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Research Article

A MARKOV MODEL FOR RELIABILITY ANALYSIS OF COAL HANDLING UNIT OF BADARPUR THERMAL POWER PLANT

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ABSTRACT

The present paper discusses the development of a Markov model for performance evaluation of coal handling unit of a thermal power plant using probabilistic approach. Coal handling unit ensures proper supply of coal for sound functioning of thermal Power Plant. In present paper, the coal handling unit consists of four subsystems with two possible states i.e. working and failed. Failure and repair rates of both subsystems are taken to be constant. After drawing transition diagram, differential equations have been generated. After that, steady state probabilities are determined. Besides, some decision matrices are also developed, which provide various performance levels for different combinations of failure and repair rates of all subsystems. Based upon various performance values obtained in decision matrices and plots of failure rates/ repair rates of various subsystems, performance of each subsystem is analyzed and then maintenance decisions are made for all subsystems. The developed model helps in comparative evaluation of alternative maintenance strategies.

Key Words: Markov Model, Availability Analysis, Performance evaluation

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INTRODUCTION

Over the years, as engineering systems have become more complex and sophisticated, the reliability prediction of engineering systems is becoming increasingly important because of factors such as cost, risk of hazard, competition, public demand and usage of new technology. High reliability level is desirable to reduce overall cost of production and risk of hazards for larger, more complex and sophisticated systems, such as thermal power plant. It is necessary to maintain the steam thermal power plant to provide reliable and uninterrupted electrical supply for long time. In order to obtain regular and economical generation of electrical power, plant should be maintained at sufficiently high availability level corresponding to minimum overall cost Performance modeling is an activity in which the performance of a system is characterized by a set of performance parameters, whose quantitative values are used for evaluating the system availability. Performance modeling has a very important role in the coal handling system of a thermal power plant.

LITERATURE SURVEY

Any production system should be kept failure free under the given operative conditions to achieve the set goals of economical production and long run performance. A highly reliable system tends of increase the efficiency of production. Many utility systems in the world Have power plants operating with fossil fuel. In the thermal power plants, there is maximum requirement of coal as a fuel. The handling of this fuel is a great job. To handle the fuel i.e. coal, each power station is equipped with a coal handling plant. Maintenance of critical equipments for coal handling plants of thermal power stations is typical job. For regular and economical According to Kumar and Pandey (1993), the failure rate of each subsystem in a particular system depends upon the operating conditions and repair policies used. From economic and operational point of view, it is desirable to ensure an optimum level of system availability. Barabady and Kumar (2007) states that the most important performance measures for repairable system designers and operators are system reliability and availability. Sorabh Gupta, P.C. Tewari, Avdhesh Kr. Sharma (2009) discussed the development of a Markov model for performance evaluation of coal handling unit of a thermal power plant. Rajiv Khanduja, P. C. Tewari, R.S. Chauhan (2009) dealt with the performance analysis of the screening unit in a paper plant using Genetic Algorithm. S. Gupta P.C. Tewari (2009) discussed the development of a performance model of power generation system of a thermal plant. Sorabh Gupta and P.C. Tewari (2009) proposed simulation model for coal crushing system of a typical thermal power plant. Sorabh Gupta, Puran Tewari (2009) dealt with the opportunities for the modeling of flue gas and air system of a thermal power plant. To maintain an efficiently operating system and avoid failure of critical equipment, it is necessary to maintain the critical parts of that equipment. There are varieties of critical equipment components in coal handling plants. These components require routine inspection to ensure their integrity. The purpose of the inspection is to identify any degradation in the integrity of the systems during their service life and to provide an early warning in order that remedial action can be taken before failure occurs.

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Coal Handling Unit

A thermal power plant is a complex engineering system comprising of various systems: Coal handling, Steam

Generation, Cooling Water, Crushing, Ash handling, Power Generation and Feed water system. In a coal fired thermal power plant the chemical energy stored in coal, is converted successively into thermal energy, then in mechanical energy and, finally in electrical energy for continuous use and distribution across a wide geographic area. The coal from railway bogies is unloaded by the wagon tippler, which is collected in two underground hoppers. From the hoppers the coal is transferred to either of the two conveyors by means of vibrating feeders. Dust suspension equipment is provided to suppress the coal dust created during the unloading of coal. From the conveyors the coal is again transferred to the next conveyor unit. Again failure of one leads convey on other, which supplies the coal to the crusher house. In crusher house the size of coal pieces is reduced. If a situation arises where coal bunkers are full, then coal is crushed and stacked with the help of stacker reclaimers. At a particular moment when coal bunkers are empty, the coal can be reclaimed with the help of stacker. The aim of layout of coal handling unit is to provide maximum flexibility and to ensure for high reliability of the plant. Thus coal handling unit is the main and most important part of a thermal plant.

NOTATIONS

1. A, B, E, D = Denotes the full capacity working states of subsystems A, B, E, D.
2. B_1 = Denotes that the subsystem B is working with standby units.
3. $\lambda_1,\lambda_2,\lambda_3,\lambda_4$ = Denotes failure rate of subsystem A,B,E,D.
4. λ_5 = Denote Failure rate of both subsystems (B and E) simultaneously
5. μ_1, μ_2,μ_3,μ_4 = Denotes repair rate of subsystem A,B,E,D.
6. μ_5 = Denote repair rate of both subsystems (B and E) simultaneously
7. E_1 = Denotes that the subsystem E is working with standby units.
8. a, b, e, d = Denotes the failed states of subsystems A, B, E, D.
9. B_1E_1 = subsystem B and E are working with standby units.
10. P_0 (t) = Indicates probability that at time (t) subsystem are working properly. At full capacity without stand by unit.
11. AV = Steady state availability of the system.

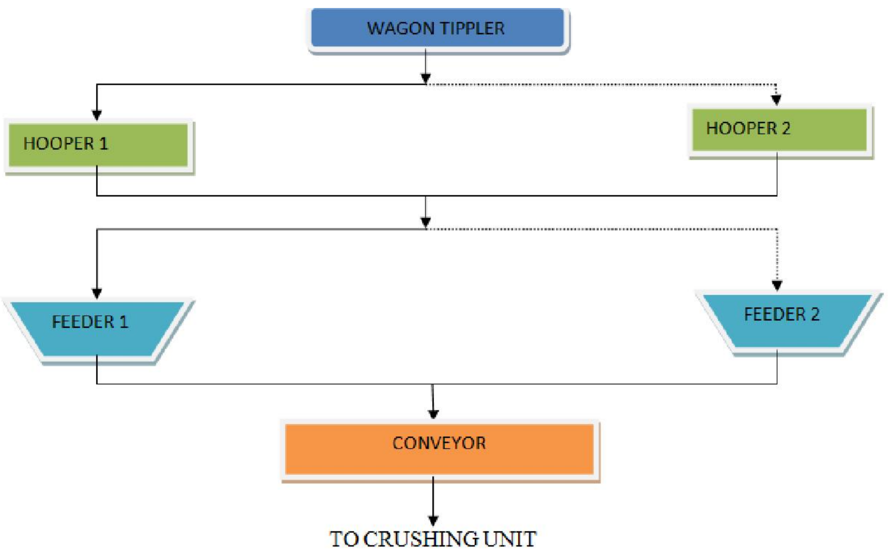

Figure 1. Schematic Diagram of Coal Handling Unit

KEY EQUIPMENTS IN CHP

1 .WAGON TRIPPLER
2. HOOPER
3. SIDE ARM CHANGER
4. FEEDER
5. CONVEYOR

MATHEMATICAL MODEL OF COAL HANDLING UNIT OF THERMAL POWER PLANT

The coal from railway bogies is unloaded by the wagon tippler, which is collected in two underground hoppers. From the hoppers the coal is transferred to either of the two conveyors by means of vibrating feeders. Dust suspension equipment is provided to suppress the coal dust created during the unloading of coal. From the conveyors the coal is again transferred to the next conveyor unit. Again failure of one leads convey other, which supplies the coal to the crusher house.

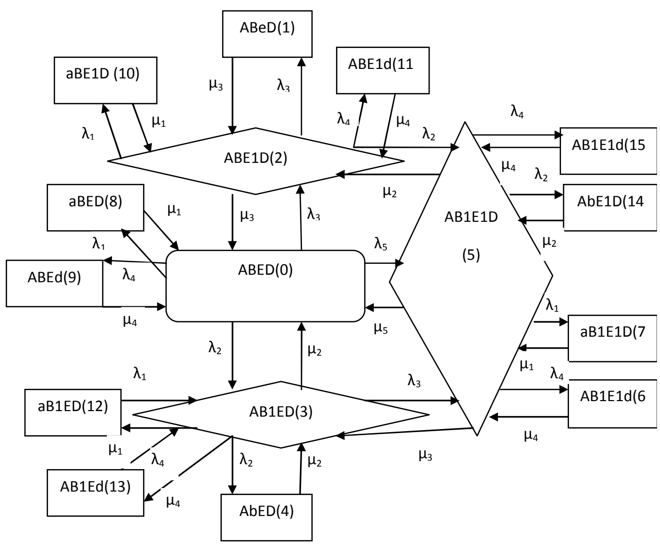

Figure 2. Transition Diagram of Coal Handling Unit of Power Plant

Using above figure building up difference differential equation

λ =FAILURE RATE
μ =REPAIR RATE

$P_0t^*(d/dt+\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5) = P_8(t)\mu_1+P_3(t)\mu_2+P_2(t)\mu_3+P_9(t)\mu_4+P_5(t)\mu_5$ 1
$P_1t^*(d/dt+\mu_3) = P_2(t)\lambda_3$ 2
$P_2t^*(d/dt+\lambda_1+\lambda_2+\lambda_3+\lambda_4+\mu_3)=P_0(t)\lambda_3+P_{10}(t)\mu_1+P_1(t)\mu_3+P_{11}(t)\mu_4+P_5(t)\mu_2$ 3
$P_3t^*(d/dt+\lambda_1+\lambda_2+\lambda_3+\lambda_4+\mu_2) = P_0(t)\lambda_2+P_{12}(t)\mu_1+P_5(t)\mu_3+P_4(t)\mu_2+P_{13}(t)\mu_4$ 4
$P_4t^*(d/dt+\mu_2) = P_3(t)\lambda_2$ 5
$P_5t^*(d/dt+\lambda_1+\lambda_2+\lambda_3+\lambda_4+\mu_2+\mu_3+\mu_5) = P_3(t)\lambda_3+P_{15}(t)\mu_3+P_{14}(t)\mu_2+P_6(t)\mu_4+P_0(t)\lambda_5+P_2(t)\lambda_2+P_7(t)\mu_1$ 6
$P_6t^*(d/dt+\mu_4) = P_5(t)\lambda_4$ 7
$P_7t^*(d/dt+\mu_1) = P_5(t)\lambda_1$ 8
$P_8t^*(d/dt+\mu_1) = P_0(t)\lambda_1$ 9
$P_9t^*(d/dt+\mu_4) = P_0(t)\lambda_4$ 10
$P_{10}t^*(d/dt+\mu_1) = P_2(t)\lambda_1$ 11
$P_{11}t^*(d/dt+\mu_4) = P_2(t)\lambda_4$ 12
$P_{12}t^*(d/dt+\mu_1) = P_3(t)\lambda_1$ 13
$P_{13}t^*(d/dt+\mu_4) = P_3(t)\lambda_4$ 14
$P_{14}t^*(d/dt+\mu_2) = P_5(t)\lambda_2$ 15
$P_{15}t^*(d/dt+\mu_3) = P_5(t)\lambda_3$ 16

Since a power plant is supposed to run for a very long period. Hence taking time as infinity(∞).

$t \rightarrow \infty$ i.e …,$\partial t \rightarrow 0$ in above equations now equation becomes

$P_0^*(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5) = P_8\mu_1+P_3\mu_2+P_2\mu_3+P_9\mu_4+P_5\mu_5$ 17
$P_1^*(\mu_3) = P_2\lambda_3$ 18
$P_2^*(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\mu_3)=P_0\lambda_3+P_{10}\mu_1+P_1\mu_3+P_{11}\mu_4+P_5\mu_2$ 19
$P_3^*(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\mu_2)=P_0\lambda_2+P_{12}\mu_1+P_5\mu_3+P_4\mu_2+P_{13}\mu_4$ 20
$P_4^*(\mu_2) = P_3\lambda_2$ 21
$P_5^*(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\mu_2+\mu_3+\mu_5) = P_3\lambda_3+P_{15}\mu_3+P_{14}\mu_2+P_6\mu_4+P_0\lambda_5+P_2\lambda_2+P_7\mu_1$ 22
$P_6^*(\mu_4) = P_5\lambda_4$ 23
$P_7^*(\mu_1) = P_5\lambda_1$ 24
$P_8^*(\mu_1) = P_0\lambda_1$ 25
$P_9^*(\mu_4) = P_0\lambda_4$ 26
$P_{10}^*(\mu_1) = P_2\lambda_1$ 27
$P_{11}^*(\mu_4) = P_2\lambda_4$ 28
$P_{12}^*(\mu_1) = P_3\lambda_1$ 29
$P_{13}^*(\mu_4) = P_3\lambda_4$ 30
$P_{14}^*(\mu_2) = P_5\lambda_2$ 31
$P_{15}^*(\mu_3) = P_5\lambda_3$ 32

On computing the values of failure rate (λ) and repair rate (μ).

$\lambda_1=0.001$
$\mu_1 = 0.3$
$\lambda_2=0.005$
$\mu_2 = 0.2$
$\lambda_3=0.002$
$\mu_3 = 0.2$
$\lambda_4=0.005$
$\mu_4 = 0.1$
$\lambda_5=0.003$
$\mu_5=0.3$

On solving using Engg. Equation Solver (EES) we get

$P_0=0.7972$ $P_8=0.02657$
$P_1=0.000138$ $P_9=0.03986$
$P_{10}=0.0000426$
$P_2=0.0138$ $P_{11}=0.00069$
$P_3=0.02584$ $P_{12}=0.0008615$
$P_4=0.0006461$ $P_{13}=0.001321$
$P_5=0.006173$ $P_{14}=0.0001012$
$P_6=0.0003086$ $P_{15}=0.00004046$
$P_7=0.0002058$

NORMALISING CONDITION

The probability of full working capacity namely P_0 determined by using normalizing condition; i.e. sum of the probabilities of all full working states, reduced capacity states and failed states is equal to 1.

$P_0+P_1+P_2+P_3+P_4+P_5+P_6+P_7+P_8+P_9+P1_0+P_{11}+P_{12}+P1_3+P_{14}+P_{15}=1$

STEADTY STATE AVAILABILITY (AV)

The steady state availability of coal crushing system may be obtained as summation of all full working and reduced capacity working state probabilities

$AV = P_0+P_2+P_3+P_5$

Above defined model will be used for availability analysis of coal handling unit.

PERFORMANCE EVALUATION

The developed model is used to predict the availability, hence to evaluate the performance of coal handling system of thermal power plant for known input values of failure and repair rates of its subsystems. The performance of the system is mainly affected by the failure and repair rates of its subsystem. From maintenance history sheet of coal handling system and through the discussions with the plant personnel appropriate failure and repair rates of all subsystems are taken and availability matrices are prepared accordingly by these failure and repair rates values in above (AV) equation.

RESULTS AND DISCUSSION

On the basis of availability values as given in Tables below the performance evaluation is done using the developed model (using Markov approach). The following observations are made from Table 1, 2, 3 and 4 which reveals the effect of failure and repair rates of various subsystems on the availability of coal handling unit. From Table 1 and Figure 3 it can be concluded that as failure rate of tippler increases from 0.001 to 0.005 i.e., from1 time in 1000 hour to1 time in 200 hour availability decreases by 1.19%. As repair rate of tippler increases from 0.3 to 0.5 i.e. once in 3.4 hour to once in2 hour then unit availability increases by 12%. From Table 2 and Figure 4 it can be concluded that as failure rate of Hooper increases from 0.005 to0.02 i.e. once in 200 hour to once in 50 hour then unit availability decreases by .79% .As repair rate of Hooper increases from 0.2 to 0.5 i.e., from once in 5 hour to once in 2 hour then unit availability increases by 0.06%.

Table 1. Availability Matrix Of Wagon Tippler Subsystem Of Coal Handling Unit

$\lambda_1\mu_1 \rightarrow$ ↓	0.3	0.35	0.4	0.45	0.5	CONSTANTS
0.001	0.9485	0.9489	.9492	.9495	.9497	$\lambda_2 = 0.005$ $\mu_2 = 0.2$ $\lambda_3 = 0.002$ $\mu_3 = 0.2$
0.002	.9455	.9463	.9470	.9475	.9479	$\lambda_4 = 0.005$ $\mu_4 = 0.1$
0.003	.9425	.9438	.9448	.9455	.9461	$\lambda_5 = 0.003$ $\mu_5 = 0.3$
0.004	.9396	.9413	.9425	.9435	.9443	
0.005	.9366	.9387	.9403	.9415	.9425	

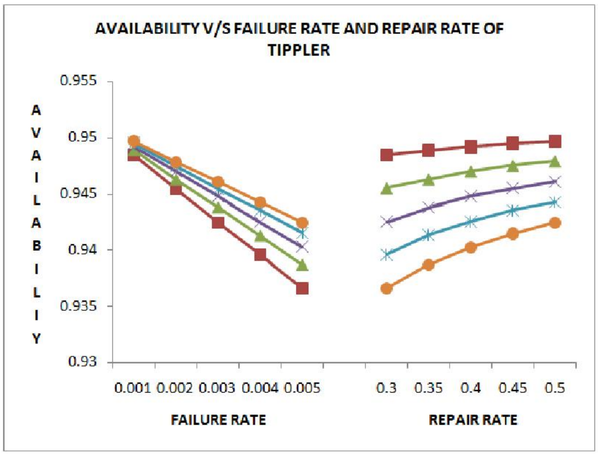

Figure 3. Availability V/S Repair Rate And Failure Rate Of Tippler

Table 2. Availability Matrix Of Hooper Subsystem Of Coal Handling Unit

$\lambda_2\mu_2 \rightarrow$ ↓	0.2	0.35	0.4	0.45	0.5	CONSTANTS
0.005	.9485	.9489	.949	.949	.9491	$\lambda_1 = 0.001$ $\mu_1 = 0.3$
0.007	.9479	.9488	.9489	.9489	.949	$\lambda_3 = 0.002$ $\mu_3 = 0.2$
0.01	.9468	.9484	.9485	.9487	.9488	$\lambda_4 = 0.005$ $\mu_4 = 0.1$ $\lambda_5 = 0.003$ $\mu_5 = 0.3$
0.015	.9441	.9474	.9478	.9481	.9483	
0.02	.9406	.9462	.9469	.9473	.9477	

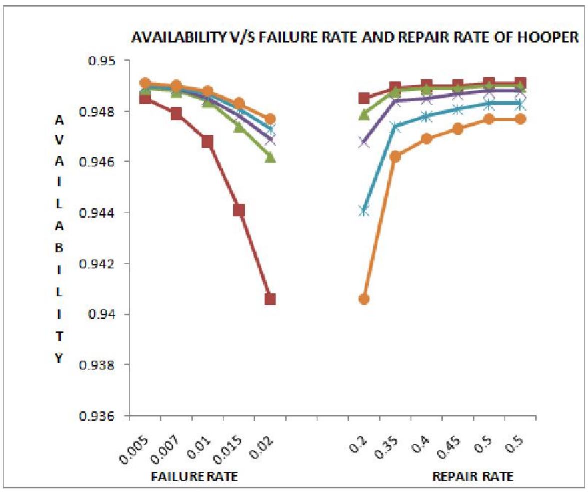

Figure 4. Availability V/S Repair Rate And Failure Rate Of Hooper

From Table 3 and Figure 5 it can be concluded that as failure rate of feeder increases from 0.002 to 0.005 i.e., from once in 500 hour to once in 200 hour then unit availability decreases by .06%. As repair rate of feeder increases from 0.2 to 0.4 i.e., from once in 5 hour to once in 2.5 hour then unit availability increases by 0.01

Table 3. Availability Matrix of Feeder Subsystem Of Coal Handling Unit

$\lambda_3\mu_3 \rightarrow$ ↓	0.2	0.28	0.3	0.34	0.4	CONSTANTS
0.002	.9485	.9485	.9486	.9486	.9486	$\lambda_1 = 0.001$ $\mu_1 = 0.3$ $\lambda_2 = 0.005$ $\mu_2 = 0.2$
0.0027	.9484	.9485	.9485	.9485	.9485	$\lambda_4 = 0.005$ $\mu_4 = 0.1$ $\lambda_5 = 0.003$ $\mu_5 = 0.3$
0.003	.9483	.9485	.9485	.9485	.9485	
0.004	.9482	.9484	.9484	.9484	.9485	
0.005	.9479	.9483	.9483	.9484	.9484	

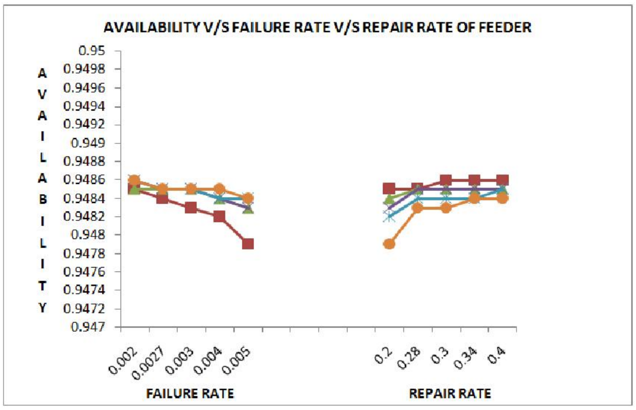

Figure 5. Availability V/S Repair Rate And Failure Rate Of Feeder

Table 4. Availability Matrix of Conveyor Subsystem Of Coal Handling Unit

$\lambda_4\mu_4 \rightarrow$ ↓	0.1	0.2	0.39	0.47	0.6	CONSTANTS
0.005	.9485	.9715	.9832	.9853	.9875	$\lambda_1 = 0.001$ $\mu_1 = 0.3$ $\lambda_2 = 0.005$ $\mu_2 = 0.2$
0.01	.9055	.9485	.9709	.975	.9795	$\lambda_3 = 0.002$ $\mu_3 = 0.2$ $\lambda_5 = 0.003 \mu_5 = 0.3$
0.02	.8303	.9055	.9473	.9552	.9637	
0.03	.7667	.8663	. 9242	.9362	.9485	
0.04	.71121	.8304	.9034	.9179	.9337	

Table 5. Optimum Values Of Failure And Repair Rates Of Subsystems Of Coal Handling Unit

S.N.	SUBSYSTEM	FAILURE RATE (λ)	REPAIR RATE (μ)	MAXIMUM AVAILABILITY LEVEL
1.	TIPPLER	0.001	0.5	94.97%
2.	HOOPER	0.005	0.5	94.91%
3.	FEEDER	0.002	0.4	94.86%
4.	CONVEYOR	0.005	0.6	98.45%

MAINTENANCE STRATEGY

Table 6. Maintenance Strategies

S.N	SUBSYSTEM	MAINTENANCE PRIORITY
1.	CONVEYOR	FIRST
2.	TIPPLER	SECOND
3.	HOOPER	THIRD
4.	FEEDER	FOURTH

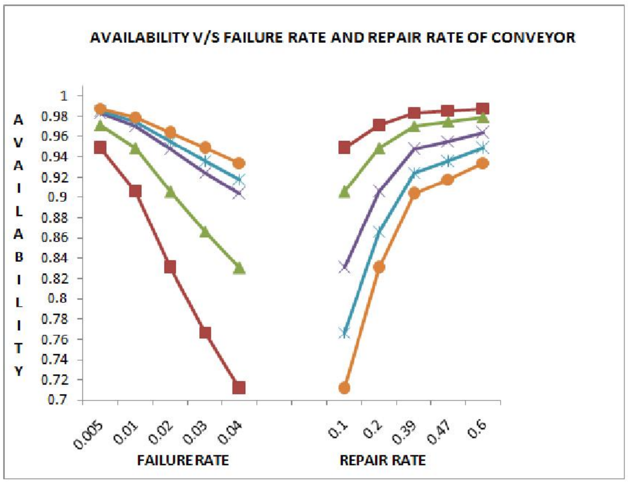

Figure 6. Availability V/S Repair Rate And Failure Rate of Conveyor

From Table 4 and Figure 6 it can be concluded that as failure rate of conveyor increases from 0.005 to 0.04 i.e., from once in 200 hour to once in 25 hour then unit availability decreases by 23%. As repair rate of conveyor increases 0.2 to 0.4 i.e. once in 5 hour to once in 2.5 hour then unit availability increases by 4%.

Conclusions

From above Tables (1, 2, 3, 4) it can be concluded that as failure rate increases unit availability decreases while with increase in repair rate the unit availability increases. From above results we can conclude that as failure rate of conveyor increases from 0.005 to 0.04 i.e., from once in 200 hour to once in 25 hour then unit availability decreases by 23%. So during failure conveyor should be given first priority to repair up. So conveyor should be the first component of coal handling unit of power plant to be taken care of.

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