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Reliability and Availability Evaluation of Hydro Power Station

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ABSTRACT: This paper presents an evaluation of Markov models used to obtain unit reliability and availability the operational data of Pathri power stations (India) for period 2007 - 2012. The most important reliability indices are found namely failure rate (λ), repair rate (μ), MTTR, MTBF, MTTF Through data collection and analysis. The data of each year and for each unit is time scheduled. After tabulating all the data, we classified for each unit the different type of failure taking into account the various sub units and systems. According to the classification we defined Markov states. Failure rate repair rate of all state are found from the classified data. The determination of availability and reliability from their definition is completed.

I. INTRODUCTION

Pathri hydro power station (PHPS) has an installed capacity of 20.4MW.It consists of 3 identical independent unit of 6.8MW capacity per each. PHPS has been constructed on upper Ganga canal at 13 km downstream of holy city, Haridwar, India. All the mechanical equipments were supplied by J.M. Vaith, Germany and electrical equipments by Siemens, Germany. Each unit of PHPS units consists of several subunits such as Turbine, Generator, Excitation system, Speed Governor, Spiral case, etc.

The objective of "Reliability Evaluation of Hydropower Station (PHPS) is: To study the Frequency of Scheduled maintenance of each individual generating unit of the station. To Evaluate MTTR, MTBF, MTTF, failure rate, repair rate, probability of occurrence of failure for the components/ subsystems of individual generating unit. To carry out Markov model and State space diagram of both hydro power station. To apply the common concepts of probability to find the overall reliability of Hydro power station.

II. METHODOLOGY

The most important reliability indices are found namely failure rate (λ), repair rate (μ), MTTR, MTBF, MTTF Through data collection and analysis. An evaluation of Markov models used to obtain unit reliability and availability the operational data of these stations for period 2007 – 2012. The data of each year and for each unit is time scheduled. After tabulating all the data, we classified for each unit the different type of failure taking into account the various sub units and systems. According to the classification we defined Markov states. Failure rate repair rate, MTTR, MTTF, MTBF of all state are found from the classified data. The determination of availability and reliability from their definition is completed.

III. MODELING

Hydro-Unit Model: To drive the Markov model of a Hydro-unit we assume: The failure and repair rates are exponentially distributed. There are no transition between the scheduled and force outages. The unit after repairing is immediately returning to up state.

From the above definition a developed Markov model is driven as follows:

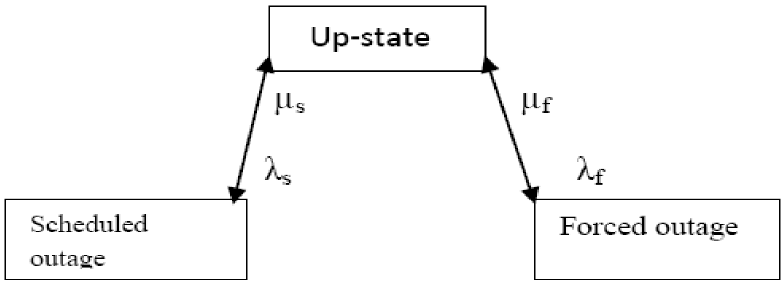


Fig.1 *Three- state Markov model*

We classify events of Hydro-unit and it's down state into:

1. Reserve, Preventive maintenance, and overhaul.
2. Generator.
3. Turbine (inlet gate, penstock, spiral case, butter fly valve, turbine bearing and runner)
4. Excitation system (thyristor, cooling system, equipped transformer, etc…..)
5. Governor system (servo motors, wicket gate, speed governor, etc……)
6. Main Unit Transformer.
7. Main Unit Circuit Breaker.
8. External Effects.

More developed model is driven as follows:

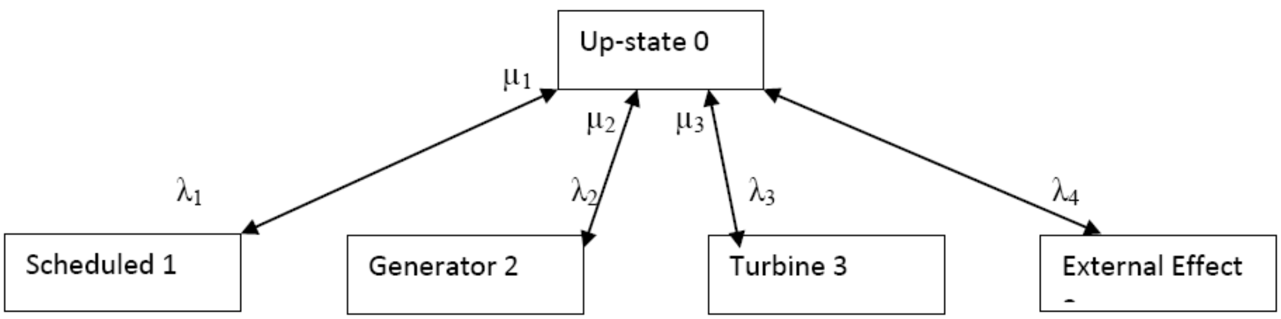


Fig.2 *Developed hydro-unit model*

Table 1: State Probability Value & Frequency of Encountering States

State Number	State probability		Rate of departure	Frequency of state
0	$\mu_1\mu_2\mu_3\mu_4\mu_5\mu_6\mu_7\mu_8/D$	d0/D	$\lambda_1+\lambda_2+\lambda_3+\ldots\ldots+\lambda_8$	$(\lambda_1+\lambda_2+\lambda_3+\ldots\ldots+\lambda_8)\,d0/D$
1	$\lambda_1\mu_2\mu_3\mu_4\mu_5\mu_6\mu_7\mu_8/D$	d1/D	μ_1	$\mu_1 d1/D$
2	$\mu_1\lambda_2\mu_3\mu_4\mu_5\mu_6\mu_7\mu_8/D$	d2/D	μ_2	$\mu_2 d2/D$
3	$\mu_1\mu_2\lambda_3\mu_4\mu_5\mu_6\mu_7\mu_8/D$	d3/D	μ_3	$\mu_3 d3/D$
4	$\mu_1\mu_2\mu_3\lambda_4\mu_5\mu_6\mu_7\mu_8/D$	d4/D	μ_4	$\mu_4 d4/D$
5	$\mu_1\mu_2\mu_3\mu_4\lambda_5\mu_6\mu_7\mu_8/D$	d5/D	μ_5	$\mu_5 d5/D$
6	$\mu_1\mu_2\mu_3\mu_4\mu_5\lambda_6\mu_7\mu_8/D$	d6/D	μ_6	$\mu_6 d6/D$
7	$\mu_1\mu_2\mu_3\mu_4\mu_5\mu_6\lambda_7\mu_8/D$	d7/D	μ_7	$\mu_7 d7/D$
8	$\mu_1\mu_2\mu_3\mu_4\mu_5\mu_6\mu_7\lambda_8/D$	d8/D	μ_8	$\mu_8 d8/D$

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

Plant Modeling: To Model PHPS the three units should be studied together. The number of failure rates and repair rates of a unit for five year and for all the units are taken to determine the plant availability and reliability.

The state probabilities are determined by the same ways as for unit modeling. The probability of state 1 is the probability that the three units (PHPS) are up

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

Probability of state 8 is the probability that all the units are down

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

The frequency of encountering state 1 is, f1 = (λ1 + λ2+λ3) P1

The frequency of encountering state 8 is, f8 = (μ1 + μ2+ μ3)/ P8

IV. RESULTS

Hydro-Unit Modeling: For PHPS, The failure rate and repair rates for these states and their probability are shown bellow in table.

For evaluation of reliability and availability we will take the unit-I of PHPS,

$$\text{Availability} = \frac{P0}{P4+P6} = 0.99794$$

According to the definition of reliability is considered as the probability of unit without failure.

$$\text{Reliability} = P_0 + P_3 = 0.996650$$

Similarly we calculate all unit of availability and reliability of PHPS, the result is as shown in Table3 .Failure states are reset into the first repair state and therefore, the transition probabilities out of the failure states and out of the first repair state are identical.

Plant Modeling: PHPS: The maximum number component of state in a three component ,where each component can exist in two states, is 2^3 or 8.This is shown in fig.3 in λ and μ which represents the failure rate and repair rates of component and U and D indicates that the component is up or down respectively. The states to be combined for system success and failure are: 2-out-of-3 system - success = states 1,2,3,4 Failure =states 5,6,7,8 as shown in Table 4.

Table 2: Failure Rates, Repair Rates and State Probabilities for PHPS and CHPS

Pathri hydro power station(PHPS)
Down States event of hydro unit 1

State Number	Basic Event	No.of occurrence	Total repair times(hrs)	MTTR in hrs	MTBF in hrs	MTTF in hrs	Repair Rate in μ	Failure Rate in λ	Probability of occurrence	State Probability
0	Up State									0.995421
3	Turbine(inlet gate,penstock,spiral case,butter fly valve,turbine	11	54.2	4.92727	3986.2	3981.255	0.20295	0.00025	0.001236088	0.00122938
4	Excitation system(thyrister,cooling system,equipped transformer,and etc.)	4	9.55	2.3875	10962	10959.61	0.41885	0.00009	0.000217798	0.00021442
6	Main unit transformer	7	26.55	3.79286	6264	6260.207	0.26365	0.00016	0.000605501	0.0006056
			108.22				0.88545	0.00050	0.002059387	
Reliability=0.996650 Availability=0.997940										

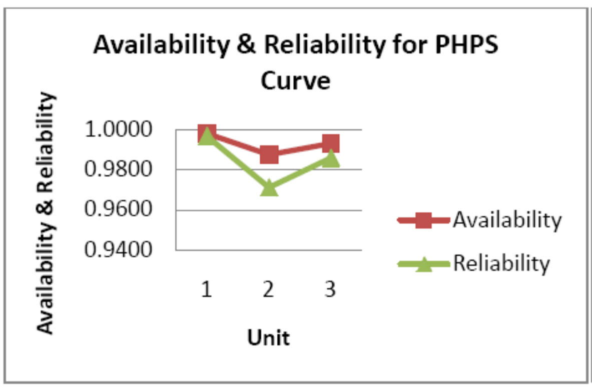
Pathri hydro power station(PHPS)
Down States event of hydro unit 2

State Number	Basic Event	No.of occurrence	Total repair times(hrs)	MTTR in hrs	MTBF in hrs	MTTF in hrs	Repair Rate in μ	Failure Rate in λ	Probability of occurrence	State Probability
0	Up State									0.564728
2	Generator	4	31.6	7.9	10962	10954.1	0.12658	0.0000913	0.000721191	0.0038339
3	Turbine(inlet gate,penstock,spiral case,butter fly valve,turbine bearing,and runner)	3	214.25	71.4167	14616	14544.58	0.014	0.0000680	0.00491019	0.028115
6	Main unit transformer	8	267.3	33.4125	5481	5447.588	0.02993	0.0001836	0.006133449	0.4063897
8	External Effect	3	36	12	14616	14604	0.08333	0.0000685	0.000821693	0.00038339
			549.15				0.25385	0.00041	0.012586523	
Reliability=0.971118 Availability=0.9874134										

Pathri hydro power station(PHPS) Down States event of hydro unit 3										
State	Basic Event	No.of occurrence	Total repair times(hrs)	MTTR in hrs	MTBF in hrs	MTTF in hrs	Repair Rate in μ	Failure Rate in λ	Probability of occurrence	State Probability
0	Up State									0.9830485
3	Turbine(inlet gate,penstock,spiral case,butter fly valve,turbine bearing,and runner)	16	119.25	7.45313	2740.5	2733.047	0.13417	0.00037	0.00273	0.00273785
4	Excitation system(thyrister,cooling system,equipped transformer,and etc.)	3	4.2	1.4	14616	14614.6	0.71429	0.00007	0.00010	9.6432E-05
5	Governor system(servo motor,wicket gates,speed governor,and etc)	4	151.15	37.7875	10962	10924.21	0.02646	0.00009	0.00346	0.00033151
8	External Effect	3	32.12	10.7067	14616	14605.29	0.0934	0.00007	0.00073	0.00074211
			306.72				0.96832	0.00059	0.00701	
		Reliability=0.985786		Availability=0.99298503						

Table 3: System Availability and Reliability of (PHPS) 2007-12.

UNIT	Availability	Reliability
1	0.9979	0.9967
2	0.9874	0.9711
3	0.9930	0.9858



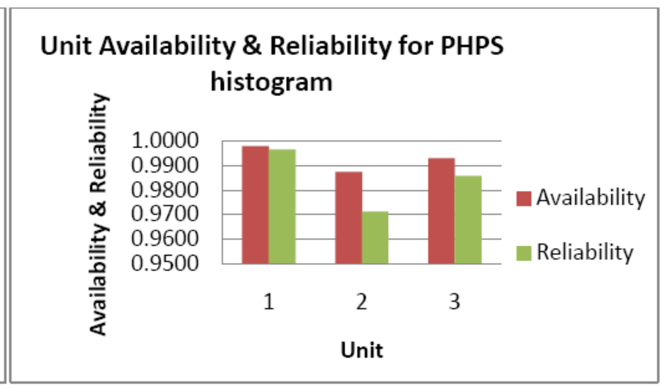


Fig. 3. Availability & Reliability of PHPS.

Table 4: PHPS State Probability and Availability, Reliability Determination 2007-12.

State Number	State Probability	Frequency Of State
1	0.335310000	0.000146540
2	0.213010000	0.000056000
3	0.203061000	0.000042600
4	0.211300000	0.000000050
5	0.000000094	0.000000011
6	0.000000096	0.000000117
7	0.000000003	0.000000006
8	0.000000000	0.000000000

2-out-of 3 system, State Probability = 0.942681, So, Reliability of PHPS = 0.942681, Availability of PHPS = 0.97012

V. DISCUSSION AND CONCLUSION

The weak points that cause poor point reliability and availability for PHPS are given in Table 5.

Table 5: Unit Major Faults That Affect the Reliability Indices for PHPS.

Unit No.	Cause of trip	Down time in Hr due to trip
Unit-1	Turbine (inlet gate, penstock,…etc)	54.2
Unit-2	Main Unit Transformer	267.3
Unit-2	Turbine (inlet gate, penstock,…etc)	214.25
Unit-3	Turbine (inlet gate, penstock,…etc)	119.25
Unit-3	Governor system (servo motors, wicket gates, Speed governor and etc...).	151.15

Our study of the plant availability and reliability that the maintenance program and skill of Engineers and technicians play an important role for improving the performance of the units and increasing the availability and reliability of the units and the power plant.

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