Criticality Analysis of GTPPS

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ABSTRACTS

The paper is concerned with the study of criticality analysis of components of Gas Turbine Power Plant Systems (GTPPS) and the failures occurring in the plant. Failure mode and effect and criticality analysis (FMECA) is carried out to estimate the criticality number for different components and failure modes. In addition the failure effects, higher effects and end effects are incorporated in the final FMECA sheet. The criticality results compensating provision will highlight possible ways to tackle the failures economically. The findings in this Paper are (1) criticality index of the components (2) Critical failures (3) compensating provision of critical failure.

Keywords: *Maintenance, Criticality Analysis, Failure mode effect and Criticality Analysis (FMECA), Failure rate*

1) Introduction

A power plant may be defined as an assembly of machines or equipments that generate either mechanical or electrical energy from fuel and delivers it to the transmission section. Its main equipment is generator which is coupled to a prime mover to generate, electricity. The type of prime mover determines the type of power plants. Which are divided into two types, viz. conventional and non conventional [28]. The different types of conventional power plants are steam, diesel, gas turbine, nuclear, and hydro electric power plants. The non-conventional power plants are thermo electric generator, solar energy, fuel cells, photovoltaic solar cell, magneto hydrodynamic generator (MHD) biomass and biogas, geo thermal, wind energy, ocean thermal energy conversion, wave and tidal wave power plants [3]. The power plant which uses natural gas or liquefied natural gas (LNG) as fuel is called Gas Turbine Power Plant System (GTPPS) [13].

Compared to large power stations, such as coal fired stations and nuclear stations, the capital investment of gas turbine driven power plants is lower and the construction lead times are shorter [14]. Moreover reserved natural gas is easy to transfer from one location to any other location and is sufficiently available with respect to other fuels [12]. The life cycle costs of GTPPS can be decomposed into three major elements: Project Investment Cost, Fuel Cost, Plant Operations and Maintenance Cost [9, 29]. In modern times, it is observed that the operation and maintenance costs may comprise up to 15% to 20% of the total life cycle costs [27]. The productivity of GTPPS is optimized by generation scheduling, maintenance scheduling, outage planning, and advanced technology up-gradation. Every power plant had some unit commitment [27, 35].

Gas turbine units degrade and deteriorate as they age. Different preventive maintenance activities such as combustion inspection, hot gas path inspection and complete overhauling are scheduled at prescribed maintenance intervals for each gas turbine unit [2]. In this context the maintenance practices may be optimized to achieve the maximum profit. By minimizing system maintenance cost rate considering generation scheduling.

The Failure Mode and Effects Analysis (FMEA) is also carried out to identify the critical components of GTPPS and the maintenance policy for those critical components based on RCM concepts are proposed [16]. N. Keren *et al* present a methodology that uses equipment reliability databases and a process of benchmarking to establish a continual improvement procedure [19]. S.O.T Ogaji *et al* used non linear Gas Path analysis such as oil analysis, vibration analysis model to predict the fault and finally concluded that over-instrumenting the engine does not necessarily provide a better diagnosis but increase the unnecessary cost [25]. N.S Arunraj *et al* presented the maintenance selection procedure based on risk of equipment failure and cost of maintenance. The mathematical tool analytical hierarchy process (AHP) and goal programming is used for maintenance policy selection [1].

Planning is needed to increase service time and quality service of GTPPS. The analysis and measurement of criticality of equipments is required to further reduce the risk of the consumers and operating personal and may be done by different tools and techniques, such as Failure Mode and Effect Analysis (FMEA), Failure Mode and Effect and Criticality Analysis (FMECA), Fault Tree Analysis (FTA), Cause and Effect Analysis, Pareto Analysis, Scatter Diagram, Check sheet, TTT plot, Serial Correlation tests, Duane Plot, We Bull analysis, Markov analysis and Petrinet analysis and energy market. As GTPPS is a very complex system, the vital issue of the operating personnel is to identify its critical components at the time of maintenance to minimize its downtime [31]. The availability of a complex system is strongly associated with the parts reliability and maintenance policy, which not only has influence on the parts repair time but also on the parts reliability affecting the system degradation and availability [34]. The reliability of its component parts will increase if the items are properly maintained.

Under the ongoing reformation of the electric supply industry in China and India, the transmission part is particularly taken care of separate power grid and as a result generation companies can concentrate more on power production and thus entering and capturing the power market for selling their product [10]. For the survival of existence in the power market, generation utilities are expected to improve the usability and reliability of machines by the most efficient measures. The development of the modern new technologies has promoted fundamental changes in the working structure and processes of GTPPS [12].

Accordingly the concept of looking after all the equipments has come down to the concept of significant Fews that is the Critical Equipments. The method of identifying these critical equipments is done by Failure Mode Effect and Criticality Analysis [FMECA] and Failure Mode and Effect Analysis [FMEA].

Failure Modes and Effect Analysis (FMEA) and Failure Modes Effects and Criticality Analysis (FMECA) were first developed as formal design methodologies in the 1960s by the aerospace industry with their obvious reliability and safety requirements [24]. FMECA process is a procedure by which each potential failure mode in a system is analyzed to determine the results or effects on the system and to classify each potential failure mode according to its Criticality number and is ranked according to the Criticality Index Number [21, 26]. FMECA technology can be employed in reliability analysis as well as in supportability analysis for equipment development at present [18]. Among many systematic techniques, FMECA has been applied to analyze the safety and reliability of many complex systems for many years, such as Medical Technological Industries [17], Food Industry [33], Process Industry [7] and GIS components [32]. As it is applicable for above-mentioned complex systems, it may also be applicable to GTPPS. In this context, it helps to find out the critical components and failure modes of maintenance system at the operating stage. This paper contains description of subsystems of GTPPS; failures modes of subsystems of GTPPS, the methodology for calculating criticality index of GTPPS, Subsequently the results of failure mode and effect, criticality analysis of GTPPS and failure mode effects, end effects, compensating provisions and failure detection procedures are incorporated. The list of terms and abbreviations used in this paper are added at the end of the paper in appendix A.

2) Description of GTPPS Components and Failures

The gas turbine obtains its power by utilizing the energy of burnt gases and air which is at high temperature and pressure by expanding through the several ring of fixed and moving blades. A compressor is required to get the high pressure of the order of 4 to 10 bar of working fluid. The turbine drives the compressor and coupled to the turbine shaft.

Gas turbines are described thermodynamically by the Brayton cycle, in which air is compressed isentropically, combustion occurs at constant pressure and expansion over the turbine occurs isentropically back to the starting pressure.

Thrust and journal bearings are a critical part of design. Traditionally, they have been hydrodynamic oil bearings, or oil-cooled ball bearings. These bearings are being surpassed by foil bearings, which have been successfully used in micro turbines and units. In this paper the journal bearing is designated as no #2 bearing and supportive thrust bearing is no #1 bearing.

Gas turbines are constructed to work with oil, natural gas, coal gas, producer gas, blast furnace gas and pulverized coal with varying fractions of nitrogen and impurities such as hydrogen sulfide are used as Fuel. Each unit of GTPPS consists of five main components, viz turbine, compressor, combustion chamber, Generator and electric system supporting the whole unit. The various stages of operation are shown in the figure 1.

<Take in Figure 1>

The main components of the GTPPS plant is described with following sections:-

(1) Compressor

The compressor in a GTPPS power plant handle a large volume of air or working media and delivering it at about 4 to 10 atmosphere pressure with highest possible efficiencies. The axial flow compressor is used for this purpose. The common types of failures found in the compressor of GTPPS system is as follows:

(a) High Exhaust Temperature
(b) Differential Trouble Air inlet

(2) Combustion Chambers

The combustion chamber perform the difficult task of burning the large quantity of fuel, supplied through the fuel burner with extensive volume of air supplied by the compressor and releasing the heat at all conditions required by the turbine. The common types of failures found in the combustion chambers of GTPPS system is as follows:

(a) Loss of Flame
(b) Servo Trouble

(3) Gas Turbine

A gas turbine used in power plant converts the heat and kinetic energy of the gases into work. The basic requirements of the turbines are lightweight, high efficiency, reliability in operation and long working life. The common types of failures found in the Gas Turbine component of GTPPS system is as follows:

(a) High Pressure (H.P) Turbine under speed
(b) Low Pressure (L.P) Turbine Over speed
(c) Wheel space differential temperature high
(d) Mist eliminator Failure/Trouble
(e) Turbine Lube Oil Header Temperature High
(f) Low hydraulic pressure
(g) Bearing drain oil temperature high

(4) Generator

Generator is a machine which converts mechanical energy into electrical energy (or power). In a generator, an e.m.f. is produced by the movement of a coil in a magnetic field. The common types

of failures are found in the Generator of GTPPS system is as follows:
(a) P.M.G bolt broken

(5) Electrical Systems

The A.C. power circuit ignition system receives an alternating current that is passed through a transformer and rectifier to charge a capacitor. When the voltage in the capacitor is equal to the breakdown value of a sealed discharge gap, the capacitor discharges the energy across the face of the ignition plug. Safety and discharge resistors are fitted in the circuit. Except this various circuit breakers, Relay system, Bus Bars, control panels, transformers are used in electrical systems. The main function is linking the produced generation to hungry consumers'. The common types of failures found in the Electrical systems of GTPPS system is as follows:
(a) De Synchronization with Grid
(b) Relay Fault
(c) Under Frequency

3. Criticality Index

In the failure analysis there are two types of Criticality Numbers one is Component Criticality Number (CCN) another is Failure Mode Criticality Number (FMCN) are used. A component may have more chances modes of failures. Each failure mode has criticality numbers. When all failure mode criticality numbers are added this will give the component failure mode criticality number which is represented as follows:

$$C_r = \sum_{i=1}^{N} (C_m)_i$$

Where $(C_m)_i$ denotes the individual failure mode criticality number.

R – denotes rth Component
m – failure mode, i– i th failure mode
N – total number of failure modes of a component

For a particular severity classification the C_r for an item is the sum of the failure mode criticality numbers $(C_m)_i$ is defined as Criticality number of ith Failure mode of a Component and is calculated as follows:

$$(C_m)_i = \beta.\ \alpha.\ \lambda.\ T$$

Where β be the loss probability
α be the failure mode ratio
λ be failure rate
T be operating hours probability [18].

β loss probability
It represents the conditional probability that the failure rate with the specified criticality classification will occur given that the particular failure mode occurs For complex system β is difficult to calculate and thus primarily a matter of judgment.

Failure rate
The failure rate is expressed in terms of failures per unit of time such as failures per hour or failures per 100 or 1000 hours. It is computed as a simple ratio of the number of failures f during a specified test interval to the total test time of the items or undergoing test and it is denoted by λ [4].
Calculation of failure rate: -

Thus, $\lambda = f / T$.
Where λ = failure rate
F = No of failures during the test interval
T = total test time.

Failure mode ratio (α):
An item has several modes of failures. The failure mode ratio is the probability expressed as a decimal fraction that the item will fail in the identified mode of failure if all the several failure modes probabilities of that item are listed. For example an item bearing has three failure mode(1)scored bearing(2)scored bearing race(3)cracked bearing race. Suppose it was estimated that 50 % of the bearing failures are in the first Mode, 40% in the second Mode and 10 % is in the third mode than failure Mode ratios are 0.50, 0.40, 0.10 when multiplied by the component failure rate this will give the Mode failure Rate. The sums of all the Component failure Mode ratios are equal to 1. Here we have calculated as the numbers of failures for particular failure mode divided by the total failures of the unit [18].

4. Steps in Performing FMECA of GTPPS

The procedure for carrying out the criticality value estimation of GTPPS systems are described in the following section as mentioned below:

Step I: Development of Functional Block Diagram:

The first step is to obtain all the information which includes specifications, operating conditions, operating data, and stress results, available at the operating stage of GTPPS system. It is also important to describe the GTPPS very efficiently and its description may be done at the highest level. At this highest level of description, the system is to be represented by a functional block diagram. The functional block diagram of the GTPPS, as prepared, illustrates the operation, interrelationship, and interdependence of the functional entities of the system. The functional block diagram of this system is shown in Fig. 1 and 2 as follows.

<Take in Figure 2>

In the Table 1, as shown below, the components that support each system function are described. In the Table 2, different functions and functional description are provided in the first two columns respectively. The components involved in the third column of the Table 1 are known as components involved in fulfilling that function.

<Take in Figure 1>

Step II: Identification of Relevant Parameters and Variables, and Collection of Relevant Data

The parameters of GTPPS subsystems and system are as follows:
(i) Different functional relationships
(ii) Different operating modes existing
(iii) Effects of failures
(iv) Next higher effects of failure modes, and end effects of failure mode

The relevant variables are as follows:
(i) Types of failures, and
(ii) Failure times

Decisions regarding sample sizes and sampling frequency for the variables identified and units of analysis, system-level as well as subsystems of GTPPS are to be made and objectives of the study. A standardized framework and format for data collection is to be designed for this purpose. The compensating provision of each failure modes are to be identified.

Step III: System-level Analysis

On completion of data collection, Criticality number of each failure modes of GTPPS and subsystems are identified, selected and calculated. The criticality number is the product of failure mode ratio, loss probability, operating hours and failure rates and for each GTPPS subsystem and failure modes are calculated. A logic diagram for performing these FMECAs is made for this purpose. Details of constructing logic diagram are available in reference [6].

Step IV: Suggestion for Improvement

In this stage, suggestions on design changes of GTPPS subsystems are to be made. It is worth mentioning that design options are to be separately analyzed, so that reliability implications may be considered. Analyzed results may be used to update the system performance. The methodology for FMECA of GTPPS is explained in detail with the help of flow diagram as shown in Fig.3 Here a basis for demarcation of criticality number more than 40 is taken as most critical component and failure mode criticality number more than 5 is taken as most critical Failure modes. The failure detection modes are shown below in Table 5 [30].

<Take in Figure 3>

<Take in table 2>

5. Results

Rukhia Power plant is situated around 10 kilometers south direction of Agartala, the capital of the state Tripura. It has total 8 units. Each unit consists of main components and sub components. Among the 8 units four units are of 8 M.W. capacities. The two units retired from operation in the year 1996, and rest two units are of 21 M.W. capacity. The retired units are commissioned in the year 1990 All the rest 6 units are commissioned after 1995 .Each unit consists of main components and sub components. The data collection period is from 24.01.05 to 19/06/2010 = 5.5 years (approximate)) = 1995 days = 47880 hours. Each unit consists of one compressor unit, one combustion unit, one turbine unit, one generator unit and supporting electrical systems. The plant runs using the Brayton thermodynamic cycle.

The failure rate is expressed in terms of failures per unit of time:-

λ=F/T

Total failures observed = 858

Here we have taken Unit no 4 for the analysis

Analysis of the failure events of unit no = 4 (Period from 24.01.05 to 19/06/2010 = 5.5 years (approximate) =1995 days=47880 hours

Total repair time=497 hours

So total operation time without repair time = 47880-497=47383

So failure rate of unit 4 = 253/47383=5.336X10 $^{-03}$ failures/hour.

Based on the analysis (given in section 3 and 4) the component failure rates for different modes and criticality indexes are shown in table 6 and 7. The result shows that Combustion chamber is the most critical component and H. P. Turbine under speed, Loss of flame, Resynchronization, P.m.g. bush damaged are the most critical failure modes. A table showing the failure modes of different failures and their effects next higher effects and how to compensate these effects are presented in FMECA table 8. Details of constructing the table are discussed in Reference [4]

<Take in table 3>

<Take in table 4>

<Take in table 5>

6. Discussion

The research work undertaken addresses several issues on failure analysis and criticality determination of Gas Turbine Power Plant systems. The main focus of this research is to study the working and performance of G.T.P.P.S. systems and to carry out in particular, failure and Criticality analysis of Power plant sub components and components. The results derived have been calculated from the Rukhia Power Plant run on GTPPS. In essence, the research in the field of failure and criticality of GTPPS power plant systems is needed mainly because of the following two reasons:

(i) Criticality determination of the existing power plant and methodologies for failure analysis for finding the critical failure modes and components and taking preventive measures to improve the plant reliability.

(ii) It is felt that a comprehensive modeling of GTPPS criticality systems taking into account of all the required input variables is to be developed the appropriate reliability model is also required to be developed, based on the pre and post measures taken on the basis of criticality results.

The important findings of the research are listed below.

1.) From a simple to a complex one, about thirty six different kinds of failure modes have been developed to represent different failures occurring in the GTPPS systems

2.) The different types of failures and their causes are listed, so that one can easily understand about the nature of failures and how to tackle these failures.

3.) The criticality analyses for all the failures are carried out, so as to identify the potential critical failures and future maintenance planning to tackle the particular failure not occurring in future in power plants. Similarly the critical items in component level were also identified so that the manager can make advance planning about that equipment about possible design changes or maintenance strategy to tackle these components in future.

7. CONCLUSIONS

The research work on the GTPPS system, the first of its kind for the power plant in eastern India has contributed significantly to the body of knowledge in failure mode and criticality analysis. In particular, the following contributions are worth mentioning:

(i) About 36 different failure modes are identified and their criticality numbers are determined so as to know the potential mode of failures and to take necessary actions. Such a broad research framework is a unique comprehensive.

(ii) About 6 different components are analyzed to find the critical equipments When such components are identified the plant manager can fix the maintenance strategies and design modifications for the improved performances.

(iii) The risky components and failure modes are easily identified by incorporating the occurrence of failure mechanism. Thus as a result both the RPN and Criticality can be identified in one analysis

8. Scope for Further Research

Though a number of pertaining issues of Gas Turbine Power Plant systems has been investigated by the author, any study of this scale opens up new opportunities to carry out similar studies in future. However, based on experience and research in this area, the author identifies the following important areas, or issues of GTPPS systems, which need further research:

(a) In order to lessen the effect of subjectivity in the tools used in Criticality modeling a fuzzy-based modeling approach may be employed for enhancing the applicability and usefulness of research

(b) In order to simulate the proposed methodology, the F.M.E.A. approach may be used,

(c) The methodology as described in this Paper assumes the subsystem of the GTPP as repairable or replaceable one. In many circumstances or in extreme conditions many of these subsystems and components may not be repairable on their failure. For example the unit I and VI are failed totally after running only8760 and 4320 hours. The reliability estimation methodology needs to be developed under this condition

(d) A pertinent and F.T.A. approach can be developed for identification of faults

(e) Risk based method for maintenance policy selection and comparative cost basis maintenance can be incorporated

9. NOMENCLATURE

(1) H.P.:-High Pressure
(2) Low Pressure
(3) P.M.G:- Permanent magnet generator
(4) GTPPS Gas Turbine Power Plant System
(5) G.E.: General Electric corporation
(6) λ Failure rate
(7) α Failure mode ratio
(8) β loss probability
(9) m = failure mode
(10) FMECA: failure mode effect and criticality analysis
(11) FMEA: Failure Mode and Effect Analysis
(12) TTT plot: Total time on test plot

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J = Journal Paper
C = Conference Paper
B = Reference to a book
T = Technical report
BC = Reference to a chapter in an edited book
W = Website
P = PhD Thesis
O = Others

List of Figures

1) Figure 1: Block Diagram of single shaft Gas Turbine Power Plant

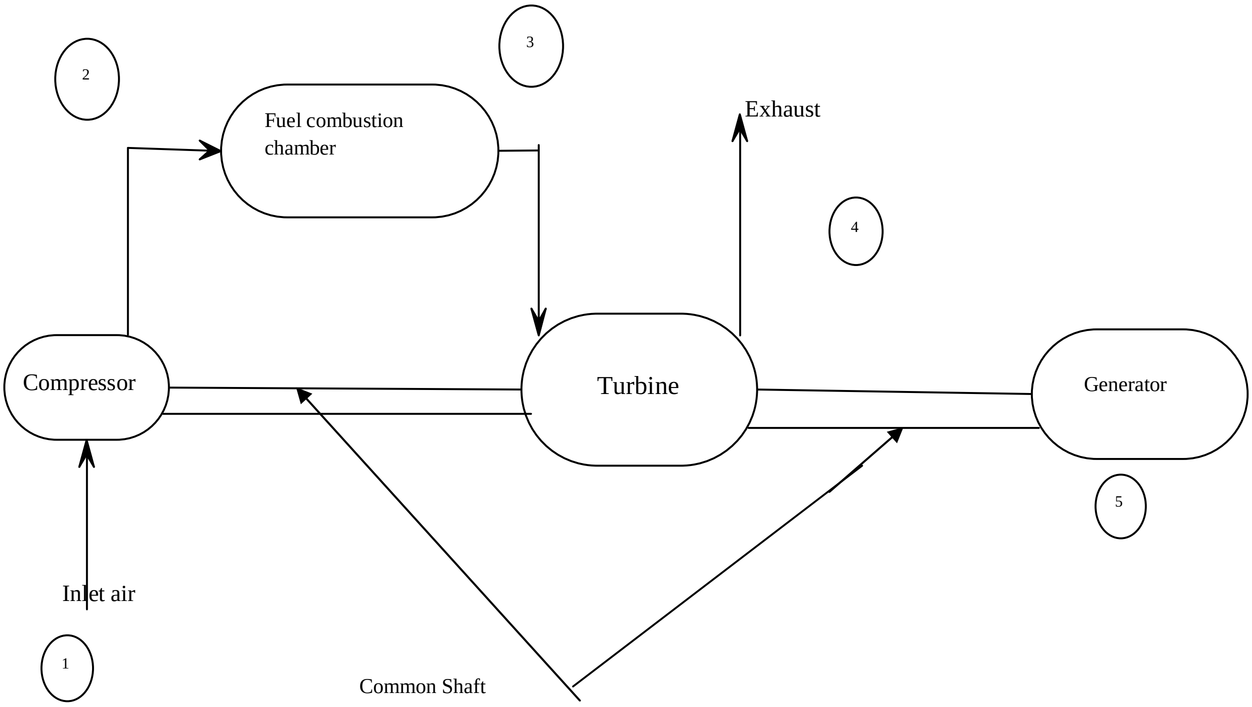

Figure 1: Block Diagram of Single Shaft Gas Turbine Power Plant

2) Figure 2: Functional Block diagram of Gas Turbine Power Plant system.

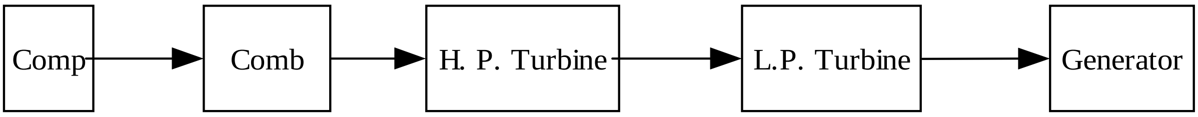

Figure:-2 Functional block diagram of gas turbine power plant system

Figure 3:-Steps for carrying out the F.M.E.C.A. for identification of critical component s and failures of G.T.P.P.S

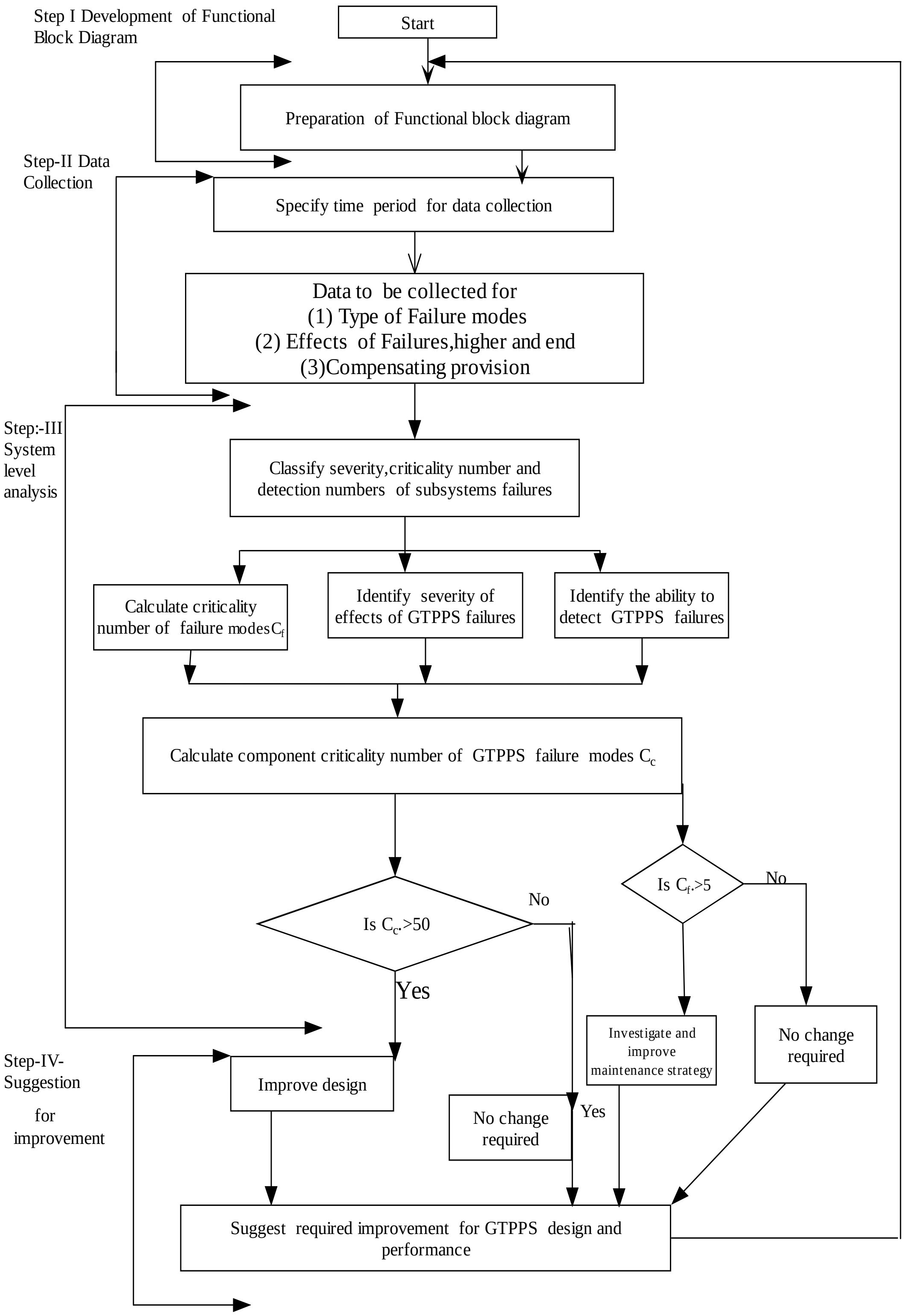

Figure 3 Steps for carrying out FMECA for identification of critical components and failures of GTPPS

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List of Tables

Table 1: Functional Description of GTPPS

Function	**Functional Description**	**Components Involved**
COMP	Provide high pressure air	compressor
COMB	Burn fuel	G.C.V. valve, S.R.V. valve, combustion chamber
H.P. Turbine	Convert heat energy to mechanical energy	Shaft, compressor, turbine
L.P. turbine	Convert heat energy to mechanical energy	Common shaft, coupled generators
Generator	To produce power	Stator, rotor, permanent magnet generator

Table 2:-- Control Detection of Design of failure cause/mechanism

Detection	**Rating**	**Criteria**
Uncertain	10	Design control will not and /or cannot detect a potential cause/mechanism and subsequent failure mode
Very remote	9	Very remote chance the design control will detect a potential cause/mechanism and subsequent failure mode
Remote	8	Remote chance the design control will detect a potential cause/mechanism and subsequent failure mode
Very Low	7	Very low chance the design control will detect a potential cause/mechanism and subsequent failure mode
Low	6	Low chance the design control will detect a potential cause/mechanism and subsequent failure mode
Moderate	5	Moderate chance the design control will detect a potential cause/mechanism and subsequent failure mode
Moderately high	4	Moderately high chance the design control will detect a potential cause/mechanism and subsequent failure mode
High	3	High chance the design control will detect a potential cause/mechanism and subsequent failure mode
Very high	2	Very high chance the design control will detect a potential cause/mechanism and subsequent failure mode
Almost certain	1	The design control will almost certainly detect a potential cause/mechanism and subsequent failure mode

Table 3: Summary of Failure Rate and Repair times of Different Components of GTPPS

Name of the components	**Total numbers of failures**	**Total Repair time taken**	**λ Value failures/hour**	**Failure mode ratio**
Compressors	16	44	0.316×10^{-3}	0.063
Turbine	27+18 =45	89	0.949×10^{-3}	0.1778
Combustion Chambers	61	114	1.2865×10^{-03}	0.241
Generators	49	70	1.05454×10^{-03}	0.197
Other electrical systems	82	180	1.7295×10^{-03}	0.324
Total	253	497	5.336×10^{-03}	1.000

(4) Table: Criticality Index table

Item	**Failure Modes**	**Criticality Index**	**Total Criticality number of the component**
Generator	P.mg bolt broken	0.1301	42.8431
	P.m.g. Bush damaged	42.52	
	Not in alignment with the generator	0.193	
Turbine	H.P turbine under speed	6.85	7.1747
	L.P. over speed	0.283	
	Heavy smoke	0.00208	
	Turbine U/S locked	0.001038	
	Nozzle Problem	0.000519	
	Servo Problem	0.000519	
	Exhaust overtemp	0.0062548	
	Start up problem	0.0146	
	Low hydraulic pressure	0.00834	
	Lub oil level low	0.00834	
	Lub oil Drain temp high	0.0187	
	Lub oil header temp high	0.0187	
	Oil leakage	0.001038	
Combustion chamber	Loss of Flame	55.2	56.26
	Servo valve problems	0.0194	
	Nozzle Problems	1.0178	
	Bearing Drain temp high	0.00364	
	Starting & other Problem	0.0190	
compressor	**Exhaust over temperature**	0.404	2.5075
	Over speed	0.202	
	Oil leakage	0.0785	
	Turbine air inlet differential high	1.81750	
	Compressor bleed valve trouble	0.00552	
Electricals	Desynchronization	9.64	10.72203
	Relay fault	0.1453	
	under frequency	0.24173	
	Synchronization	0.3717	
	Feeder fault	0.1155	
	Poor demand& shortage of gas	0.1358	
	Grid failure	0.072	

5. Table 5: Final list of failure modes and effects and compensating provisions and failure detection method traceability

			Failure Effects				
Item	Function	Failure modes	Local effects	Next higher level	End effects	Failure Detection method traceability	Compensating Provision
Gene-rator	To produce current	p.m.g. bolt broken	Bolt broken	Bush damaged	Turbine trip	6	Material design alignment problem should be addressed
		Bush damaged	Bush material struck into the rotor	Bush completely damaged	Turbine trip		
		Not in alignment with the generator	Turbine stopped working	Coupling damaged	Turbine trip		
Turbin e	Convert heat energy to mechanical energy	H.P turbine under speed	Firing temp goes beyond limit	High alarm appears	Turbine trip	4	To find the causes & fill the oil level
		L.P. over speed	L.P. turbine over speed	alarm appears	Turbine trip	4	Turbine load compensating
		Heavy smoke	Heavy smoke	Excessive heating	Fire occurred	2	Remove the vapour &finding out the causes
		Turbine U/S locked	turbine under speed, locked	Under speed alarms appears	Turbine trip	10	Turbine should not be kept in droop speed.
		Nozzle Problem	Nozzle problem	alarms appears	Turbine trip	4	Nozzle schedule maintenance
		Servo Problem	Servo valve problem	Vibration high	Load decreased	10	Turbine should not be kept in droop speed.
		Exhaust overtemp	Exhaust overtemp	High alarm appears	Turbine trip	6	By decreasing load
		Start up problem	Faulty spark plug	Electrical control out of adjustment	Turbine not working	4	To find the causes & correct it
		Low hydraulic pressure	Low hydraulic-pressure	Oil pressure falls below the alarming limit of 50Kg/cm ^{2}	Turbine trip	3	Clean the line and filter
		Lub oil level low	Lub oil level low	Lub oil headertemp crosses the limit	Turbine trip	2	To arrange for cooling arrangements
		Lub oil Drain temp high	Lub oil drain temp high	Fog air filter become clogged	air inlet diferential trouble occurs	2	To arrange for cooling arrangements
		Lub oil header temp high	Temperature crosses the limit of 180^{0}C	Inactive pad damaged	Turbine will be tripped	5	Air filter regular maintenance
		Oil leakage	Oil leakages	Oil leakage in pipes, hydraulic pump,lub oil pump	Oil pressure low	2	To arrange for filling arrangements
Comb ustion chamb er	To burn the fuel	Loss of Flame	Sparkplug unable to create spark	alarms appears	Turbine trip	5	Changing the flame detector, spark plug
		Servo valve problems	Servo valve problem	Vibration high	Load decreased	2	To find out the causes & to keep turbine in droop speed mode
		Nozzle Problems	Nozzle problem	alarms appears	Turbine trip	4	Nozzle schedule maintenance