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Reliability & Availability Evaluation of Turbo Generators and Boilers of A Thermal Power Plant

P. Lalitha Chamundeswari[1], Dr. V Vijay Babu[2]

[1]ME Scholar, [2]Professor

Abstract - The Reliability of a power system depends on the reliability of its generation system. It is essential that a proper method be used to model the data in order to compute the availability of a unit. In this paper a Two state Markov model is presented to evaluate the reliability and availability of Boilers and Turbo generators of Thermal power plant in Visakhapatnam steel plant over the period of April 2009 to March 2014. In this paper a thermal power plant is modeled by defining the failure (λ) and repair rates (μ) and also MTTR and MTBF are also found. Finally the reliability and availability of thermal power plant of Visakhapatnam steel plant is completed.

Keywords: Reliability, Availability, Thermal Power Plant, Two state Markov model.

I. INTRODUCTION

Thermal power plant of Visakhapatnam steel plant has a captive capacity of 270 MW which is sufficient to meet the steel plant needs under normal operating time. Steel industry is a power intensive industry and requires uninterrupted power supply to critical loads. This requires a dependable and reliable captive power source which can cater to all important loads of the plant all the time for safe and smooth operation of the steel plant. In case of partial outage of captive generation capacity due to breakdown, shutdown or other reasons, the short fall of power is making the plant unreliable in operation. This plant is located in Visakhapatnam district Andhra Pradesh state of INDIA.

The main objective of "Reliability & Availability evaluation of Boilers and Turbo generators of a thermal power plant" is to evaluate the MTTR, MTBF, failure rate, repair rate and the probabilities of the various defined failure states. For this computation a Two state Markov model is used the state transition diagram for the various failure states of individual components is provided. There by reliability and availability of the individual units over the entire period of consideration is Boilers and a Turbo generator is drawn.

Data Collection:

The thermal power plant in Visakhapatnam Steel Plant has 4 Turbo Generators, three of 60 MW capacities each (TG-1 to 3) and the fourth one is of 67.5 MW capacity (TG-4) also the Thermal Power Plant has 5 Boilers each of 330 T/hr Steam capacity at 101 KSCA and 540^{o}C. Normally 4 Boilers are kept in full load operation to produce 247.5 MW if any failure or disturbance caused in any sub parts of these units it causes significant effect on system operational reliability. The unit failure will affect the system reliability and availability of the unit and the power plant.

The failure data over the period 2009-2014 is collected for each individual unit. All possible failure reasons for both boilers and turbo generators have been classified into various failure states and each is given a state number. The basis for this period is that, operation of complex systems such as Boilers and Turbo generators, which are designed for continuous operation, are influenced by a wide variety of disturbances such as Grid disturbances, failures (discussed above), human errors etc., and data over a wide time scale can accurately describe the behavior of the systems.

II. METHODOLOGY AND COMPUTATION

Evaluating the performance and availability of the total power plant is a very difficult task and is beyond the scope of the project. For the analysis and evaluation of reliability and availability of boilers and turbo generators a Two state Markov model is adopted. The primary point of consideration is the transition of the state from upstate to any of the down states and back (after repair).

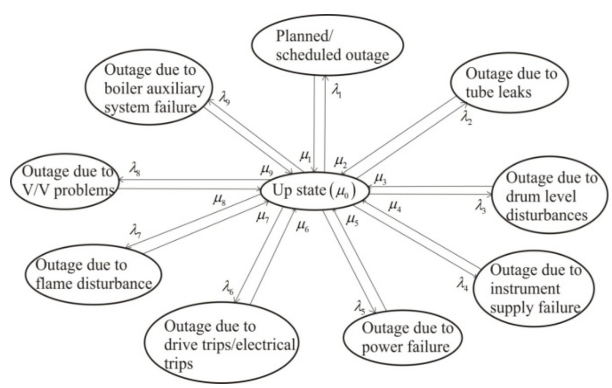


Fig.1 state transition diagram of Boilers

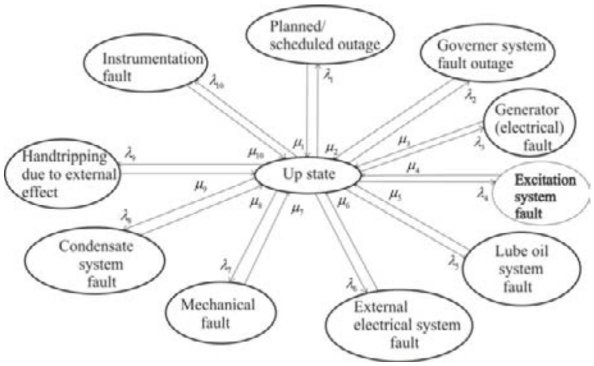


Fig.2 state transition diagram of Turbo Generators

By using the two state Markov process we can derive the state equations and the probabilities of the states can be derived.

State equation for one state is shown below:

$$\frac{dP_1(t)}{dt} = -\lambda_1 P_0(t) + \mu_1 P_1(t)$$

Probability of each unit being in state 1 that is being in upstate is given as $P_0(t) = d_0 / D$.The availability and reliabilities of both boilers and turbo generators are computed based on the state probabilities. Reliability of a boiler or turbo generator is given by the sum of probability of being in state-0 and state-1.That is $R(t) = P_0 + P_1$.The availability of the component is probability of being in state-0 that is $A(t) = P_0$.

Total Down Time = Σ (down time due to individual failure states)

No. of Outage occurrences in a specified time interval = N

Forced Outage Hours (FOH) = Downtime of a State

Forced Outage Rate (FOR) = Outage Hours of the State / SH

Mean Time to Failure (MTBF) or Mean Up Time (MUT) = SH / N

Mean Time to Repair (MTTR) or Mean Down Time (MDT) = FOH / N

Failure Rate (λ) = 1 / MTBF or 1 / MUT

Repair Rate (μ) = 1 / MTTR or 1 / MDT

Availability (A) = μ / (λ + μ) = d_0 / (Σ d)=P_0

Unavailability = λ / (λ + μ)

Reliability (R) = (d_0 + d_1) / (Σd) =P_0+P_1

TABLE 1: State Numbers and State Probabilities

State number	State probabilities	
0	μ1 μ2 μ3 μ4 μ5 μ6 μ7 μ8 / D	*d0 / D*
1	λ1 μ2 μ3 μ4 μ5 μ6 μ7 μ8 / D	*d1 / D*
2	μ1 λ2 μ3 μ4 μ5 μ6 μ7 μ8 / D	*d2 / D*
3	μ1 μ2 λ 3 μ4 μ5 μ6 μ7 μ8 /D	*d3 / D*
4	μ1 μ2 μ3 λ 4 μ5 μ6 μ7 μ8 / D	*d4 / D*
5	μ1 μ2 μ3 μ4 λ 5 μ6 μ7 μ8 / D	*d5 / D*
6	μ1 μ2 μ3 μ4 μ5 λ 6 μ7 μ8 / D	*d6 / D*
7	μ1 μ2 μ3 μ4 μ5 μ6 λ 7 μ8 / D	*d7 / D*
8	μ1 μ2 μ3 μ4 μ5 μ6 μ7 λ 8 / D	*d8 / D*
9	μ1 μ2 μ3 μ4 μ5 μ6 μ7 μ8λ9 / D	*d9/ D*

Where D= d0+d1+d2+d3+d4+d5+d6+d7+d8+d9

TABLE 2: Calculations of Turbo Generator-4 for the year 2012-13

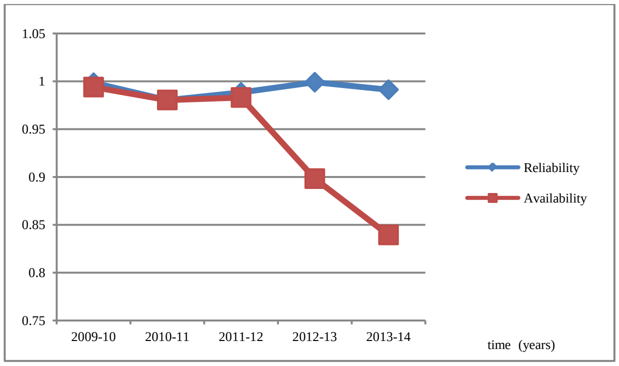
State No.	**No. of Occurrences**	**Repair Time (hr)**	**MTTR (hr)**	**MTBF (hrs)**	**μ (repair rate)**	**λ (failure rate)**	**d**	**State Probability (P)**
0							1.76E-05	0.936154466
1	4	15	3:45	2025:45:00	0.2666667	4.95E-04	3.26E-08	0.001736191
3	2	3	1:30	4045.5	0.6666667	2.47E-04	6.51E-09	0.000347238
6	4	72	18	2040	0.05555556	4.95E-04	1.56E-07	0.008333718
7	5	26	5:20	1623	0.19230769	6.18E-04	5.65E-08	0.003009399
8	2	3	1:30	4045:30:00	0.6666667	2.47E-04	6.51E-09	0.00347238
9	6	433	72:10	1420:10	0.01386963	7.42E-04	9.39E-07	0.05007175

From the above table it is clear that Reliability (R) = Po+P1=0.93789066

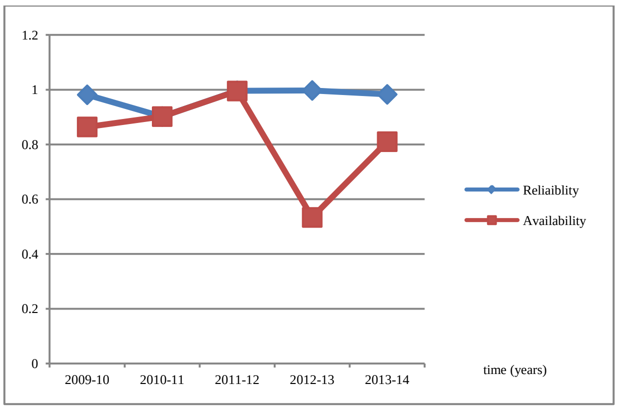
Availability (A) = Po=0.936154466

Annual unit reliability and availability unit wise are given in following figure-3 to figure-11:

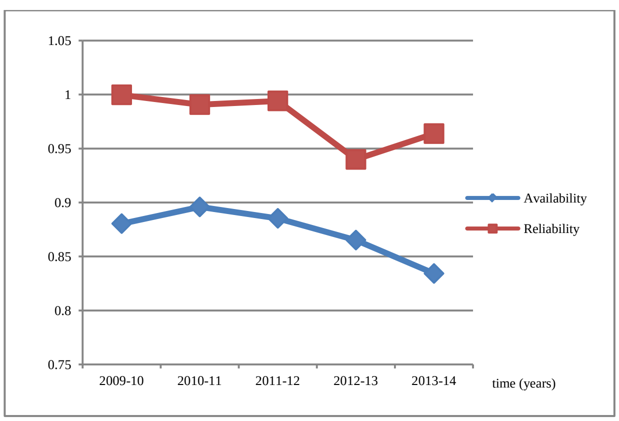
Boiler-1



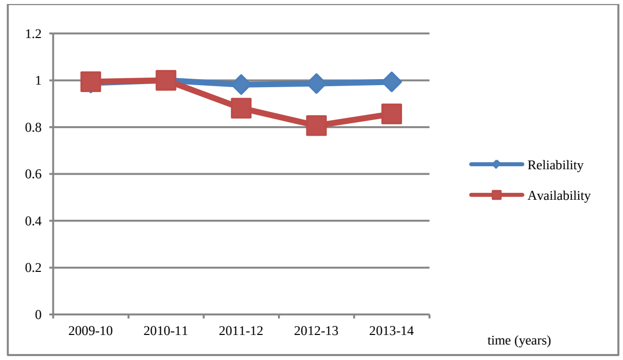
Boiler-2



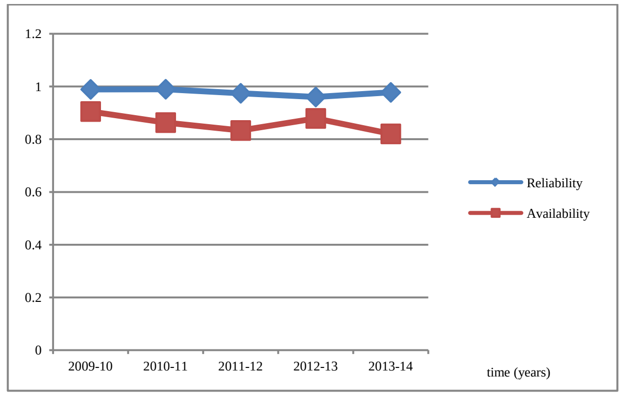
Boiler-3



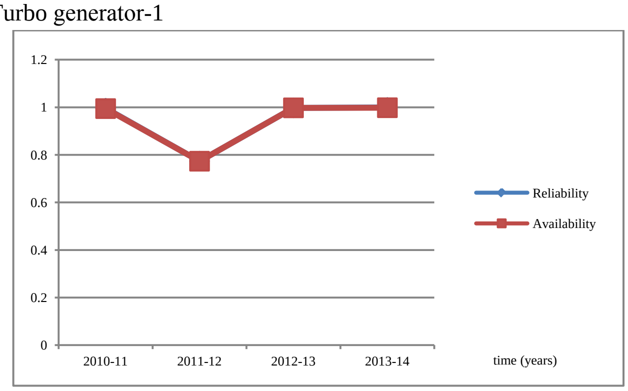
Boiler-4



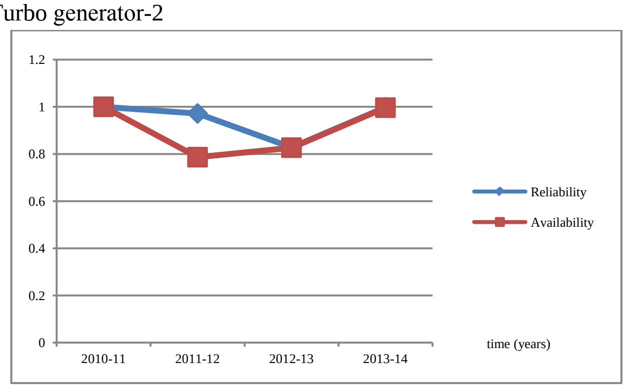
Boiler-5



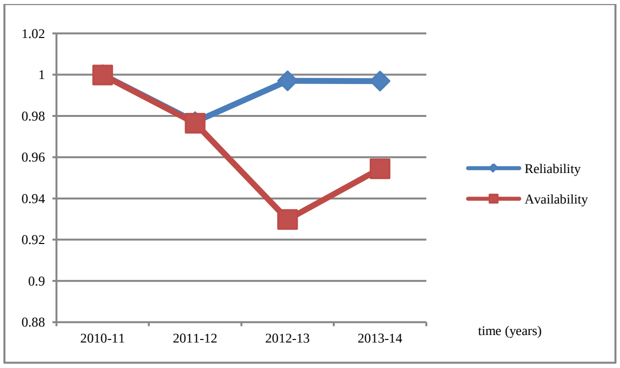
Turbo generator-1



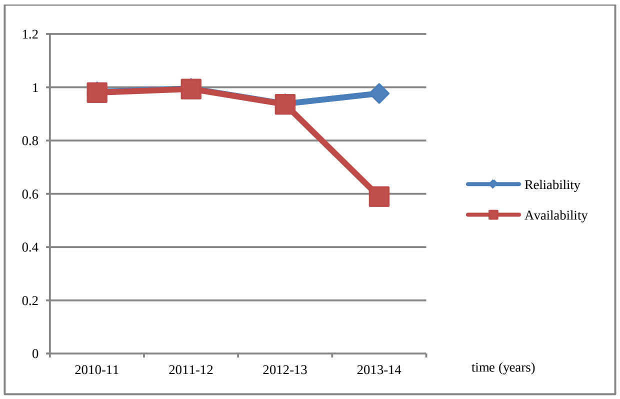
Turbo generator-2



Turbo generator-3



Turbo generator-4



III. DISCUSSIONS AND CONCLUSIONS

Boiler-1: For Boiler-1 in 2012-13 and 2013-14 the availability is less it is because of the high scheduled outage time.

Boiler-2: For Boiler-2 in 2012-13 availability is less, it is because of high scheduled outage time and outage due to critical power failure.

Boiler-3: For Boiler-3 in 2012-13 and 2013-14 availability is less it is because of outage due to tube leaks and outage due to drum level disturbances is high.

Boiler-4: For Boiler-4 in 2011-12 and 2012-13 availability is less it is because of outage due to tube leaks, outage due to drum level disturbances and outage due to flame disturbances.

Boiler-5: For Boiler-5 in 2012-13 availability is less, it is because of high scheduled outage time and outage due to boiler auxiliary system fault.

TG-1: For Turbo generator-1 in 2011-12 availability is less it is due to the generator (electrical fault), lubrication system fault, external electrical system fault and Instrumentation system fault.

TG-2: For Turbo generator-2 in 2011-12 and 2012-13 availability is less it is due to external electrical system fault and hand tripping due to external effects.

TG-3: For Turbo generator-3 in 2012-13 availability is less it is due to lubrication oil system fault, external electrical system fault and mechanical system fault.

TG-4: For Turbo generator-4 in 2013-14 availability is less it is because of lubrication oil system fault, external electrical system fault and hand tripping due to external effects.

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AUTHORS PROFILE

P.Lalitha Chamundeswari has received her Bachelor of Engineering degree in Electrical & Electronics Engineering from GITAM college of Engineering Visakhapatnam in the year 2011. She pursued her M.E with the specialization of Industrial engineering from Andhra University college of Engineering, Visakhapatnam. Her area of interest is reliability of power systems, reliable Control systems.

Dr. V. Vijaya Babu has received his Ph.D from Indian Institute of Technology Kharagpur. At present he is working as a Professor in Mechanical engineering department, Andhra University college of Engineering, Visakhapatnam.