AN APPROACH FOR COST ESTIMATION OF LOW HEADS HYDROPOWER SCHEMES AT PLANNING STAGE

By

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ABSTRACT

In Pakistan, most locations for large dam hydropower schemes have been exploited, or are too politically hot because of flooding large areas of land, displacing indigenous people's homes and ruining livelihoods, submerging national historic buildings, along with environmental constraints. The low head hydropower as run of river hydropower plants has become more popular. The small hydropower schemes may not be economically viable as the capacity of hydropower plant decreases the generating cost per unit increases. To have economically viable low head hydropower schemes, the methodology and technology applied must be different from that applied to larger hydropower plants. In this paper, an attempt is made to work out the cost of different components of low head small hydropower schemes. A relationship of cost as a function of head and discharge has been developed based on the defined cost. A comparison of cost having different heads and capacity of low head hydropower schemes is made with the available cost of existing hydropower stations. The results indicate that the correlations so developed can be successfully used for estimation of new low head hydropower schemes.

1. INTRODUCTION

The importance of using canal falls as a source of hydropower generation is now well recognized in Pakistan. The Power Generation Policy of the Government of Pakistan addresses to develop the hydropower schemes in the country at the least cost. In order to see the small low heads schemes/projects attractive and viable, a study is made to see whether the projects are economically variable or not. For that purpose, the cost of different components of the schemes have been analyzed/evaluated and a comparison is made in terms of heads and capacity with the existing low heads hydropower projects.

2. CATEGORIZATION OF HYDROPOWER SCHEMES

Hydropower schemes can be divided into three groups. Each group requires different design aspects. First group; Low Head: 3 to 20 m head. Second group; Medium Head: 20 to 60 m. Third Group; Head: above 60 m. The first group lies in the canal based schemes. Two following components are important for this group.

2.1 Civil Works

The major components of civil works are diversion channel, spillway, head race, tail race, power house building.

2.2 Electro-Mechanical Equipment

The major electro-mechanical component of power plant is the inlet valve, turbine, draft tube, gates, generator, control and protection equipment and substation for transformation of power to the transmission line. Types of turbine and generator under different operating conditions are available in the literature. There is variety of turbines available in the low head range such as propeller, open pit, tabular, bulb, vertical siphon and Kaplan. The Figures 1 and 2 depict typical layout details of canal based low heads hydropower schemes. The power house and spillway are placed side by side in the diversion by pass channel.

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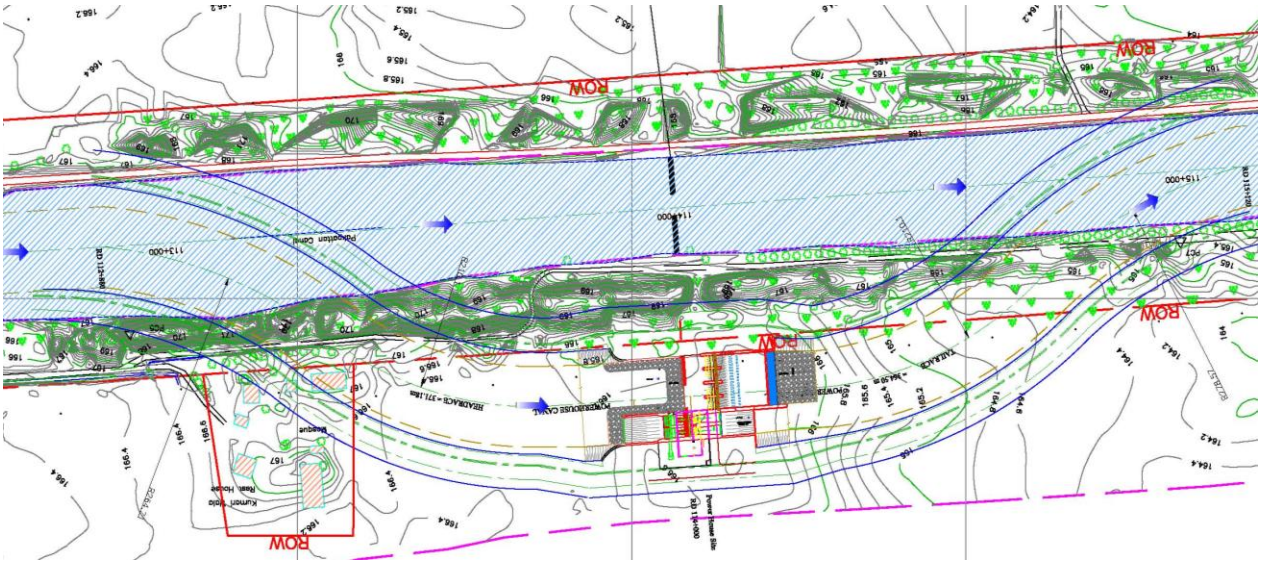

Fig.-1: Typical layout of low head hydropower schemes (Irrigation Canal Based)

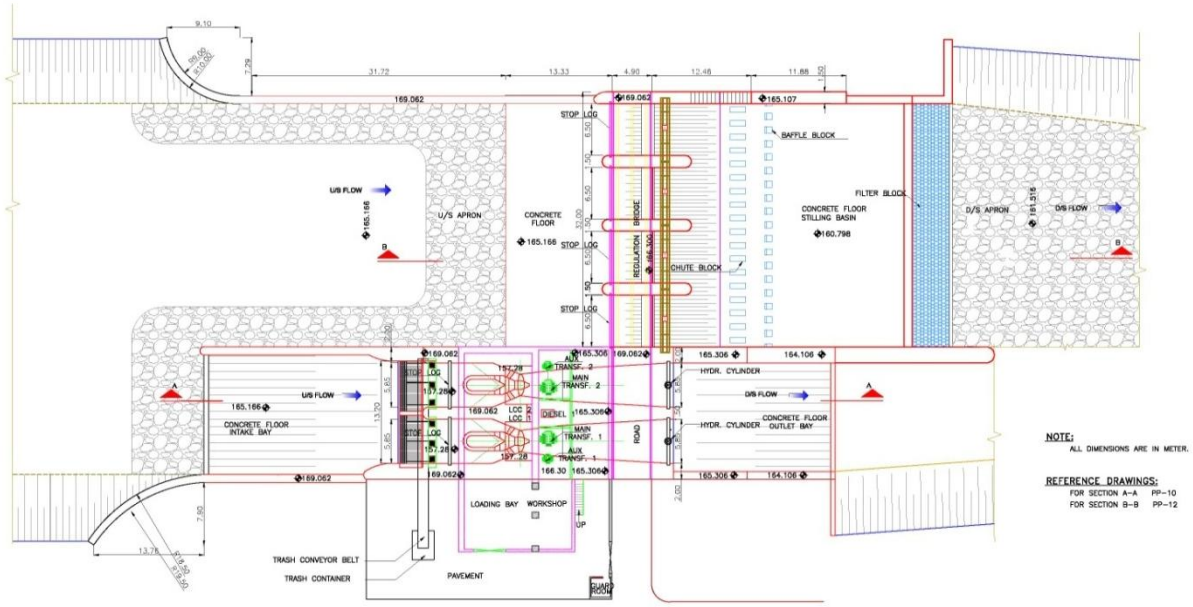

Fig.-2: Typical arrangement of Power House and spillway in a by-pass diversion canal

3. SMALL HYDROPOWER TECHNOLOGY

The hydraulic turbines convert water pressure into mechanical shaft power which can be used to drive electric generator. The power available is proportional to the product of pressure head and volume flow rate. The well known formula used for hydropower system output is depicted below.

$$P = \eta \times \rho \times g \times Q \times H$$

Where '*P*' is the mechanical power produced at the turbine shaft (Watts), 'η' is the hydraulic efficiency of the turbine, 'ρ' is the density of the water (Kg/m^3), '*g*' is the acceleration due to the gravity (m/s^2), '*Q*' is the volume flow rate passing through the turbine (m^3/s) and '*H*' is the effective water pressure head across the turbine (m). The best turbines can have hydraulic efficiencies in the range 80% to over 90%.

4. ANALYSIS FOR COST OF LOW HEAD HYDROPOWER PROJECTS

To consider a project viable, the economic and financial study is important along with engineering study. The Project costs have been estimated in terms of survey / field data, engineering design, drawings, specifications, rates of work items etc. The detailed investigations for topography, hydrology, environment, ecology, geology and construction material has also been considered.

The Project Cost depends on the size of civil works and electro-mechanical equipment. The layout of the schemes and size of the machines are determined with respect to the runner diameter of the turbine. The civil works including design were considered diversion channel, spillway and Power House building. The hydro-mechanical equipment including design adopted for cost purposes were gates, turbines, governor and gearbox etc. The electric equipment was included generator, control and other accessories. As a general practice, trash rack, gates and valves were considered in the civil works while governor, turbine and gear box have been considered in the electro-mechanical equipment. The direct cost was included cost of civil works plus preliminary works (offices, buildings etc) and resettlement / environment costs, hydro-mechanical equipment, transmission lines. The base cost included land compensation, physical contingencies @ 3%, mechanical contingencies @ 3% and Admn. Audit & account cost @ 2.5% of direct cost. The capital cost was included duties and taxes @ 5% on foreign component. Thus Financial cost /Project cost was calculated based on price contingences (escalation) and also interest payments during construction as per standards of CPI (Consumer Price Index).

For present study, different heads and discharges having typical layout as shown in Fig.-1 and Fig.-2 with Power House and gated spillway in by pass channel have been considered. The quantities and cost of works have been determined and shown in the Table-1 below.

Table 1: Details of cost analysis of low head hydropower schemes

Head (m)	Capacity (Kw)	Runner Dia (m)	Total Cost (M.Rs.)	Cost per Kw (Rs.)
3	1000	3.01	75.79	75789
5	1000	2.05	70.77	70772
8	1000	1.52	66.44	66448
10	1000	1.30	64.59	64590
3	2000	4.25	130.50	65250
5	2000	2.95	121.52	60758
8	2000	2.90	114.09	57047
10	2000	1.74	110.73	55365
5	4000	4.03	208.64	52161
8	4000	2.90	195.90	48975
10	4000	2.48	190.12	47531
5	5000	4.60	248.31	49661
8	5000	3.30	233.13	46627
10	5000	2.72	226.25	45253

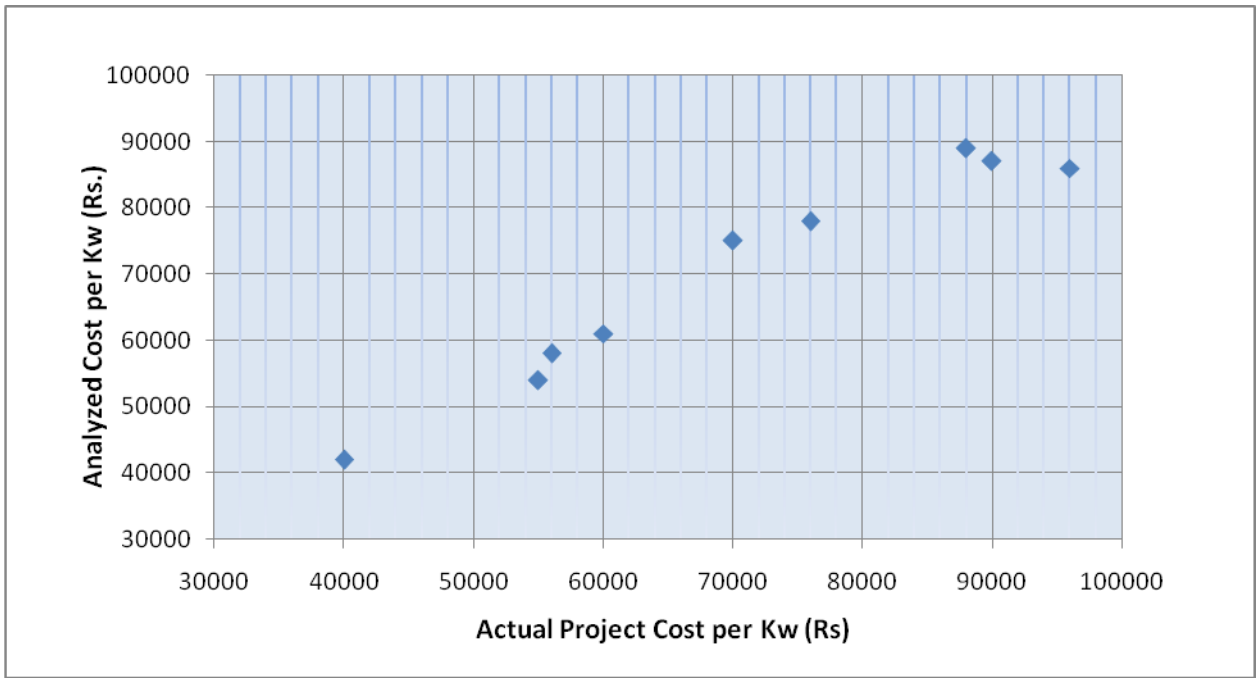

Fig.-3: Comparison of Analyzed Cost versus Actual Project Cost.

An equation has been developed in respect of cost function depending upon installed capacity and head parameters. The exponents have been taken from regression analysis in two steps. In first step, the analysis has been done between installation cost and installed capacity. Later the results were analyzed with the head in the second step to find out the coefficient and exponent of the head. The equation thus obtained is shown as below.

$$C = 401691\, P^{-0.2201}\ \ H^{-0.1341}$$

Where '***C***' cost per Kw in Rupees, '***P***' capacity in Kw and '***H***' head in meter.

The above equation has been verified by taking data of some low heads hydropower schemes which are currently being implemented in Punjab, Pakistan as shown in Fig.-3. A maximum deviation of 9% has been observed which indicates a good prediction for cost estimation of low head hydropower schemes at planning stage.

5. CONCLUSIONS

An equation has been developed to find out cost estimation of low head hydropower schemes. The relation so developed gives the prediction of cost with an accuracy of ±9% which is a fair decision towards a low head power projects. The co-relation can be successfully used with a slight variation under different conditions of power site.

6. REFERENCES

1. Low head hydropower at Barrages and Link Canals Falls Stage -1, ranking studies by German Agency for Technical Cooperation.

2. Project Feasibilities and reports on low heads hydropower schemes in Pakistan.