Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 3, Issue 9; April-June, 2016, pp. 773-775

http://www.krishisanskriti.org/Publication.html

Analysis for Turbine Maintenance Cost Correlation in Mini Hydropower Projects

Ravi Kumar[*1] and S.K. Singal[2]

[1,2]Alternate Hydro Energy Centre Indian Institute of Technology Roorkee, Roorkee, Uttarakhand- 247667, India
E-mail: [1]er.ravi.49@gmail.com, [2]sunilksingal@gmail.com

Abstract—*Mini hydropower* ***is a tiny scheme of electricity generation for local area and also selling in national grid. In India it ranges from*** *101kW to 2000 kW* ***renewable energy source.*** *Proper maintenance of mini hydropower plants can decrease failure time and extend equipment life. The inappropriate maintenance is beginning of the rise in maintenance cost and cannot be cost effective to perform it repeatedly. Due to increase in the maintenance cost of turbine in Mini hydropower plants, an attempt has been made to develop the correlation for the maintenance cost of turbine by linear regression analysis with curve fitting tool in Matlab software, considering net head and capacity as cost influencing parameters. The developed correlation has been compared with the collected cost data of the existing hydropower stations for validation.*

Keywords*: Renewable energy, Mini hydropower, maintenance cost data, linear regression analysis.*

1. INTRODUCTION

Hydropower is a Renewable non- polluting and environmentally friendly source of energy, whereas for increased **in energy demand** consumption and production of electricity from conventional sources are increased which make bad effect on environment and human health with increase GHG emission. Therefore, we need to give more emphasis on the development of renewable sources of energy, which is clean and no emission of toxic gases. **Hydropower energy is the oldest energy technique known to mankind in which potential of water pressure energy can be used as mechanical energy on the turbine shaft and further this mechanical energy can be used by generator to generate the electricity energy generation [1,2].** Out of the total renewable energy generation installed capacity of 42849.38 MW in the country, small/mini hydropower contributes about 4273.47 MW up to May 2016 [3].**Despite the magnitude of potential of Mini and Micro Hydropower Projects, only a marginal amount of power is so far tapped from these sources.** The turbine is the most impotent part of any hydropower project and have so much cost.

The O&M cost also goes too high for turbines in hydropower plants. The present study is aimed to develop the O&M cost correlation for hydro turbine in mini hydropower projects based on the cost sensitive parameters as net head and installed capacity of power plant [4].

2. HYDROPOWER PROJECT CLASSIFICATION IN INDIA

There is a general tendency all over the world to define Small Hydropower by the power output. Different countries follow different norms, the upper limit ranges between 5 to 50 MW. In India, hydro projects up to 25 MW station capacities have been categorized as small hydropower (SHP) projects. Table 1 shows the classification of hydro schemes in India [1].

Table 1: Classification of hydropower schemes in India. [5]

Type	Station capacity
Pico	Up to 5kW
Micro	Up to 100 kW
Mini	101kW to 2000 kW
Small	2001kW to 25000 kW
Medium	100,000 kW & below

3. LITERATURE REVIEW

Electro-mechanical equipment of the small and mini hydropower plants contribute higher percentage in the installation cost and affect the project feasibility more. All the cost like installation cost of project civil works, equipment costs, replacement costs, fixed and variable operating and maintenance costs (O&M) are estimated in different way because of different site conditions in each project[1,2,5]. An attempt has been made to briefly review the previous works related to cost aspect of electromechanical equipment of small and mini hydropower plants.

Kumar and Singal [4] developed the equations for O&M cost of SHP plants ranging from 2 to 25 MW having different type of turbines. Singal and Saini [6] developed the correlations for the cost of low-head SHP schemes having different head and capacity has been compared with the available cost of the existing hydropower stations. Ogayar and Vidal [7] developed the correlation for different types of turbines for a power range below 2 MW. Singaland Saini [8] determined the cost of

different components of low head SHP schemes. Based on the determined cost, co-relations in the form of cost as function of head and discharge have been developed. The cost based on the developed co-relations, having different head and capacity has been compared with the available cost of the existing hydro power stations. Kumar and Singal [9] discussed various maintenance models to evaluate the fault information, condition improvement by maintenance and reliability. These are capable of describing actual processes more realistically, and also facilitate optimisation for maximum reliability at minimal costs. Cavazzini et al. [10] proposed a new approach based on the head, power and flow rate to estimate the cost of small and micro hydropower plants. The resulting correlations are validated with previous correlations available in the literature and found good accuracy with mean error less than 20%.Mishra et al. [11] developed a correlation to determine the cost based on the cost influencing parameters as power and head using three different methods, namely; sigma plot method, linest method and longest method. Also identify the best correlation among the three models closer to the actual cost of electro-mechanical equipment. Mishra et al. [12] developed cost correlation for electro-mechanical equipment, in which they used capacity and head as cost influencing parameter, whereas runner diameter of the turbine, ratings of electrical equipment can also be used as cost influencing parameters.

4. DATA COLLECTED AND ANALYSIS

O&M cost data of hydroelectric turbine were collected from power plants under Punjab Genco Ltd., Himachal Pradesh state electricity board and Manimahesh hydel power project co-society ltd. Chamba, Himachal Pradesh. Punjab Genco Ltd a wholly owned company of Punjab Energy Development Agency (PEDA), the State Nodal Agency is responsible for promotion and development of non-conventional and renewable energy sources including small hydro power plants in the State of Punjab.

All projects have the capacity range equal and less than2000 kW, which comes under the schemes of mini hydropower project in India. Details of O&M cost of each project turbine is given in table 2 below.

Table 2: Maintenance cost detail of turbine in rupee (₹).

S. No.	Site name	Capa-city (kW)	Head (m)	Date of com-mission	Axis	Turbine	O&M cost (₹)	O&M cost/ kW (₹)
1	Chupki	1500	2.72	1999	Ver-tical	Semi Kaplan	203000	135.33
2	Narangwal	1500	2.57	1999	Ver-tical	Semi Kaplan	220000	146.67
3	Tugal	1500	2.42	1999	Ver-tical	Semi Kaplan	232500	155.00
4	Dalla	1000	2.66	1999	Ver-tical	Semi Kaplan	100000	100
5	Sal-II	2000	30	1999	Hori-zantal	Francis	480000	240
6	Dikleri	2000	80	2013	Hori-zantal	Francis	550000	275

From literature, it is found that there are many correlations developed related to the optimization of installation cost based on head and power as parameters forSHP and mini hydro power plants. In the present study, correlation for maintenance cost of turbine has developed by using linear model analysis approach with the help of curve fitting tool in matlab software. Considering head and capacity as cost sensitive parameters the methodology of developing linear model is shown by equation 1 below:

$$C = a+Pb+Hc \quad (1)$$

Where:

- C is maintenance cost of component in rupees per kilo Watt (₹/kW);
- P is capacity of the plant energy in kilo Watt (kW);
- H is the net head of the plant in meter (m);
- a, b and c are correlation constant.

Before correlation development, maintenance cost data are converted in per kW cost to the equality of data as shown in table 2 and then developed the correlation by best curve fitting tool. The goodness of fit i.e.R^2 value is 0.9836, whereas 1.0 indicates best fitting of linear model line data. Graphical representation of developed correlation shows in Fig. 1. The correlation developed for turbine w.r.t maintenance cost per kW in rupee (₹) is given below:

$$C_t = -19.4+P*0.111+H*0.9438 \quad (2)$$

Where C_t = maintenance cost of turbine (₹)

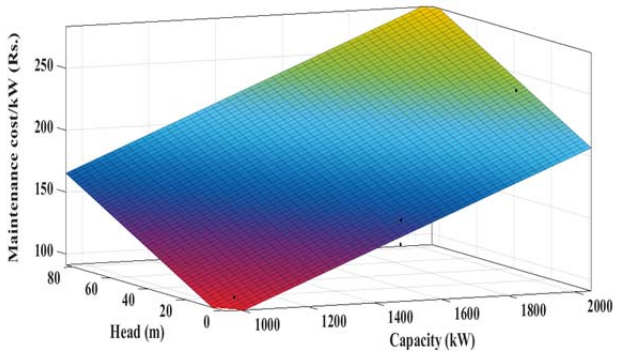

Fig. 1: Graphic representation of correlation for turbine maintenance cost.

5. RESULT AND DISCUSSION

An analysis for correlation development of maintenance cost of hydroelectric turbine for small and mini hydropower projects has been carried out. The costs correlations were developed by using linear model analysis approach with curve fitting tool. The maintenance costs as obtained by using the developed correlation for turbine was compared with the actual cost data as received from the power plants. The difference in the analysed maintenance costs and the actual

O&M costs data collected from the existing SHP project sites is determined and given in Table 3. The comparison of the maintenance costs as obtained from the developed correlations with the actual collected costs data of 6 existing SHP project sites is shown in Figure. 2 to validate the developed maintenance cost correlations. From table 3 the error between the actual cost and cost from the developed correlation is found from -10.59 to 5.88% which appears to be in good agreement.

Table 3: Comparison between the actual maintenance cost data and analyzed maintenance cost for hydroelectric turbine.

S. No.	Com-ponent	Site name	Capa-city (kW)	Head (m)	Actual maintenance cost/kW (□)	Analyzed main-tenance cost/kW (□)	Error (%)	R square (%)
1	Turbine	Chupki	1500	2.72	135.33	149.66	-10.59	98.36
2		Narangwal	1500	2.57	146.67	149.53	-1.94	
3		Tugal	1500	2.42	155	149.38	3.62	
4		Dalla	1000	2.66	100	94.11	5.88	
5		Sal-II	2000	30	240	230.91	3.78	
6		Dikleri	2000	80	275	278.11	-1.12	

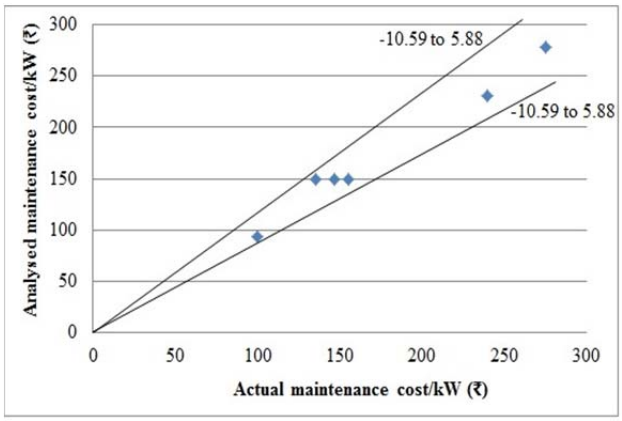

Fig. 2: Percentage error in actual maintenance cost data and analyzed maintenance cost as per correlations for hydroelectric turbine.

6. CONCLUSION

Hydroelectric turbine is a main component of mini and small hydropower plants. To determine the realistic maintenance cost of hydroelectric turbine mini hydropower plants, the correlation for maintenance cost of turbine is developed and presented in the study. The correlation was developed for turbine by linear model analysis approach with curve fitting tool in Matlab software by considering net head and capacity as cost sensitive parameters. To validate the developed costs correlations, a comparison of actual maintenance cost data collected for the existing power stations is made. The maximum deviation in the costs varies in the range of -10.59% to 5.88%. These correlations can be further modified by considering the major break downs, depreciation and inflation rate in cost etc. as parameters and based on the project site condition for future study.

7. ACKNOWLEDGEMENT

The authors greatly acknowledge the financial support from Ministry of new and Renewable Energy, Govt. of India in the form of research scholarship to carry out this work.

REFERENCES

[1] Naidu, B.S.K., "Small Hydro: Highest-Density, Nonconventional, Renewable-Energy Source", 1st edition,*National Power Training Institute, New Delhi*, 2005.

[2] Salhi, I., "Modeling and regulation of a micro hydroelectric power plant", *IEEE international symposium on industrial electronics (ISIE'08).Cambridge), UK*. 2008. Pp. 1639–44.

[3] http://www.cea.nic.in/reports/monthly/installedcapacity/2016/installed_capacity-05.pdf (access on 13 June, 2016).

[4] Kumar, R. and Singal, S.K., "Analysis for O&M cost estimation for the turbines in SHP schemes",*IEEE-International Conference on Research and Development Prospectus on Engineering and Technology*, Vol.1,March 2013, pp. 238-242.

[5] Saxena, P. And Kumar, A., "Hydropower development in India",*IGHEM,* Oct. 21-232010, AHEC, IIT Roorkee, India.

[6] Singal S.K. and Saini R.P., "Analytical approach for development of correlations for cost of canal-based SHP schemes",*Renewable Energy* 33, 2008,pp.2549–2558.

[7] Ogayar B. and Vidal P.G., "Cost determination of the electro-mechanical equipment of a small hydro-power plant",*Renewable Energy* 34, 2009, pp. 6–13.

[8] Singal, S.K. and Saini, R.P., "Analytical approach for cost estimation of low head small hydro power schemes", *International Conference on Small Hydropower - Hydro Sri Lanka*, 2007, pp. 1 – 6.

[9] Kumar, R. and Singal, S.K., "Cost effective, reliable and accurate maintenance model for SHP plants using RCM",*IEEE - International Conference on Reliability, Optimization and Information Technology, MRIU*,Feb. 2014, pp. 3.

[10] Cavazzini,G.,Santolin, A., Pavesi,G. and Ardizzon,G., "Accurate estimation model for small and micro hydropower plants costs in hybrid energy systems modelling",*Energy*, 103, March 2016, pp. 746-757.

[11] Mishra, S., Singal, S.K. and Khatod, D.K., "Approach for Cost Determination of Electro-Mechanical Equipment in RoR SHP Projects",*Smart Grid and Renewable Energy*, 2,2011, pp. 63-67.

[12] Mishra, S., Singal, S.K. and Khatod, D.K, "Cost analysis for electro-mechanical equipment in small hydropower projects", *International Journal of Green Energy* (DOI:10.1080/15435075.2012.727367.