1.2 Reliability

The reliability is the probability of a system/device to perform required function for a specified duration of time without any failure under stated conditions for which it is designed. The measure of reliability for repairable system is Mean Time between Failure (MTBF) and for non-repairable systems is Mean Time to Failure (MTTF). Mathematically reliability of a component for period t can be represented as: $R(t) = e^{-\lambda t}$, where λ is mean failure rate.

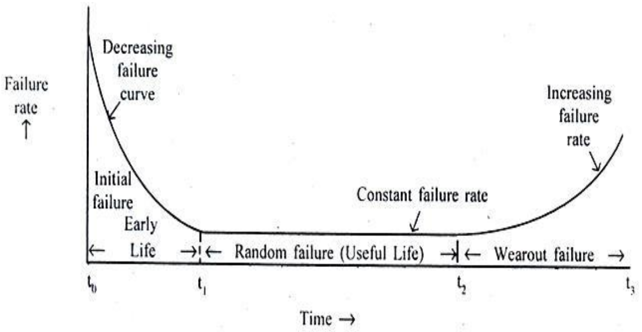

Figure1.1: Bath-Tub Curve

In the reliability analysis the Bath-Tub Curve (Figure1.1) is widely used for time dependent failure rate of items. This curve has three distinct regions: early life period, useful life period, and wear out period. The early life period is also known as infant mortality period. This period is shown on graph by a decreasing curve between t_0 and t_1. During this period the failures occur due to incorrect installation, defective parts, defects in manufacturing and design. The early life period failures can be reduced by quality control techniques. During the useful life period failure rate remains constant and failures occur unpredictably. This is shown on graph by t_1 and t_2. The reasons behind the failures are incorrect use, human errors, and insufficient design margins. These failures can be reduced by incorporating redundancy in the system. The wear out period begins when useful life period passed. This is shown on graph by an increasing curve between t_2 and t_3. During this period the hazard rate increases. In this period the failures occur due to aging, misalignment, creep, friction, limited life of components, and less preventive maintenance. These failures can be reduced by executing effective preventive maintenance policies and replacement of wear out components.

1.3 Markov Process

A. A. Markov was a Russian mathematician and professor in Saint Petersburg University in 1878. He worked on number theory, limits of integrals, convergences of series, and continued fractions application to probability theory. He remembered for

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his study of Markov Chains. The Markov chains are used as a standard tool in medical decision making. The Markov started the theory of stochastic processes.

When the states of systems are probability based, then the model used is a Markov probability model. To analyze the system availability there are several approaches e.g. Monte Carlo Simulation approach applied for the extremely complex system to analyze availability, but the cost of experimentation was very high so the Markovian approach is frequently used for the availability analysis.

Markov models are used for availability analysis of series or parallel system in which one element is occurred at a time e.g. failure or repair. The Markov model evaluates the probability of jumping from one state to next state until; the system has reached the final failed state.

State transition diagrams defined the probability transitions from initial state to final state. These diagrams become more complicated for the systems with several non-repairable elements and more than two states. This situation become more complex for repairable systems in which failure and repair rate both are considered.

When there are no. of elements are more then transition diagram become more complex to understand. To solve this Markov model reduction techniques are used to reduce no. of states while maintaining the accuracy of the model.

In a Markov reduction technique the no. of elements which have nearly same impact on the system can be combined. In another technique system can be divided into subsystems and each subsystem can be modeled separately. For example if a system has 10 elements and each element has two states (good and failed) then total no. of possible states becomes:

Total no. of states = $2^n = 2^{10} = 1024$.

If the system is divided in two subsystems, each of which has 5 elements, then no. of possible states for each subsystem becomes:

No. of states = $2^n = 2^5 = 32$.

Hence for the complete system the no. of states will be 64. So, it is easier to solve 64 states than 1024 states. Figure 1.1 illustrates the procedure used to develop a Markov model.

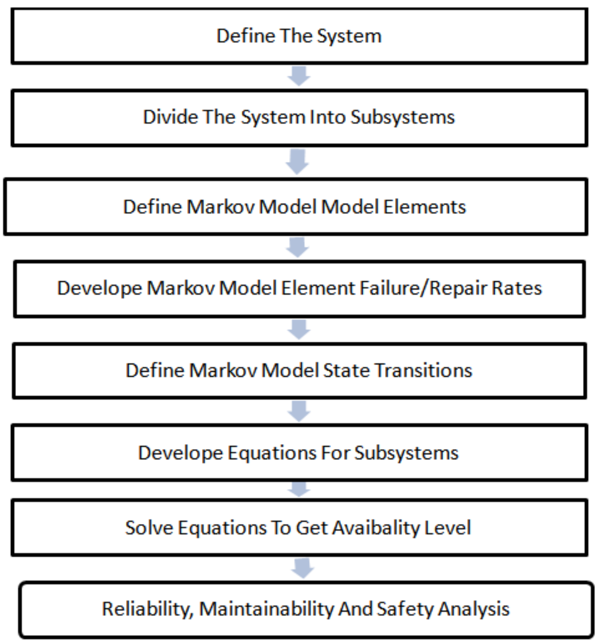

Figure1.3: Markov Modeling Process

II. DEVELOPMENT OF PERFORMANCE MODELS

2.1 Description of various systems of power plant

The power plant is a huge and complex system in which there are various series and parallel systems are arranged in a complicated manner. To study all the systems is impossible in limited time. So, my dissertation purposes I selected the following independent systems:

1) Steam Generating System
2) Turbine and Condensate System

2.1.1 Steam Generating System

The system is comprised four subsystems (Figure 3.2), arranged in series which are as follows:

1) **Subsystem (G1):** It consists of a unit of an economizer. It is a single unit which is arranged in series and has no replacement. Therefore, it causes severe effect on the system performance i.e. failure of the system.
2) **Subsystem (G2):** This subsystem consists of a unit of Boiler which produces steam. If that unit failed then whole system will failed. It is the single unit and has no replacement.
3) **Subsystem (G3):** It consists of a unit of Superheater that's converting the steam in saturated steam. If that failed then will tends to shut down. It is the single unit which has no replacement.
4) **Subsystem (G4):** This subsystem consists of two units of reheater that's convert low pressure steam into superheated steam. Failure of first unit forces to start stand by unit of the reheater. The complete failure of unit occurs when stand by unit also failed.

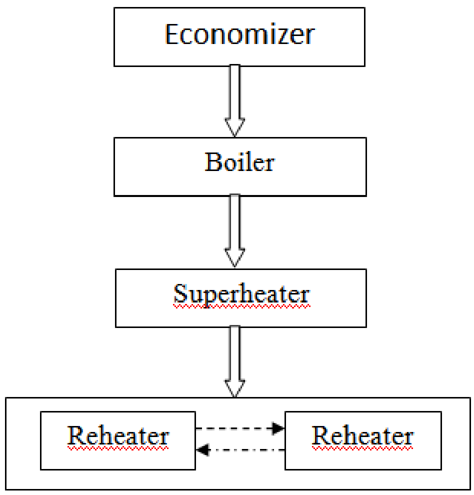

Figure 3.2: Block diagram of steam generating system

2.1.2 Turbine and Condensate System

The system is comprised four subsystems (Figure 3.3), arranged in series which are as follows:

1) **Subsystem (T1):** This subsystem consists of a unit of HP turbine. Failure of this unit stopped the power generation. There is no replacement available in the concerned system. So failure of this unit tends to failure of the system.

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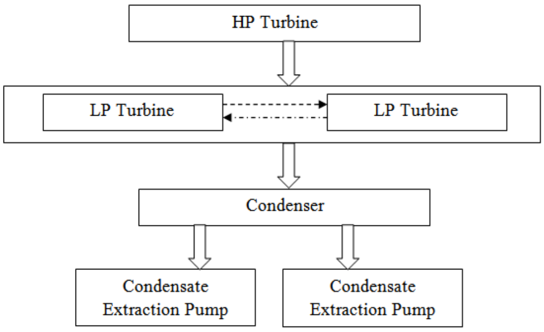

Figure 3.3: Block diagram of Turbine and Condensate system

2) **Subsystem (T2):** It consists of two units of LP turbine in which one unit is in stand by condition. If a unit failed then stand by unit will in operating condition. Complete failure of system occurs when stand by unit also failed.
3) **Subsystem (T3):** This subsystem consists of a unit of condenser. This is also arranged in series with no replacement. So, failure of the system leads to complete failure of the system.
4) **Subsystem (T4):** It consists of two units of condensate extraction pump. Both the units are arranged in parallel to each other. Failure of one unit reduces the processing capacity. The complete failure of the system occurs when both the units failed simultaneously.

III. PERFORMANCE ANALYSIS

3.1 Data for Boiler subsystem

The failure and repair rates for boiler subsystem is computed in the following manner, which is shown in Table 3.1

Table 3.1: Data Table for Boiler Subsystem

Days	Total production Time (Hrs.)	Total Down Time (Hrs.)	No. of failures	MTBF	MTTR	Failure Rate (α_2)	Repair rate (β_2)
29 days	696	82	2	307	41	0.0033	0.024
34 days	816	44	2	386	22	0.0026	0.045
20 days	480	36	1	444	36	0.0023	0.028
47 days	1128	72	3	352	24	0.0028	0.041
49 days	1056	80	4	244	20	0.0041	0.050
18 days	432	33	1	399	33	0.0025	0.030
56 days	1344	138	3	402	46	0.0025	0.022
30 days	720	54	2	333	27	0.0030	0.037
77 days	1848	156	4	423	39	0.0024	0.026

3.2 Data for Condenser subsystem

The failure and repair rates for condenser subsystem is computed in the following manner, which is shown in Table 3.2

Table 3.2: Data Table for Condenser Subsystem

Days	Total production Time (Hrs.)	Total Down Time (Hrs.)	No. of failures	MTBF	MTTR	Failure Rate (α_7)	Repair rate (β_7)
38 days	912	66	3	282	33	0.0035	0.030
27 days	648	82	2	283	41	0.0034	0.024
44 days	1056	87	3	323	29	0.0031	0.034
31 days	744	88	4	164	22	0.0061	0.045
47 days	1128	102	3	343	34	0.0030	0.029
35 days	840	264	6	96	44	0.0104	0.022
55 days	1320	112	4	302	28	0.0033	0.036
67 days	1608	175	7	204	25	0.0049	0.040
21 days	504	42	2	231	21	0.0043	0.047

IV. CONCLUSIONS AND SCOPE OF FUTURE WORK

4.1 Findings of present research work

The model developed for availability analysis of the two operating systems of power plant is based on probabilistic approach. This gives the various combinations of failure and repair rates for operating systems of power plant. The best combination for maximum availability level is shown in Table 4.1.

From Table 4.1, it is clear if we follow the above strategy, the availability level for both SG and TC systems can be achieved near to 90%, while current availability level for SG system is 82.5% and for TC system is 78.3%.

Table 4.1 Maximum Availability Level for SG and TC Systems

Operating systems	Maximum availability level	Failure rates	Repair rates
Steam generating system	90.1%	$\alpha_1 = 0.001$ $\alpha_2 = 0.002$ $\alpha_3 = 0.0001$ $\alpha_4 = 0.003$	$\beta_1 = 0.02$ $\beta_2 = 0.05$ $\beta_3 = 0.01$ $\beta_4 = 0.03$ or $\beta_1 = 0.02$ $\beta_2 = 0.02$ $\beta_3 = 0.01$ $\beta_4 = 0.06$
Turbine and condenser system	89.8%	$\alpha_5 = 0.002$ $\alpha_6 = 0.001$ $\alpha_7 = 0.003$ $\alpha_8 = 0.0005$	$\beta_5 = 0.03$ $\beta_6 = 0.02$ $\beta_7 = 0.05$ $\beta_8 = 0.01$

This research work also solves the maintenance problem. For high availability of the systems the maintainability would also be high. Fig 4.1 reveals that in steam generating system the reheater and boiler subsystem has high failure rates while the repair rates are less and for Superheater subsystem there is very high repair rate compare to failure rate. So, there is need to shift the scheduled maintenance time from Superheater to boiler and reheater subsystems.

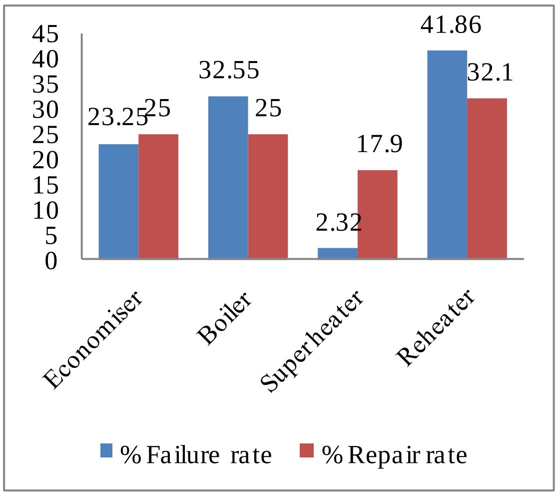

Figure 4.1: Percentage failure and repair rates for SG system

V. SCOPE FOR FUTURE WORK

The future scope of research is to extend the developed model further and make it more effective. This research work gives the solutions for only steam generating system and turbine and condensate system but a power plant is a huge and complex system so, in the similar pattern the analysis of

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more systems can be performed which will give the complete solution for a power plant.

In this research work maximum availability level is chosen however, optimal availability can be selected to improve the overall efficiency of the systems. This work can also be extended by taking time dependent failure and repair rates of various systems.

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