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Operational Parametric Based Reliability Estimation & Justification of Failure Criterion of Hydro Power Plant: A Case Study

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Abstract: ***Generating more Power are complex at cheaper cost, also continuous energy supplied are important Hydro power generation is one of the most successful renewable energy resources for the production electrical energy without any environmental hazard and presently it providing more than 86% of all electricity generated by renewable sources worldwide and accounts for about 20% of world electricity. To increase the percentage of green energy in account of world electricity generation the analysis must be performed to get the information about the working conditions of each component in plants so that the required maintenance action should be taken. Maintenance and operation of a hydro power plant is very complicated and the process to calculate and analyzing its compatibility and reliability is very important. In this work introducing a Markov model to evaluate the reliability parameter of THPS-I Sirmour, Rewa. For this work the operational data regarding failure and maintenance time taken to repaired and analysis of all parts of generating unit of the power plant for period of 2010-2015 is considered. The availability and reliability of individual unit of power plant is evaluated by taking into account different reliability Parameters, namely failure rate (λ), repair rate (μ), MTTR, MTTF, MTBF through the collected data and tabulating the required information for the analysis. By this analysis work we can improve reliability of all the components of each unit of power plant. The sub-unit that is commonly failed during operation is like- penstock, butter fly valve, spiral case, turbine, generator, excitation system, speed governor etc. Reliability plays a key role in the cost-effectiveness of systems***
Keywords: Hydro power plant, Reliability evaluation, Reliability parameters, Markov analysis, Total schedule outage hrs and Total forced outage hrs.

I. INTRODUCTION

A. About THPS/SHPS

It is a canal based power plant. This hydro power plant was installed by the 'Madhya Pradesh State Electricity Board' (MPSEB), which now becomes Madhya Pradesh Power Generation Company Ltd (MPPGCL). Resource water is received from Bansagar Dam it is located at Deolond, Shahdol District, Madhya Pradesh (M.P), India. It is a multipurpose river valley project on Sone River situated in the Gangas basin in Madhya Pradesh, India with both irrigation and 425 MW of hydroelectric power generation.
Hydro power station is situated at Sirmour, Rewa District (M.P). Plant coordinates location 24° 51′ 10″ N 81° 22′ 21″ E. SHPS have installed capacity of 315 MW. It has three numbers of identical independent unit each having capacity of 105 MW. Francis turbine is used with available head of 180m.

B. Components of THE THPS/SHPS

For analysis point of view the reasons are divide into two groups due to that the entire system get shuts down and which affects the reliability and availability of the plants are-

1) *Planned/Scheduled Outage:* It includes Preventive Maintenance/Planned maintenance (Overhauling, Trash rack Cleaning, Shaft seal works, Spiral casing inspection, Penstock inspection, cooling system etc.)
2) *Breakdown/Forced Outage:* The following are components/equipments are considered for this analysis which fails frequently which leads to entire systems get shut down and stop power generation.

a) Generator
b) Power Transformer
c) Governing system
d) *Turbine:* It includes guide vane link rod change, shear pin change, head cover repair, Turbine oil change, intake gate maintenance etc.

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e) Excitation System: Excitation Systems includes excitation power and excitation device
f) External Effects: It includes the shortage of water due to insufficient rain, flood Transmission line failures and accidental case.
For this work the time taken by the two above mentioned criterion is considered to evaluate the reliability of the hydro power station for the period of 2010 to 2015. These

C. Markov Analysis Method/ Approach

The concept was developed by Andrei A. Markov graduated from Saint Petersburg University 1878)

1) For many years Markov models and Markov analysis methods were relegated to that list of exotic but rarely used stochastic modeling techniques at least for reliability and maintainability purposes.
2) Stochastic modeling is derived from Greek which means random or chance. It is a quantitative description of a natural phenomenon is called a mathematical model of that phenomenon. In reliability, maintainability and safety (RMS) engineering stochastic modeling is used to describe a systems operation with respect to time. The component failure and repair times typically become the random variables.
3) Markov analysis looks at a sequence of events and analyzes the tendency of one event to be followed by another. A Markov process is completely characterized by its transition probability matrix.

D. Transition Probability

The movement of probability from one state to another state or remaining in the state during a single time period is called a transition probability and the square matrix with transition probability P_{ij} is called transition probability matrix.

E. Classification of Markov Process

1) Discrete (Time) parameter or continuous (Time) parameter Markov process.
2) Discrete state space or continuous state space Markov process.

Why Markov Analysis
The reasons of applying these methods are follows-

a) A deterministic model predicts a single outcome from a given set of circumstances where as a Markov model predicts a set of possible outcomes weighted by their probabilities.
b) Combinational model such as reliability block diagrams and fault trees are frequently used to predict the RMS of complex systems but unfortunately these methods cannot accurately model dynamic system behavior. Because of its unique ability to handle dynamic cases Markov analysis can be a powerful tool in the RMS analysis.

F. Research Objectives

Since the TONS/Sirmour hydro power plant is one of the major power generation units of MPPGCL undertaken by Government of M.P. and as this is a national/state property so it's our moral duty to enhance the performance and increase the reliability & availability of the power plants. The objective of this work is as follows:

1) To evaluate the availability, reliability and reliability parameters which quantify generating unit reliability are computed for three units for separate year and for the all the six years.
2) To develop a Markov model for TONS/Sirmour hydro power plant.
3) To calculate the maintainability of the system so that to build better design and planning support system for maintenance of failed unit so that performance of hydro power plant can be improved and power generation can be continuous and stable
4) To provide criteria for future proposal and serves as a basis for power generation expansion planning of hydro power plant.

II. LITERATURE REVIEW

Adam Baharum, Faris Mahdi Alwan, and Saad Talib Hasson et al. [1] In this work he is presenting an algorithm for estimating the performance of high-power station connected in series, parallel, and mixed series –parallel with collective factor failures caused by any part of the system equipment. The objective of this work is to increase the life lifetime of the station and reduce sudden station failures. In this work data analysis was performed using the most valid distribution of the Weibull distribution with scale parameter α=1.3137 and shape parameter β=94.618. This analysis revealed that the reliability value decreased by 2.82% in 30 days. The result of this work can be used for the maintenance of power system models and preventive maintenance model for power systems.

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Ungji Kwon, Trungtinh Tran, Sangheon Jeong, Bo Shi, Jaeseok Choiet al. [2] In this paper he is presenting a practical method of probabilistic reliability evaluation of KOREA Power system by using the Probabilistic Reliability Assessment (PRA) program and Physical and Operational Margins (POM).this work is case study to compute the Probabilistic Reliability Indices (PRI) by applying the above method. PRA & POM take large number of contingency in load stimulations and combines them with practical method of characterizing the effect of the availabilities &effectiveness of generators, line & transformers. In this paper he is simulating to above analyze the condition of the system under these constraints that are voltage violation, overload violation and voltage stability violation. The result shows of reliability indices are different type with other method.

Farshad Khosravi, Naziha Ahmad Azli, Ebrahim Babaei et al. [3] Some paper have introduced the modeling methods for reliability production of transferring distribution parts at the power system but in this work for the first time he is presenting the analysis of reliability indices for all parts of generation unit (Thermal power plants) by using the new method of modeling. In this work he is calculating the unit indices in different states of power limitations and power not supplied can be calculated. It can be also calculated the total average of annual energy not supplied on the basis of occurred different errors.

Manjit Verma, Amit Kumar, Yaduvir Singhet al. [4] In this paper he describes a fault tree technique based on generalized fuzzy numbers to a possibility distribution of reliability indices for power system are used. In this paper, the fault-tree incorporated with the generalized trapezoidal fuzzy number and minimal cut sets approach is used for reliability assessment of power systems and us by using this approach fuzzy system reliability can be analyzed in a more flexible and intelligent manner. In this work he has been constructed fault for gas power plant and due to uncertainty all the collected data are represented by generalized trapezoidal fuzzy number.

M. Valdma, M. Keel, H. Tammoja, K. Kilk et al. [5] In this work he is evaluating the reliability principle of electric power generation in a power system including thermal and wind power plants. In this work he is recommended uncertain probabilistic models of reliabilities besides of classical probabilistic model. This work is based on reliability studies of oil shale power plants and unit. In this work the power output by wind power plants is treated as non stationary random process. This case study is done on Pakri wind pork and wind power plant of Denmark.

S.O. Oyedepo, R.O. Fagbenle, S.S. Adefila, S.A. Adavbieleet al. [6] In this study he is evaluating the performance and economic analysis of (in terms of power outage cost due to system downtime) of a gas power plant in Nigeria for a period of 2001-2010 in thermal power plant. The thermal power station consists of nine gas turbine units with total capacity of 301MW. This study reveals that 64.3% of the installed capacity was available in the period. To improve the performance indices of the point he has been suggested such as training of operation and maintenance. Personal regularly improvement in O & M practices proper spare parts inventory etc. This developed performance indicator to evaluate the performance indices and outage cost for the station can also be applicable to other power station elsewhere.

Mr. S. S. Hirve, Dr. Mrs. S. R. Desh Mukh et al. [7]Since wind speeds vary from month to month and second to second, the amount of electricity produced by wind can varies constantly so the main objective of this work is to study the concept of capacity availability of wind turbine for maximum utilization of resources. This work shows excellent potential as a form of contribution to conventional power generation systems. In this work he is using wind turbine model and probability theory. Capacity availability for wind power estimation which forms an important input to proper resource utilization along with the probability of wind turbine. I this work the most commonly used analytical method for calculating reliability indices are- Markov process, the capacity outage probability table, loss of load probability (LOLP), loss of load expectancy(LOLE), loss of energy expected(LOEE). Another method used for reliability evaluation is Monte Carlo Simulation.

Shikha Bansal, S.C. Agarwal and Kuldeep Sharma et al. [8] In this work he is computing the terminal reliability of milk powder manufacturer plant based on minimizing Boolean expression technique for system of multistate elements. In this work he is developing Boolean reliability models was considered on the basis of logic, algebra of groups of incompatible events and classical logic and probabilistic method. The milk powder consists of four subsystems A, B, C, D viz. storage, hot plates, evaporator, dryer arranged in series. Sub system A&C has two units in standby with perfect switching, sub system B has two unit in parallel redundancy and sub system D has one unit. The reliability and MTTF have been evaluated for these systems and the failure rate is considered to be exponentially distributed.

Apoorva Kulakarni, Sharada Prasad C.R. et al. [9] the main objective of this project is to develop a method to evaluate the reliability of output power obtained from wind electric conversion system. The approach used for this work involves the simplified reliability model for wind energy conversion system. In this methodology four factors are calculated which are wind availability factor, constant power output factor, variable power output factor and factor for mechanical failure. To determine these factor Wiebull distribution are used and to plot the sensitivity graph for the several key parameter MATLAB are used.

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Adamu Murtala Zungeru, Adegboye Babatunde Araoye, Bajoga Buba Garegy et al. [10] In this paper (work) his aimed at evaluating the reliability performance of Kainji hydro electric power station of Nigeria. Here the adopted approach are used for reliability evaluation are based on the frequency and duration (F & D). To set the reliability parameters which quantify the generating unit reliability are computed for each unit using the annual outage duration and then overall station reliability is evaluated by the convolution of the generation and load models using the F&D. There are total eight units and Kaplan turbines are using of the installed capacity of 760 MW.

R.C.Okonkwo et al. [11] in this work he is presenting a quantitative tool for the evaluation of thermal power stations reliability in a hydro thermal system. Here he is mention that for reliability evaluation the station installation capacity and available power generation are required. In this work a relative use of the index, availability factor for the thermal and hydro power station are made.

S.M.H. Hosseini, M. Rahimpoor et al. [12] in this work he is calculating and comparing the technical, economical and reliability indices to install optimal capacity of an small hydro power plant (SHPP). In this paper a method to calculate the annual energy is presented as is the program developed using Excel software. This program analyzes and estimates the most important economic indices of an SHPP using the sensitivity analysis method. Another program developed by Mat lab software, calculate the reliability indices for a number of units of an SHPP with a specified load duration curve using a Monte Carlo method and ultimately comparing the technical, economic and reliability indices will determine the optimal installation capacity of an SHPP.

Mahendra Sahu, Amol barve et al. [13] in this work to evaluate the unit reliability and availability he used the Markov models in Pathri power station for the period of 2007-2012. To calculate the reliability indices like failure rate, repair rate, MTTR, MTBF, and MTTF through data are collected and analyzes. All these data are tabulated and classified for each unit of different type of failure taking into account the various sub units and system and then according to classification Markov states are defined. The total installed capacity of Pathri hydro power station is 20.4MW and consists of three identical independent unit of 6.8MW.

Jasbir singh, Ram Avtar Jaswal [14] in this work he deals with the probability of failure rate of thermal power plant using the Boolean algebra and covering the two area first development of a mathematical model and second evaluation of performance with the help of developed model. In this work he is taking the assumption that failure and repair rate are assumed to be constant.

Huairui Guo, PhD, Relia Soft Corporation, Mingxiao Jiang, PhD, Medtronic Inc. et al. [15] in this paper he is proposing a new approach for allocating the system reliability together with the confidence level to the sub system he also told that this proposed method can be used for the complex system with serial, parallel and k-out-of – n configuration. In his work he uses a cost based and risk based for reliability allocation.

Jeongje Park, Taegon Oh, Kyeonghee Cho et al. [16] In this study he is evaluating the reliability of interconnected power systems including wind turbine generator of multi state and he is proposing a tie line constrained equivalent assisting generator and developing a programmed model NEAREL-II for power system reliability evaluation. This is the case study of reliability evaluation for the actual power system by testing it from developed model of six countries in the northeast Asia area including wind turbine generator (ETG).

A. Ehasani, A.M. Ranjbar, A. Abbaspour et al. [17] in this work he has presented an analytical method for reliability assessment of the flat rated wind turbine power generator systems. The flat rated system is that of the MOD-2, a second generation class of wind turbine. The power velocity characteristic of the flat rated wind turbine is employed in this paper, to model the operating behavior of the installed wind turbine generators. To estimate wind power potential, the Weibull distribution model is used and the performance of the developed method is demonstrated with computational results. In this work he has also calculated Up and Down state of system and system probability of the installed wind turbine system to evaluate the reliability of the system.

Keith E. Holbert, Ogeuk Kwon at al. [18] in this work he has represented hydroelectric equipment reliability and system availability for twenty four synchronous generators and associated equipments. For this work he is collected fault data for the twenty four generators and for filtration considering only forced outage data from which equipment reliabilities are determined. In this work he has divided the eight major equipments of a hydroelectric power plant into two group based on their reliability for calculation of rehabilitation and modernization timing. After considering reliability and economics it appear that 20 to 23 year is a favorable time to rehabilitate equipment of group two which include the switchyard circuit barkers, excitation system, governor and main CB and 40 to 45 years is an opportunity time to modernize group1 equipment comprised of the rotor, turbine stator and main transformer.

Mingjun Liu, Wenyuan Li, and Juan Yu et al. [19] in this paper he has presented a method for reliability evaluation of a hybrid power generation system consists of wind and tidal powers with battery energy storages. In this work he has developed a chronological multiple state model of tidal and wind power generation system considering forced outage rate of TPGS and random nature of tidal current speed. In the evaluation of FORs of TGPS and WPGS the delivered power related failure rate of power

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electronics for both the systems are considered and also the effects of various parameters on the system reliability are investigated here.

III. METHODOLOGY

A. *Development Of Markov Model*

1) Unit Modeling

a) In order to evaluate the reliability of power generation each sub-systems, or system, must be represented by a model. These models reflect the performance of system in various states. The individual system model is referred to as unit model. Unit models indicate various states with transition rates between them. From these transition rates, probability of each state, from one state to another state is obtained for generating units.

b) Generally a hydro unit is model according to its mode of operation and it can be divided into up-state & down state.

c) Conventionally it is modeled as a 2-state. If modeled as a 2-state unit, they have up-state where the unit is fully available and down-state where the unit is on forced outage as shown in fig.1 below

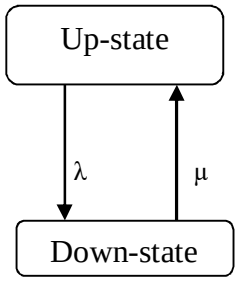


Fig.1 Two state Model

d) But now 3-state can be used for modeling. If modeled as a 3-state unit, there is a third state in which the unit is said to be derated. In this case, the unit is operating below the rated capacity because of partial failure. In this work, it is modeled as a 3-state unit, which is shown in fig.2 below.

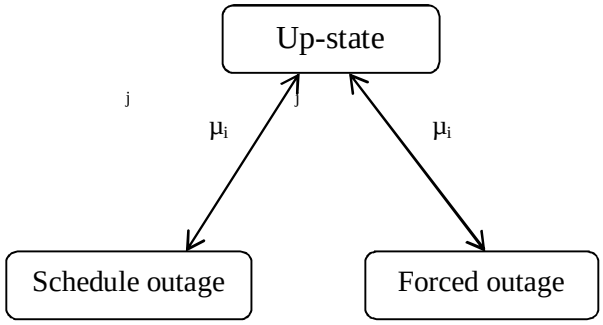


Fig.2 Three State Markov Model

Where λj and μi = Transition Rate between two states.

The developed 3 state Markov model are shown in fig.3 below

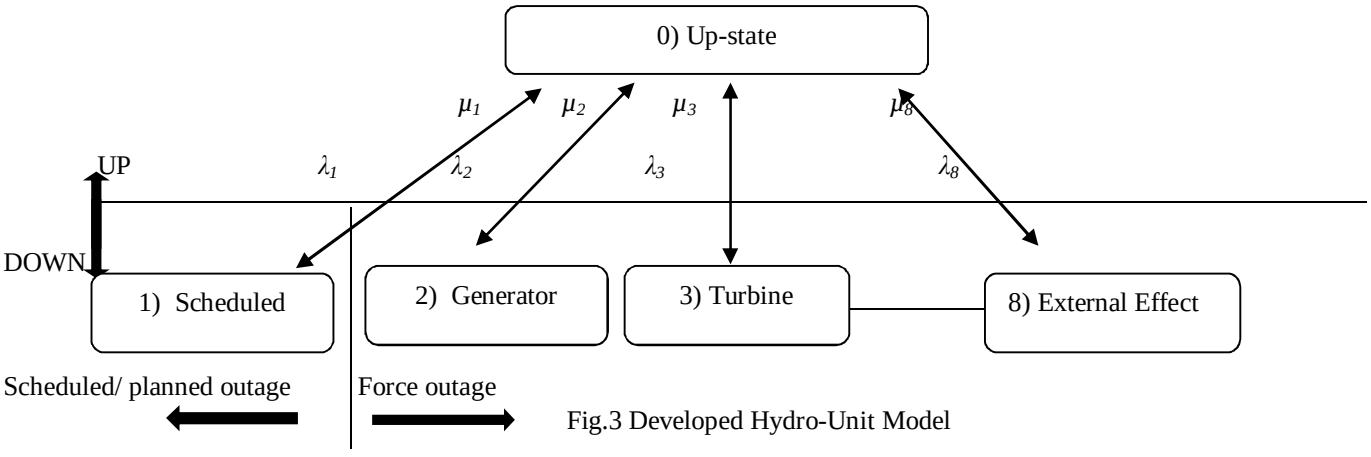


Fig.3 Developed Hydro-Unit Model

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The state transition matrix of above Fig.3 is as follows

$$\begin{bmatrix} -(\lambda_1+\lambda_2+.....+\lambda_8) & \lambda_1 & \lambda_2 & \lambda_3 & \lambda_4 & \lambda_5 & \lambda_6 & \lambda_7 & \lambda_8 \\ \mu_1 & -\mu_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \mu_2 & 0 & -\mu_2 & 0 & 0 & 0 & 0 & 0 & 0 \\ \mu_3 & 0 & 0 & -\mu_3 & 0 & 0 & 0 & 0 & 0 \\ \mu_4 & 0 & 0 & 0 & -\mu_4 & 0 & 0 & 0 & 0 \\ \mu_5 & 0 & 0 & 0 & 0 & -\mu_5 & 0 & 0 & 0 \\ \mu_6 & 0 & 0 & 0 & 0 & 0 & -\mu_6 & 0 & 0 \\ \mu_7 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_7 & 0 \\ \mu_8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_8 \end{bmatrix}$$

Fig.4 the State Transition Matrix

By using above matrix the calculated state probability and frequency each state is shown in Table No.1

Table No.1State Probability

State Number	State probability	
0	$\mu_1\ \mu_2\ \mu_3\ \mu_4\ \mu_5\ \mu_6\ \mu_7\mu_8/D$	d_0/D
1	$\lambda_1\mu_2\ \mu_3\ \mu_4\ \mu_5\ \mu_6\ \mu_7\ \mu_8/D$	d_1/D
2	$\mu_1\ \lambda_2\ \mu_3\ \mu_4\ \mu_5\ \mu_6\ \mu_7\ \mu_8/D$	d_2/D
3	$\mu_1\ \mu_2\lambda_3\ \mu_4\ \mu_5\ \mu_6\ \mu_7\ \mu_8/D$	d_3/D
4	$\mu_1\ \mu_2\ \mu_3\lambda_4\ \mu_5\ \mu_6\ \mu_7\ \mu_8/D$	d_4/D
5	$\mu_1\ \mu_2\ \mu_3\ \mu_4\lambda_5\ \mu_6\ \mu_7\ \mu_8/D$	d_5/D
6	$\mu_1\ \mu_2\ \mu_3\ \mu_4\ \mu_5\lambda_6\ \mu_7\ \mu_8/D$	d_6/D
7	$\mu_1\ \mu_2\ \mu_3\ \mu_4\ \mu_5\ \mu_6\lambda_7\ \mu_8/D$	d_7/D
8	$\mu_1\ \mu_2\ \mu_3\ \mu_4\ \mu_5\ \mu_6\ \mu_7\lambda_8/D$	d_8/D
$D=d_0+d_1+d_2+d_3+d_4+d_5+d_6+d_7+d_8$		

Table No.2 Frequency of State

State Number	Rate of departure	Frequency of state
0	$\lambda_1+\lambda_2+.....+\lambda_8$	$(\lambda_1+\lambda_2+....+\lambda_8)d_0/D$
1	μ_1	$\mu_1 d_1/D$
2	μ_2	$\mu_2 d_2/D$
3	μ_3	$\mu_3 d_3/D$
4	μ_4	$\mu_4 d_4/D$
5	μ_5	$\mu_5 d_5/D$
6	μ_6	$\mu_6 d_6/D$
7	μ_7	$\mu_7 d_7/D$
8	μ_8	$\mu_8 d_8/D$

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2) *Plant Modeling:* In this section developing the model for the entire plants (all the three units) of SHPS so that it can be simple to analyze together. In this model number of failure rates and repair rates of the entire unit for six year are taken into the consideration. This developed model will help to determine the plant availability and reliability. The transition rate matrix of fig.No.3.4 for the entire plants can be used to determine the state probability and frequency encountered in the same ways as for individual unit model transition rate matrix. When the all the three units are up state then the probability of state 1 is

$$P_1=\mu_1\,\mu_2\,\mu_3/\prod_{i=1}^{3}(\lambda i+\mu i)$$

When the entire unit is in down state then the probability of state 8 is the probability

$$P_8=\lambda_1\,\lambda_2\,\lambda_3/\prod_{i=1}^{3}(\lambda i+\mu i)$$

The frequency of encountering state 1 is

$$f_1=(\lambda_1+\lambda_2+\lambda_3)\,P_1$$

The frequency of encountering state 8 is

$$f_8=(\mu_1+\mu_2+\mu_3)\,P_8$$

B. Representation Of State Space Diagram

The number of state in the diagram is 2^3 for a 3-component system in which each state is represented as a 2-state model. In state space diagram all the system component are continuously operation either in series, parallel or series/ parallel. In this system very necessary class of systems known as standby systems can also be modeled and analyzed using state space diagrams and Markov technique. In the diagram we are represent all the state of all three unit are under the repair (R) and failed (F) condition.

If the system performing its work continuously with time without any interruption of failure that system is known as perfect system otherwise it is defective system. In reliability theory that systems are divided into two parts Repairable and Non- Repairable systems.

Where for repairable systems the eqn. are

$$MTTF = m = \frac{\sum_{i=1}^{n} m_i}{n} = \frac{1}{\lambda}, MTTR = r = \frac{\sum_{i=1}^{n} r_i}{n} = \frac{1}{\mu}$$

System Availability is used for reliability calculation of repairable system. “Availability is defined as the probability of the system that works properly at any time, under the given condition” that state is 0. Thus availability of the unit is:

Availability (A) = P_0

$$A = \frac{\mu}{\lambda+\mu}, U = \frac{\lambda}{\lambda+\mu}$$

Where

λ= Failure rate

μ=Repair Rate

A= System Availability

U= System Unavailability

T= Total working time

R= System Reliability

According to the definition of reliability, the systems work without failure. Thus reliability of the unit is:

Reliability (R) = $P_0 + P_1$

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IV. IMPLEMENTATION

TONS/Sirmour Hydro Power Plant Data Analysis: - The collected data from hydro power plants are now analyzing for the given states and gathered in the form of tables for the periods of 2010 to 2015 of all the three units individually and also for the entire hydro plants.

A. Unit Modeling

The collected data from Sirmour/TONS Hydro power plants are now tabulating to analyze and to evaluate the necessary reliability parameters. In this section the defined per unit model derived are used to calculate the state probability, frequency of state and operation behavior of the unit for separate years (2010 to 2015) are calculating to evaluate the reliability and availability of the plants as per its model id derived in above chapter 3 as a case study.

Table No.4.1 Showing Reliability and Availability Calculated of all Three Units

Unit No.	Year 2010		Year 2011		Year 2012		Year 2013		Year 2014		Year 2015	
	R	A	R	A	R	A	R	A	R	A	R	A
1	0.9490	0.8732	0.8559	0.9624	0.9281	0.9287	0.9604	0.9864	0.7722	0.8561	0.9433	0.9874
2	0.9451	0.9463	0.8894	0.9674	0.8633	0.9105	0.9131	0.9886	0.9496	0.9609	0.7760	0.9709
3	0.9209	0.9605	0.8945	0.9544	0.7100	0.7778	0.9727	0.9730	0.9832	0.9847	0.8286	0.9954

B. Plant Modeling

In this section to evaluate the Availability(A), Reliability(R), MTTF, MTTR, MTBF and state probability with the help of failure rate(λ), repair rate(μ) all six years data are taken together for unit modeling. Here each component can exist in two states one is UP state and second is DOWN state and all conditions are shown by state space diagram which gives the state condition of the systems. Table No.4.8 shows SHPS failure rate, repair rate, state probability of unit-1 and Availability, Reliability are determine in given table below for the year of 2010-15.

Table No.4.2 Showing State Probability of Hydro Power Plant

State no.	Basic Event	No. of occurrence	Repair rate(μ)	failure rate(λ)	MTTR in hrs	MTTF in hrs	MTBF in hrs	state probability
0	Up state	Nil	Nil	Nil	Nil	Nil	Nil	0.8725
1	Planned outage	13	0.0051	0.00025	194	4000	4194	0.04387
2	Generator	31	0.0246	0.00060	41	1667	1708	0.0214
3	Turbine	49	0.0255	0.00096	39	1042	1081	0.0330
4	Excitation system	14	0.1587	0.00026	6	3846	3852	0.00146
5	Governing system	17	0.1230	0.00032	8	3125	3133	0.000229
6	M.U.T	16	0.1276	0.00029	8	3448	3456	0.0020
7	M.U.C.B	33	0.0816	0.00063	12	1587	1599	0.00676
8	External Effect	19	0.1503	0.00036	7	2778	2785	0.0164

Similarly now calculation of Reliability and Availability of all three units for the period of 2010 - 15 these are evaluated in this Table.4.9 gives the value of Availability and Reliability for year 2010-15.

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Table No. 4.3 Showing Availability and Reliability FY2010-2015

	Unit-1	Unit-2	Unit-3
Availability	0.8725	0.8865	0.8892
Reliability	0.9163	0.9592	0.9440

V. RESULTS ANALYSIS & DISCUSSION

A. Results

The following are the results obtained after the calculation of individual unit, also for entire plants are plotted on bar diagram and on a line graph. The given column and line diagram shows the Availability and Reliability variation of all three units for six year 2010 to 2015

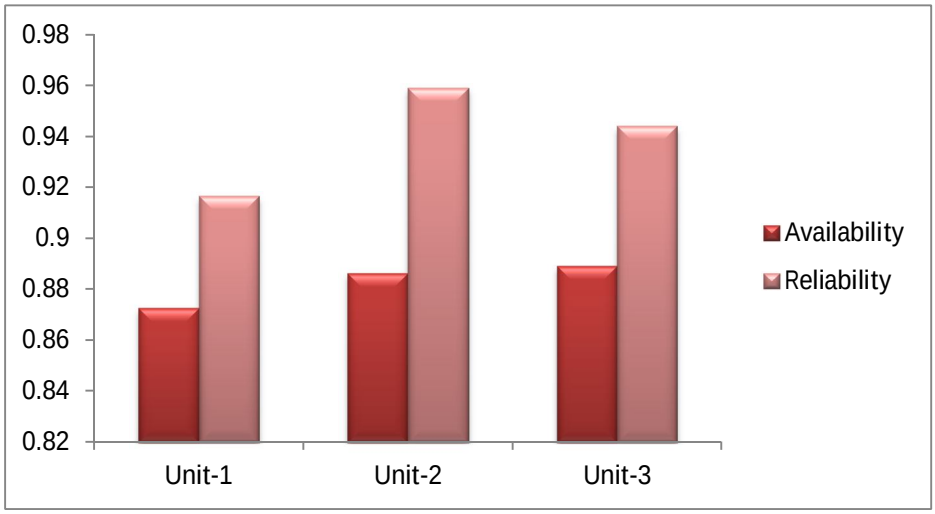


Fig.5.1 Shows Comparative Variation of Availability and Reliability Whole Plant

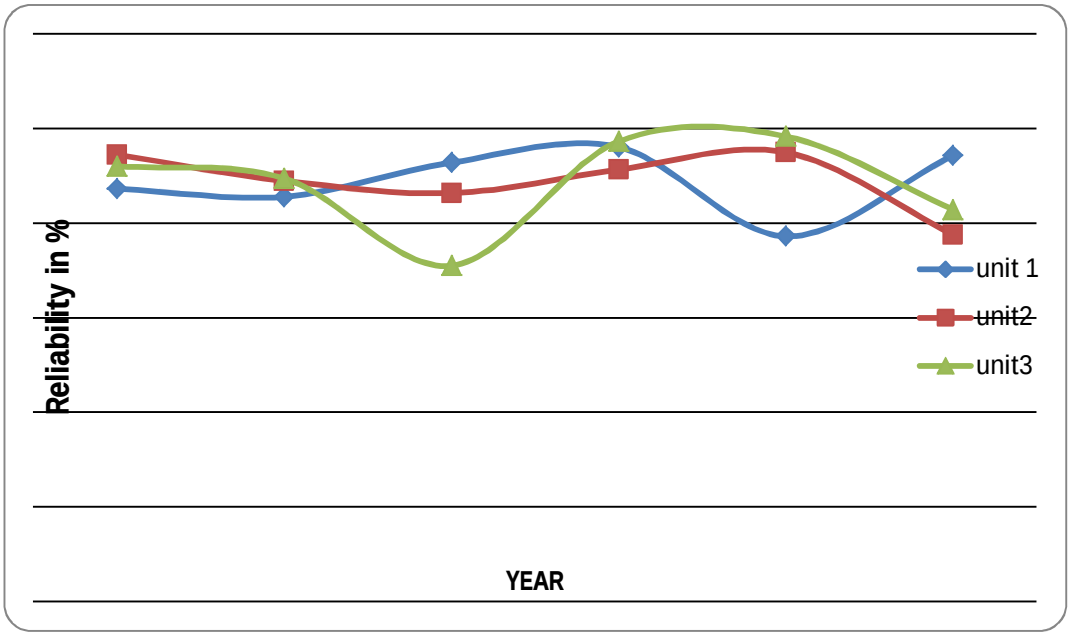


Fig. 5.2 Shows Comparative Variation of Reliability of Three Units

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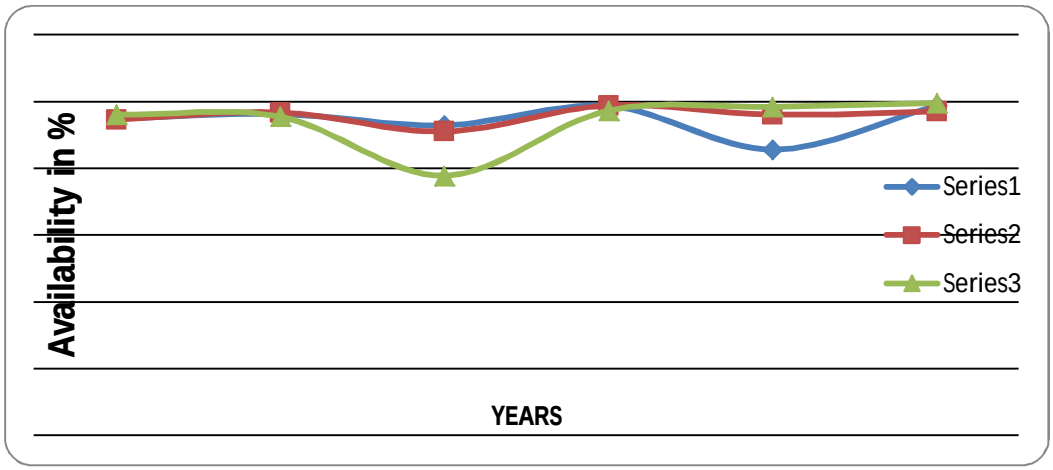


Fig. 5.3 Variation of Availability of Three Units

Table.5.1 shows the Total Scheduled outage Hours, Total force outage Hours and Availability (in % age) considering the entire 6 year data (i.e. from 2010 to 2015)

Table No.5.1 Shows TSOH, TFOH & Availability

Unit No.	Total Scheduled/Planned Outage hours	Total Forced Outage hours	Availability (in % age)
1	2517:25	4055:17	87%
2	3983:25	2419:12	89%
3	3050:50	3245:21	89%

B. Causes of Failure in TONS/SHPP

The following are some Causes of poor reliability & availability which fails during the working operation in SHPS are given in table 5.2

Table No. 5.2 Six Year Major Faults That Affect the Reliability of SHPS

Unit No.	Cause of Fault	Down during 52584 hours of operation fault
Unit-1	Turbine (inlet gate, penstock,…etc)	1915:45
Unit-1	Generator	1256:05
Unit-1	Main unit circuit breaker	404:40
Unit-2	Turbine (inlet gate, penstock,…etc)	904:48
Unit-2	Governor system (servo motors, wicket gates, speed governor,….etc)	668:05
Unit-3	Turbine (inlet gate, penstock,…etc)	1094:50
Unit-3	External Effects	1104:06

C. Discussions

In this study "Markov Method/approach has been used for the evaluating the reliability parameters of an existing Sirmour hydro power plant which has generating capacity of 105MW×3. SHPS are one of the major powers generating station in Madhya Pradesh Rewa. The sole purpose of this work is intended to provide improved criteria for future proposal and serves as a basis for power generation expansion planning of hydro power plant on the basis of calculated value of reliability parameters. The following are some remarkable findings experienced during this case study are summarized below.

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1) Governing system was not proper working in "auto" mode that cause it was every time there is a failure of the auto governing system; it was working in manual mode because of fault in spare parts. When governor in manual mode and governor reached a sudden full load that cause some system disturbance and unit was trips due to over speed limit of load.
2) Part of turbine inlet gate, penstock, spiral case, butter fly valve, turbine bearing, and runner that fault affect the availability and reliability of the power plant. When all the part of the turbine was not proper overhauling that cause the unit was trip.
3) In generator fault like partial discharge, overheating, winding circulating current, arcing and continuous sparking can cause the deterioration of the insulation.
4) The availability of the machines at SHPS are more for unit third (0.8892), then for unit second (0.8865) and then for first unit (0.8725).
5) The reliability of unit-2 (0.9592) is more than for unit-3 (0.9440) and then for unit-1 (0.9163) is minimum. See in table no.4.9
6) The total planned/schedule outage hrs for unit 2 (3983:25 hrs) is more, then for unit 3 (3050:50) and for unit 1 (2517:25). See in table no.5.1. This schedule outage also consists of reserve and idle outages in addition to scheduled preventive maintenance. Schedule outage should have to be of the similar duration in each unit but seen different for the units.
7) Since the schedule/planned outage hours for unit 2 & 3 take more time but due this the forced outage hours i.e. the time required for maintenance after brake down is less and also the total time required is less compare to unit-1 and hence availability of the unit-2 and unit-3 is 89% compare to unit 1 is 87% for whole plants in year 2010 to 2015.

This station has been using traditional manual approach to clean its trash racks, and it is seen that to clean the trash rack for planned scheduling takes maximum time in rainy seasons. If modern racking machines are used for this cleaning purpose, a large amount time could be saved and would increase the availability of all units. This work developed a methodology for quantitative reliability study of generation systems with hydro power. This methodology assists power system planners in designing generation systems with renewable power, in particular hydro power system, which meets the required reliability standards. Peaking units required to backup renewable power plants can be determined using this method. It also helps to compare the cost of conventional power plants with the effective value of renewable power plants.

VI. FUTURE SCOPE

The work reported in this work involves the development of new that is Markov methods for Reliability evaluation and enhancement of Sirmour Hydro Power Systems. In this study all the necessary data have been calculated for individual units and for whole plants which are required for proper monitoring, maintenance of the system but the effects of partial or derated output of the components, for example, cooling system, lubricating system etc. have not been included. It is recommended that further study on reliability evaluation of hydro power stations Sirmour should be carried out with this consideration. Besides this, all the components in this work are considered as repairable item with constant failure rate, even though they contain some repairable and replaceable items. Thus further study can be done on the basis of actual probability distribution by taking into account such eventualities and can also continue this study for the cost and reliability analysis with the unit power generation capacity of hydro power stations.

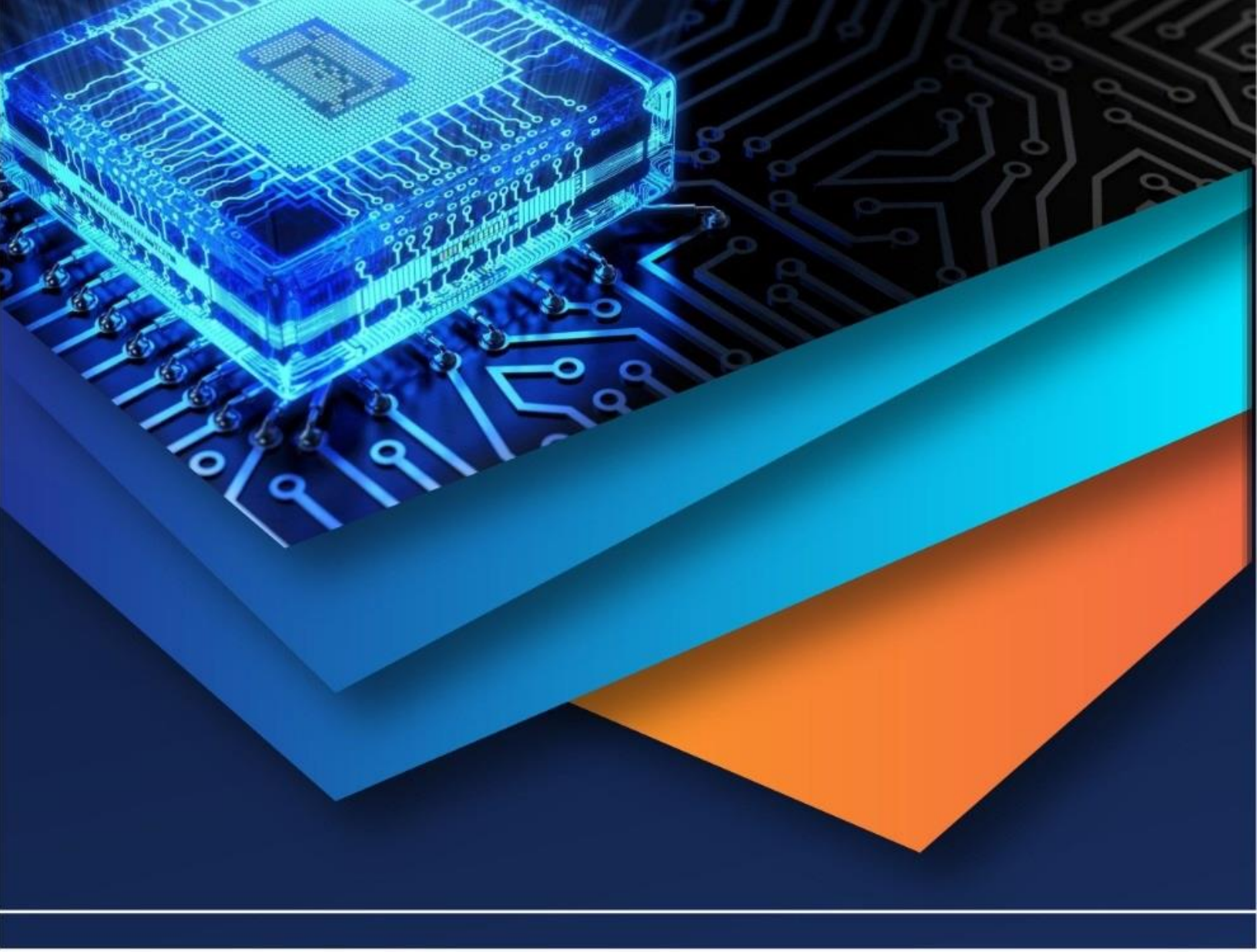
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