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Strategy Selection For Reliability Based Maintenance In Hydropower Plant: A Case Study On Bijaypur-I Small Hydropower Plant

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Abstract

Maintenance is any activities that are carried out to preserve the function of the system. So its role is important in keeping and improving the availability, reliability, quality, safety requirements and operating cost levels of the product and service industries. The role of maintenance in energy sector cannot be quantify easily. As the country like Nepal where the government of Nepal aim to large transition of energy consumption from 198 kWhr to 700 kWhr in the coming five year creates great role of reliability. so to supply reliable energy to the consumer, it needs firstly the source of energy must be reliable. As hydropower is main source of energy , so to make hydropower reliable each hydropower should select specific maintenance strategy which is most important task. so this paper approach to selection of strategy for the implementation of reliability based maintenance. As Reliability based maintenance is an integrated approach of preventive and breakdown maintenance to make maintenance activities cost effective and applicable to all type of industries. This paper foster the approach with the case study of Bijaypur-I Small Hydropower Plant which is located in Kaski District. From the study of past seven years failure data of BSHP-I the reliability and availability of the plant were analysed to find the critical assets of the plant. The study concluded that the reliability of BSHP-I was only 0.986 which is lower than the sunkoshi hydropower and the cooling system is the main contributing component and marked as critical assets. The study also highlights some of the solution to improve the reliability of critical assets such as redundancy, increase the time of flushing, use of cyclone separator to separate the dissolved limestone and dissolved sand , and to use close loop cooling system instead of open system. Beside this the study also suggest the maintenance strategy for BSHP-I unit-I by critical analysis of the various component of the hydropower plant which will be helpful to reduce the cost of maintenance by balancing the cost of preventing maintenance and breakdown maintenance

Keywords

critical assets, cooling system, cost, hydropower,reliability,maintenance, strategy

1. Introduction

Reliability engineering is a very fast growing and very important field in consumer and capital goods and service industries. It provides the theoretical and practical tools to ensure that the product and services that deliver by the system is reliable by specifying the probability and capability of systems can perform their required functions in specified environments for the desired period of operation without failure. And it provides feedback to engineering, manufacturing, quality control, and service for improvements and necessary corrective actions. Electricity is one of the most important human needs in this modern age. So reliability of such facilities plays important role in the quality of life and the economy of the county. Uncertain power outage due to the problem in power plant may question marks to the power supplier and also losses to the power producer. The reliability of the services can only be fulfilled when the machinery parts are in well condition i.e. if they are reliable. So, the need of improve in the reliability of assets (production systems) and promote uptime and availability has become one of the most important factors in the growing competition in consumer goods and services which uplift the importance of improving maintenance; in addition, increasing maintenance costs are considered among the most important reasons for seeking more effective ways of maintaining production assets. RCM is a technique to develop Preventive Maintenance; it emerged in the 1960s in the aircraft industry as a substitute for preventive maintenance. It depends on the theory of preventing potential failure which could have serious consequences and originated in response to the heavy increase in maintenance costs. All the other strategies such as Preventive, Proactive and Reactive Strategy are integrated optimally in RCM, together with their respective advantages, in order to achieve the highest level of reliability in the equipment and thus that in the components of the whole facility. so it is a modern and developed theory of maintenance, because it requires an organized maintenance program. Such programs are usually based on the needs for equipment maintenance, arranged according to their importance.

2. Problem,Objective and Scope

Maintenance is any activities that are carried out to preserve the assets of the organization [1]. In Nepal Department of Electricity Development recommend five type of technical maintenance strategies which are Run to failure Maintenance, Preventive maintenance, Proactive maintenance, Predictive maintenance and Reliability centred maintenance [2]. In general preventive maintenance is considered to be worthwhile, there are some disadvantages such as huge cost and need of specialist labour. So preventive maintenance in all context such as in small hydropower is not be the cost effective strategy for every machinery/component especially for all the assets of hydropower plant. But this doesvnot mean that to adopt run to failure approach of maintenance which is quite economical than preventive maintenance in maintenance point of view as it create uncertainty in the system and greatly affect the reliability and availability of the system. Thus it is better to adopt an integrated method to preserve the function of the assets. This method is commonly known as Reliability Centred Maintenance. As RCM considered as one of the best known and most used tools to preserve the operational efficiency in critical sectors like power plants, artillery system, aviation industry, railway networks, oil and gas industry and ship maintenance but still remains unimplemented, due to lack of proper methodology and tools [3]. This paper proposes a general RCM model suitable for hydropower plants and intended to prepare the suitable maintenance strategy to uplift the reliability of the hydropower plant.

As hydropower is the main source of energy of Nepal.Government of Nepal has plan to increase the rate of per person energy consumption from 198 kWhr to 700 kWhr at the end of 15th five year plan.[4] Government plan will be successful only if the consumer which are using traditional fuels such as firewood to the another form of energy called electricity which have large range of utilities and application. A research shows that Consumers are willing to have a sustainable energy transition from traditional fuels to electricity and willing to pay 19 to 25 percent of the existing average monthly bill for reliable electricity supply [5] . And reliable electricity supply is possible only when the source is reliable. To ensure quality and reliable operation of the equipment, to maximize availability of equipment with least number of shut down and Eradication / non repetition of operational problems and also to increase the profitability of hydropower, Planned maintenance is required. Reliability Based Maintenance is a technique to develop the strategies to increase the reliability and availability of the system [6].

3. Methodology

Aiming to run the applicability of the methodology proposed in this paper, it is necessary to define a hydroelectric plant that will be taken as the basis of analysis in order to complete characterize their systems, allowing the application of Fault Tree Analysis, which forms the basis for a future implementation of Reliability based maintenance policies and asset management techniques. This study is based on the case study of Bijayapur-I Small Hydropower Project (BSHP-I). It is a multipurpose, Run of the river type, 4.5 MW small hydropower project located at Pokhara-Lekhnath Metropolitan city of Gandaki Provenance. It uses water of Bijayapur Khola and Sheti Irrigation Drainage and is 2 km from the prithivi Highway. With rated Design head 65.4 m and discharge 8.3 m3/s is operating since Bhadra 9, 2069 BS. BSHP-I was developed by Bhagabati Hydropower Company (p) ltd, with the financed of Rastriya Banijya Bank, Nabil Bank and Napal Bank Ltd. It has two units of horizontal shaft Francis turbines to generate electricity.

The method adopted in this study is shown in figure. Marchov three state model was adopted to define the state i.e up state and down state in hydropower which classifies the down state into two categories, Scheduled Outage and Forced Outage[7]. Forced outage includes all of the failure due to the failure in Electromechanical component in hydropower and Scheduled outage includes the failure of plant due to insufficient flow, flood, system error in the NEA, Problem in the grid transmission line and planned shutdown for the inspection and maintenance. Fault tree analysis technique was used to identify the critical assets and computational technique of fault tree analysis was used to calculate the reliability and availability of the plant. The data for analysis was taken from log sheet maintained from F/Y 2069/70 to F/Y 2075/76 at BSHP-I and the field survey of BSHP-I.

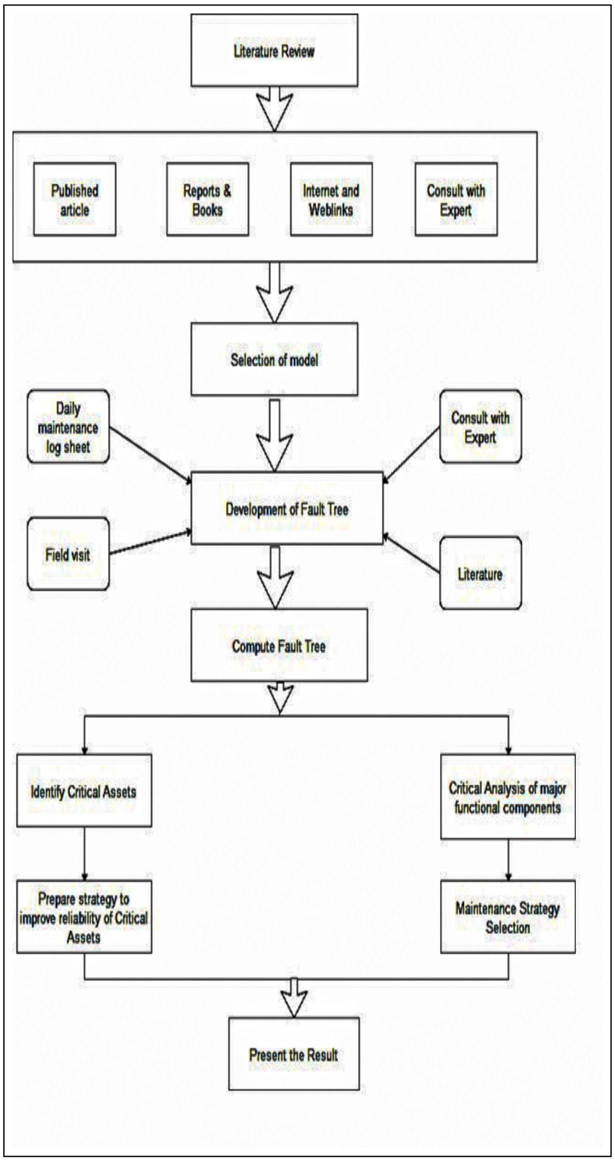

Figure 1: Research Framework

4. Result and Discussion

4.1 Reliability and availability analysis

The failure data from the log sheet of BSHP-I were analyse through the Analytical Hierarchical Based fault tree analysis method. Firstly the fault tree of the BSHP-I was constructed with the help of failure data, interaction with the operation in-charge of BSHP-I and different literature related to operation and maintenance of hydropower

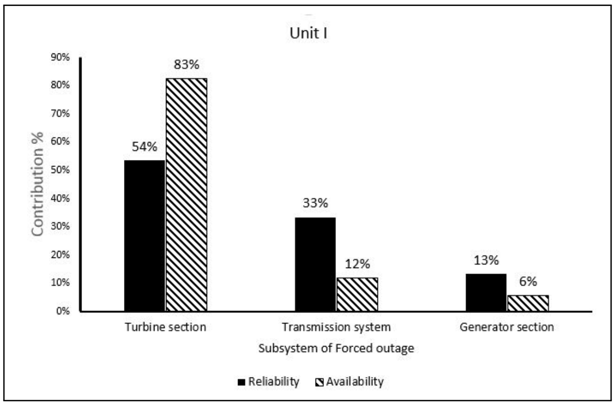

Figure 2: Contribution of three main subsystem of hydropower in reliability and availability in unit I

Figure 2 shows the reliability and availability contribution percentage of each subsystem of unit-I in Electromechanical system. As from the analysis of past seven years data it is found that the reliability and availability of unit-I collectively found as 0.9268 and 0.9034 respectively where the contribution of turbine section is 54 and 83 percentage respectively. After the analysis it is found that the reliability of turbine section is 0.976408 and availability of generator section of unit –I is found as 0.9994146 and transmission system is 0.985237. Similarly the availability of turbine section is 0.971873, generator section seen as 0.998114 and transmission section is 0.995973. from the above data and data presented in figure it can be clear that the contribution of turbine section to decrease reliability and availability is greater than other section for unit-I of BSHP-I.

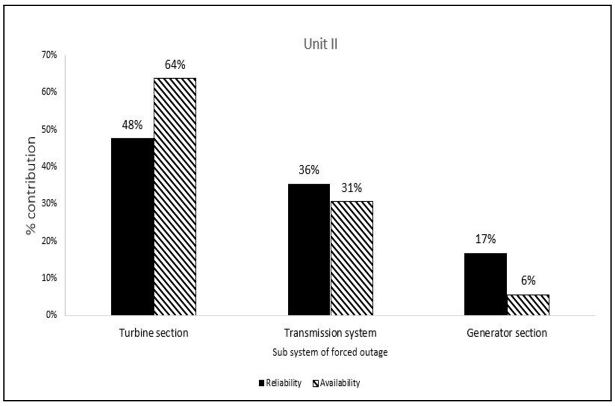

Figure 3: Contribution of three main subsystem of hydropower in reliability and availability in unit II

Similarly in Unit-II, figure 3 shows the contribution of three subsystem of Unit-II in Electromechanical system. As from the analysis of past seven years data it is found that the reliability and availability of unit-II collectively found as 0.933 and 0.9244 respectively where the contribution of turbine section is 48 and 64 percentage respectively as the reliability and availability of turbine section is found as 0.980237 and 0.991631 respectively. Similarly for generator section the reliability and availability is found as 0.99298 and 0.999259 respectively. And reliability and availability of transmission section is same as unit –I, as BSHP-I has single transmission line for both the unit to transmit generated electricity to lekhnath substation. In case of unit –II we can conclude that the reliability and availability of turbine section is less than other subsystem and figure clearly shows that the contribution of turbine section for Electromechanical failure is higher so it implies the critical assets in reliability based maintenance.

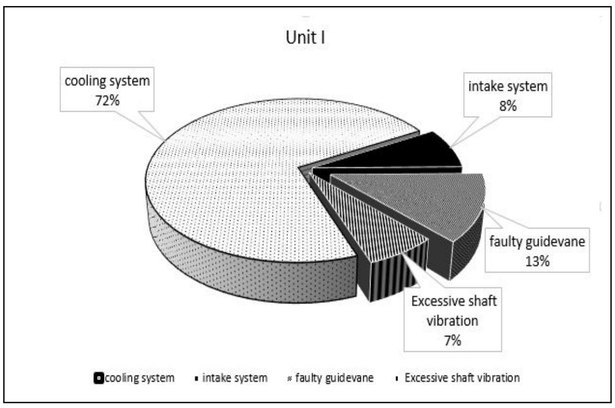

Figure 4: Contribution of component of turbine section in reliability and availability in unit I

As from the fault tree analysis the failure in turbine section are caused due to main four causes cooling system failure, problem in intake gate system, due to faulty guide-vane and due to excessive shaft vibration. From the analysis it is found that the contribution of cooling system in reliability is 72 percent in unit-I which is more than other subsystem which is shown in figure 4. As in cooling system all total 40 failure were observed with total breakdown hours of 501 hours were recorded in past seven years of study. Whereas there were only 9 failures in intake gate system, 8 failures in guidevane and 4 failures due to excessive shaft vibration. However the breakdown time is higher due to excessive shaft vibration which affects plant for 1116.36 hours where faulty guidevane and intake system fails for 39.4 hours and 68 hours respectively. As faulty guidevane and excessive shaft vibration are the intermediate event of fault tree whereas cooling system and intake system are the basic event. As the contribution of cooling system is more than other event so cooling system is the critical assets of unit –I.

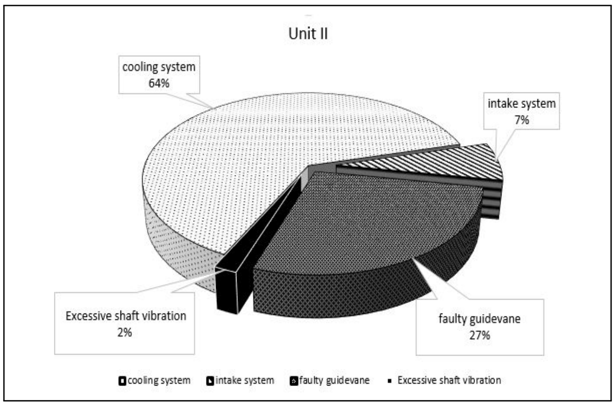

Figure 5: Contribution of component of turbine section in reliability and availability in unit I

Similarly, from the analysis it is found that the turbine section contributes more in reliability than other component also in unit-II. And as explain in unit I in unit II also the contribution of cooling system in reliability is more than other subsystem. The contribution of cooling system is found 64 percentage which is more than other subsystem of problem in turbine system in fault tree. From the analysis of data it is observed that 33 failure with 295 hours of outage were recorded in past seven years which was taken in consideration. While faulty guidevane is also another subsystem which contributes 27 percentage in the reliability of the plant where it fails for 14 times and disturb 118.18 hours. Excessive shaft vibration and problem in intake gate fails only for one and three time in seven years period of analysis. And the contribution of different subsystem is shown in figure below. As cooling system is the basic event of fault tree so in order to find out he critical assets cooling system is observed as the critical assets in unit II.

As from these analysis it can be concluded the reliability of BSHP-I is 0.986 which is low than that of sunkoshi hydropower plant whose reliability is measures as 0.997 [8] and from the analysis it is concluded that both the system suffers majorly from insufficient flow and due to the failure in cooling system. So the reliability strategy should be focused on the cooling system and following strategy are recommended to improve the reliability of the BSHP-I

Redundancy From the point of view of economy, ease of maintenance, and ease of adaptation of existing equipment, it would be desirable to make the largest possible units redundant . In this case if we add a parallel panel of filter, the reliability of the cooling system can be improved form 0.989 to 0.999 and availability from 0.953 to 0.997.

Frequency of flushing As reliability of the cooling system is 0.989, for the flushing time of 15 days . If the flushing frequency is increased to 3 times than now the reliability will increased to 0.998 and availability improved to 0.989

Cyclone Separator In power station, if victimized by silts water, frequent choking of strainers requiring their cleaning every week or every day in some situations. Solution lies in incorporating additionally the cyclone separators[9] on the discharge side of the cooling water pumps the cyclone separators draw water through tangential slots and accelerate the filtration process taking advantage of the centrifugal force. It is claimed that they can arrest 90 percent of silt particles of size as small as 74 microns.

Closed circuit cooling water system In arrange to dispense with the unfavorable impact of residue, a closed circuit cooling framework could be considered, consisting of a water tank of adequate capacity, heat exchangers and circulating pumps. Initial filling and make up water can be drawn from shaft sealing water supply, to keep circulating in a closed cycle through coolers and heat exchangers. Closed circuit frameworks could be temperate in the long run since they can be outlined to consume less power compared to that required for pumping water from the tail race or indeed compared to the misfortune of generation related with penstock tapping[9].Also this issue can also be overcome by presenting a near close loop together with an open loop circuit of cooling water supply which passes through a Tubular Heat Exchanger directly submerged into Draft Tube water where heat exchange might takes place[10].

4.2 Critical Analysis

Criticality analysis is a tool used to evaluate how equipment failures impact organizational performance in order to systematically rank plant assets for the purpose of work prioritization, material classification, Maintenance strategy development and reliability improvement initiatives[11].For this the component of different component of Unit-I of BSHP-I were selected from the fault tree of BSHP-I as per the contribution in the performance of the hydropower. The equipment criticality (EC) is assessed based on the effect of errors/faults, right from the time of installation and is quantified with scores 1, 2, 3 as shown in table. The formula for calculating EC is:

$$EC = (30P + 30R + 25A + 15C)/3$$

where, EC: is the equipment criticality (percentage),

P: is the production, R: is the Contribution in Reliability,

A: is the equipment availability,

C: is the capital cost[12].

The reliability parameter of different component of BSHP-I unit-I is shown in table 1 and the critical analysis is shown in table 2. From these analysis it is found that the critically of cooling system and Breaker system has higher than other component. With referring the critically of each equipment the maintenance strategy is allocated. From the analysis, intake system of unit-I seen less critical among the selected component and concluded to select the run to failure strategy of maintenance while other component such as lubrication system of turbine section, Insulator of transmission system and Rotor of Generator section has the critical range between 50 to 65 so condition based maintenance or proactive maintenance strategy is suitable.

5. Conclusion

This paper proposes an analytical hierarchical based fault tree analysis approach to find out the critical assets and strategy selection for reliability based

Table 1: Reliability Parameter of BSHP-I unit I

SN	Component	MTBF	MTTR	Availability	Reliability
1	Intake System	12514.29	1.16	99.991	0.9981
2	Cooling System	1251.43	11.72	99.072	0.9810
3	Governor	30660.00	3.00	99.990	0.9992
4	lubrication system	61320.00	74.49	98.879	0.9996
5	Bearing	61320.00	362.13	99.413	0.9996
6	Insulator	30660.00	32.23	99.895	0.9992
7	Breaker failure	4088	7.15	99.825	0.9941
8	Transmission equipment	4088.00	3.03	99.926	0.9941
9	Rotor	30660	8.46	99.972	0.9992
10	Excitation system	4716	7.60	99.839	0.9949
11	Runner	30660	6.18	99.980	0.9992
12	Transformer	20440	4.08	99.980	0.9988
13	Guide vane	10220	5.57	99.946	0.9977

Table 2: Critical Analysis of the component and maintenance strategy

SN	Component	Contribution on reliability	Availability	Impact on Production	Maintenance Cost	Equipment Critically	Maintenance Strategy
1	Intake System	2	1	1	1	43.3	BM
2	Cooling System	3	3	2	1	80.0	PM
3	Governor	2	1	2	2	58.3	CbM
4	lubrication system	1	2	2	1	51.7	CbM
5	Bearing	1	3	2	3	70	PM
6	Insulator	2	2	1	1	51.7	PM
7	Breaker failure	3	2	3	1	81.7	PM
8	Transmission equipment	3	1	3	2	78.3	PM
9	Rotor	2	1	2	2	58.3	CbM
10	Excitation system	3	2	2	2	76.7	PM
11	runner	2	1	2	2	58.3	CbM
12	Transformer	2	1	3	2	68.3	CbM
13	Guide vane	3	1	1	1	53.3	CbM

maintenance in hydropower plant and is used to identify the critical assets and maintenance strategy for Bijaypur-I small hydropower plant. From the analysis of unit I and II of BSHP-I it is found that the reliability of the plants is 0.9268 and 0.933 respectively and availability is 90.34 and 92.44 percent respectively. Collectively the reliability of BSHP-I is found 0.9819 and can be concluded low reliablity as compared to sunkoshi hydropower. As in BSHP-I, most of the time it suffers from insufficient flow and problem in cooling system due to soluble limestone in the water of sheti river and concluded cooling system contribution in EM system is significant in reliability and availability of the plant. So this paper recommend some strategy to improve the reliability of cooling system. To improve the reliability and availability of the whole system it will be insufficient by implementing strategy in only one component so this paper approach a critical analysis of the major component whose contribution are significant from the analysis of Fault tree of Unit-I. This study identifies the major component of BSHP-I and analyze the criticality of the component with the help of fault tree of unit-I and the result presents the technical maintenance strategy as recommend by Department of Electricity Development. which will help to reduce the cost of maintenance as the extra cost incurred by adopting preventive maintenance will get balanced with the cost saving by adopting breakdown maintenance and proactive maintenance for the rest of the component of the plant.

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