A SOFT COMPUTING FRAMEWORK FOR RELIABILITY ANALYSIS OF THERMAL POWER PLANTS

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Abstract : The thermal power plant is an assembly of various mechanical and electrical equipments which helps in the production, generation and transmission of electric power. In this process, there are several components which undergo repairs and failures due to various factors such as wear, temperature and so on. Hence, there is a need to estimate the reliability of these components as well as for the entire system for proper functioning and its safety.

In the present work, the most important equipments of a thermal power plant are considered for reliability analysis. These equipments are turbine, boiler, compressor, generator and condenser which consists the maximum failures due to their rapid working and large no. of components .The frequent failure of the components both uneconomical and hazardous problems for the entire plant.

In this work, reliability analysis has been performed for all the machines using empirical and parametric methods and a comparison between these methods has been performed and it has been observed that parametric method gives more accurate and efficient results than empirical method. To simplify the traditional analysis, in this work a software package using html language has been developed which gives quick implementation of reliability analysis of systems. It is very useful for the managers and supervisors in the process industries for reliability and maintainability analysis and to implement better maintenance policies.

Keywords: Maintainability analysis, parametric method, process industries, Reliability analysis.

Introduction: The thermal power plant is an assembly of various mechanical and electrical equipments which help in the production, generation and transformation of electric power. In this process, there are several components which undergo repairs and failures due to various factors such as wear, temperature … so on. Hence, there is a need to estimate the reliability of these components as well as for the entire system for proper functioning and its safety. Chee T.S. and Yeo K.T, (2000) described the risk analysis of Build Operate Transfer, (B.O.T) Power project by using three techniques namely probability analysis, sensitivity and Variance analysis to reduce the risk and increase reliability. Della S.A et al (2006) explained a system called ORAP (Operational Reliability Analysis program) which is reliable and maintainable report system with special focus on gas turbines. The main purpose of the ORAP is to support the industry on high reliability. Implementing this modeling process consists various phases such as Identification of critical systems and components, anticipation of system failure modes, achievement of goals for increased reliability and minimized costs . Cun Li gang et al (2011) presented reliability analysis on the electrode plates driving system with the analysis of the water resistance test system of high speed diesel locomotive. Stress strength interference theory and item stress analysis are applied to its mechanical and electrical parts to derive reliability calculation formulae .

In the present work, the most important equipments in a thermal power plant which consists of the turbine, boiler, generator compressor and condenser are considered for reliability analysis. These equipments consist of the maximum failures of the components which cause both uneconomical and hazardous problems for the entire plant. To perform the reliability analysis, in this work a systematic frame work has been proposed with the application of empirical as well as parametric methods.

Introduction to Reliability Assessment of System:

Reliability is defined as the probability of a component or system that will perform a desired function for a given period of time when used stated operating condition. Reliability Engineering, like other engineering and scientific disciplines, should adhere to the scientific method. In this context the steps required in following the scientific method include problem definition, observation and the collection of data, the analysis of the data and formulation of one or more mathematical models, verification of the model, solution of the model and implementation of the solution. In the present work, the most important equipments in a thermal power plant which consists of the turbine, boiler, generator compressor and condenser are considered for reliability analysis. The Reliability analysis of these equipments is described first by using empirical method and after that by using parametric methods as follows.

Reliability Analysis of Turbine Using Empirical Method:

Empirical methods of analysis are also referred to as nonparametric methods or distribution free methods and it is very easy to conduct for the analysis. The objective is to derive, directly from the failure times, the failure distribution, reliability function, and hazard rate function. This method however is used in case when no theoretical distribution adequately fits the data.

In the present study, initially the empirical method has been considered for the reliability assessment of the turbine as follows:

Model calculation for Reliability Analysis of Turbine:

In this work, the number of failures of turbine in five years has been collected from maintenance log books of the Vemagiri thermal plant. The calculation of reliability, failure rate and probability density functions are given below in table and represented in the Figure.

Reliability $R(t_i) = n_i / n$

Failure density $f(t) = (n_i - n_i+1) / (t_i+1-t_i).n$

Hazard Rate $\lambda(t) = f(t)/R(t) = (n_i - n_i+1) / (t_i+1-t_i).n_i$

Where n_i (i=1, 2, k) = no. of units survived at time t_i (i=1, 2 ...k)

n= no. of. Units at the risk at the start of the test.

$R(t) = n_i / n = 105/119 = 0.8823$

$f(t) = n_i - n_i+1 / (t_i+1-t_i)\, n = 119-105 / (6*119) = 0.0112$

$\lambda(t) = f(t)/R(t) = 0.8823/0.0112 = 0.0126$

By using the above mentioned empirical formulae the reliability, failure rate and probability density functions of turbine are calculated and presented in Table 1 and the reliability of this equipment w.r.t time has been represented in Figure 1.

Table1. Reliability analysis for Turbine

Time	No.of. failures	No.of survivals	Reliability	Probability density function	Hazard rate
0	0	119	1	0	0
6	0	119	1	0.0196	0.0196
12	14	105	0.8823	0.0112	0.0126
18	8	97	0.8151	0.01400	0.01717
24	10	87	0.7310	0.0196	0.0268
30	14	73	0.6134	0.007002	0.0114
36	5	68	0.5714	0.0126	0.0220
42	9	59	0.4957	0.019600	0.0395
48	14	45	0.3781	0.007002	0.0185
54	5	40	0.3361	0.005602	0.01666
60	4	36	0.3025	0.005602	0.01851
66	4	32	0.2689	0.005602	0.0208
72	4	28	0.2352	--------	-------

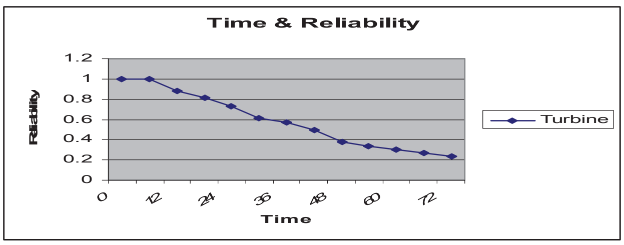

Fig 1. Reliability analysis of Turbine

By using the similar procedure the calculations of reliability is performed for the remaining equipments of the plant and are presented as follows.

Name of the Equipment	Reliability
Boiler	0.8025 (R_1)
Compressor	0.7836(R_2)
Turbine	0.8293(R_3)
Condenser	0.8291(R_4)
Generator	0.71001(R_5)

3.2. System Reliability Evaluation using Empirical Method:

Reliability Block Diagram for the present thermal power plant is as follows.

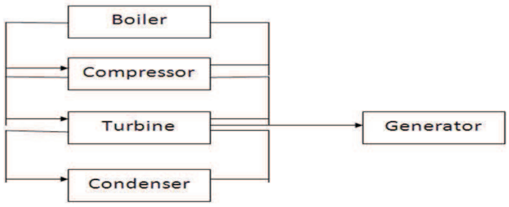

Fig 2. Reliability Block Diagram

Let E_1 = the event that component does not fail

E_2 = the event that component does not fail

Then $P(E_1) = R_1$ and $P(E_2) = R_2$

Where R_1 = the reliability of component 1

Where R_2 = the reliability of component 2

Therefore $Rs = P(E_1 \cap E_2) = P(E_1)\, P(E_2) = R_1 * R_2$ assuming that the two components are independent.

Generalizing to n mutually independent components in series, then

$Rs(T) = R_1(t)*R_2(t)* ......* Rn(t) < \min\{R1(t), R2(t), ...Rn(t)\}$

Generalizing to n mutually independent components in parallel, then

$Rs = P(E_1 \cup E_2) = 1-(1-P(E_1))(1-P(E_2))$

For combined series and parallel systems both these formulas are used.

The system reliability is calculated as follows:

The complete system is in combined series and parallel combination system as shown in Figure2. So the system reliability is given as follows:

$R(s)_1 = 1-(1-R_1)(1-R_2)(1-R_3)(1-R_4) = 0.4326$

$Rs = Rs_1 * R_{s2} = 0.4326*0.71001 = 0.3071$, where R_{s2} is the reliability of the Generator.

4. Reliability Analysis Using Parametric Method:

The available theoretical distributions in parametric methods are normal, lognormal, Weibull, exponential. Parametric statistics is a branch of statistics that assumes that the data has come from a type of probability distribution and makes inferences about the parameters of the distribution. Most well known elementary statistical methods are parametric. Generally speaking parametric methods make more assumptions than non parametric methods. If those extra assumptions are correct parametric methods can produce more accurate and precise estimates. They are said to have more statistical power.

4.1. Introduction to Weibull method:

The probability density function of a Weibull random variable x is:

f (x, λ, K) = { o$^{K/λ(X/λ)}$ e$^{-(x/λ)}$ x ≥ o, X < o. (t/θ) ß

Reliability R (t) = exp- (t/θ) ß

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Failure rate function λ (t) = (β/θ) (t/θ) ß$^{-1}$

Failure density f (t) = exp-(t/θ) ß* $^{(}$β/θ) (t/θ) ß$^{-1}$

4.2. Model calculation for Reliability Analysis of Turbine:

In this work, the number failures of turbine in five years have been collected from the maintenance log books of the power plant. By using an available statistical software the distributions of the number of failures has been calculated and indentified that they are best fitted to weibull distribution as shown in Figure3.

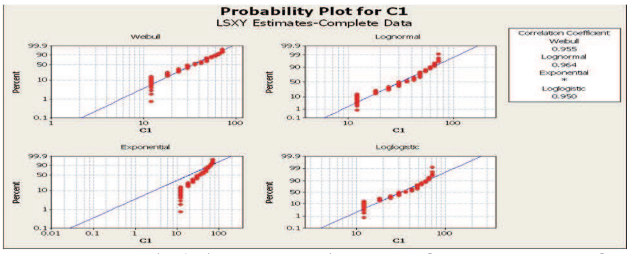

Fig 3. Probability Distribution fitting curve for turbine

The parameters obtained from the above process are ß= 3.16087, θ= 7.34968. Using these parameters reliability, failure rate and f (t) have been calculated according to weibull distribution as follows.

4.3. Reliability analysis of turbine using Parametric method:

Reliability R (t) = exp- (t/θ) ß = exp-(6/7.34968) $^{3.16087}$ = 0.5906

Failure rate function λ (t) = (β/θ) (t/ θ) ß$^{-1}$ = = 0.2774

Failure density f (t) = exp-(t/ θ) $^{ß * (}$β/θ) (t/θ) ß$^{-1}$ = = 0.16

Table2. Reliability analysis of turbine using Parametric method

Time	No. of. failures	Reliability	Failure rate	Hazard rate
0	0	1	0	0
6	0	0.5906	0.2774	0.1638
12	14	$9.007*10^{-3}$	1.24052	0.01117
18	8	$4.2811*10^{-8}$	2.9793	$1.2754*10^{-7}$
24	10	$5.0940*10^{-19}$	5.5474	$2.8238*10^{-18}$
30	14	$9.2287*10^{-38}$	8.9846	$8.2916*10^{-39}$
36	5	$1.2558*10^{-66}$	13.3230	$1.6731*10^{-65}$
42	9	0	18.5894	0
48	14	0	24.8072	0
54	5	0	31.9972	0
60	4	0	40.1780	0
66	4	0	49.3666	0
72	4	0	59.5785	0

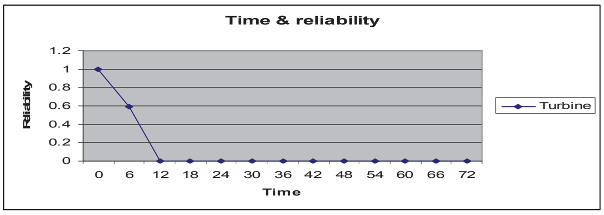

Fig 4. Reliability analysis of Turbine

By using the similar procedure the calculation of reliability, failure rate and probability density functions is performed for the remaining equipments of the plant and are presented as follows.

Name of the Equipment	Reliability
Boiler	0.7367 (R_1)
Compressor	0.6552 (R_2)
Turbine	0.7691 (R_3)
Condenser	0.7634 (R_4)
Generator	0.4673 (R_5)

System Reliability Evaluation using Parametric Method:

By using the similar procedure as explained earlier, the System reliability has been calculated and comparison between parametric and Empirical methods has been made as follows.

Method used	System reliability
Empirical method:	0.3071
Parametric method:	0.3348

Conclusions: In this work, the reliability analysis of all the equipments of a thermal power plant has been performed. It has been observed that the parametric method gives more accurate and efficient results in performing the system reliability analysis. The presented soft computing frame work for the reliability analysis is very useful for practicing engineers, managers and supervisors in various industries.

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