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Hydropower Potential at Simly Dam Site, Islamabad, Pakistan: Technical and Economic Review

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ABSTRACT

Renewable forms of energy are the most widespread focus these days, specifically the use of multiple options for generating alternate resources of energy. Hydropower is the best option known in terms of available renewable energy sources. In Pakistan, hydropower potential is immense, particularly in its existing Indus basin water resources systems. Since going for large hydropower developments is pretty costly and takes a lot of years, therefore, it would be advantageous if small hydropower plants are constructed on various locations having substantial hydropower potential. In this study, the hydropower potential at Simly dam site was investigated firstly for the run of the river scenario and secondly for the flows going to the filtration plant, based on the data for years 2016-20. It was found that in run of the river case, with the availability of 71 m head and 4.78 m3/sec inflow, 2.57 MW power can be generated from this small hydropower development. Similarly, for the second scenario, 0.87 MW power can be produced by utilizing the hydraulic energy of water going towards the filtration plant. When the benefit cost ratio was estimated, the run of the river case was found more suitable with ratio of 1.4. Consequently, it was understood that this small addition to hydropower can help to fulfill 1/6 part of power demand of people living in Islamabad.

Keywords: *Hydropower Potential, Benefit cost Analysis, Filtration Plant, Run of the river, Simly Dam, Islamabad, Pakistan*

1. Introduction

Energy crises are generally observed across the globe, particularly in the 3rd world countries of Asia and Africa continents. Conservation of water and energy has gained prime importance for the last few decades, and has become imperative in resolving such issues. In the last two decades, oil and natural gas prices have increased manifold and has made renewable energy sources more as a domineering alternate. One of the four fundamental requirements of human being are food, water, energy and environment [11].

Hydropower is a renewable energy source most widely used all around the world through installation of hydropower plants. There are three types of hydropower facilities, Impoundment, diversion, pumped storage, and even on water supply network wherever possible. The advantages of these facilities compared to run of the river hydropower plants could also be summarized to draw real term benefits. Pakistan is also facing acute energy shortages since a decade. Though the country posse's immense renewable energy potential in many forms and particularly in hydropower, which tantamount to nearly 55,000 MW, and only 6,700 MW has so far been tapped [11, 16].

Hydropower energy potential is generally divided into three segments which include; a) gross theoretical potential, b) technical potential, and c) economically feasible potential. If all the available water resources are used for electricity generation, then the maximum amount of electricity that could be generated is called the gross theoretical potential [1].

Table 1: Electricity Consumption in different regions of the world (Per Capita) [11]

Region	Power Consumption
World	2,000 KWh/year (average)
USA	10,500 KWh/year
Sweden	12,500 KWh/year
Norway	21,000 KWh/year
Pakistan	300 KWh/year

The amount of readily available hydropower capacity, using existing technology is called the technically exploitable potential or simply saying technical potential. The amount of hydropower generating capacity calculated based on feasibility study of each site giving positive outcome at current price is called the economically feasible potential [3]. The economic feasibility potentials may vary a lot from the technical potential depending on local conditions, therefore at each potential site, an in-depth study is required, this is the reason why gross theoretical potential gains major attention [2, 4].

Hydropower Potential Assessment Tool (HPAT) is novel modeling package which help to evaluate the previous and upcoming small-scale run-of-river hydropower potential resource for some particular site or distributed over a specified region. Using HPAT, hydropower potential resource is assessed by a combination of a digital elevation model and a fully-distributed streamflow model. HPAT model was demonstrated by implementing it on small scale run-of-river project near Sweet Home, Oregon, USA [7]. Another country scale model on Europe's hydropower potential was presented to analyses the probable effects of global change. A comparison was made between the current conditions of water use and climate with the future scenarios and the results compared the current hydropower potential and its mid- and long-term projections. Water GAP (the global water model) was used to calculate discharge, this made an integrated evaluation taking into consideration both the climate and socioeconomic changes. The study is mainly carried out into two major phases. In the first phase, estimation of the 'gross' hydropower potential was made which provided an overview of the general trend and distribution of the hydropower potential across Europe. In the second phase, the 'developed' hydropower potential from currently present hydropower projects was estimated that shown a

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more accurate picture of the current electricity production and also allowed a better estimate of the future hydropower production [8].

A study proposed the potential sites for hydropower generation and how it is affected by seasonal climate, on a resort island, in Tioman. In terms of energy requirement, this island represented most of the resort island in South China Sea. Main source of electricity on this island was diesel-fuel but the major disadvantages of diesel include the high and ever change price of fuel, cost inefficiency in terms of operation and maintenance, and most importantly its environmental risks. In order to avoid these disadvantages, micro-hydropower plants were proposed at potential sites by the help of hydrological studies and topographic maps. 26 potential sites were investigated, out of which 10 sites were identified as micro-hydro potential. The seasonal monthly variation in the river flow was analyzed and the maximum hydropower potential was estimated during northeast monsoon season [9]. Similar research was also found where authors combined the water temperature and projections of streamflow with three global hydrological models (GHMs) for the first time [10]. This helped to analyze the structural uncertainties and parametrize these GHMs in terms of water temperature and water availability [5]. Considering the lowest and highest representative concentration pathways (RCP2.6 and RCP8.5), the GHMs were forced with bias-corrected output of five general circulation models (GCMs). Afterwards the impact on gross hydropower potential and cooling water discharge capacity of rivers worldwide was quantified using ensemble projections of streamflow and water temperature. Results showed that the expected increase in global gross hydropower potential could be between +2.4% (GCM-GHM ensemble mean for RCP 2.6) and +6.3% (RCP 8.5) for the 2080s compared to 1971–2000. Countries lying in Central Africa, central Asia and the northern high-latitudes showed the strongest expected increases in hydropower potential. Whereas by 2080s, 18–33% of the world population are expected to be living in these areas. Global mean cooling water discharge capacity was projected to decrease by 4.5-15% (2080s). The largest reductions are found for the United States, Europe, eastern Asia, and southern parts of South America, Africa and Australia, where strong water temperature increases were projected combined with reductions in mean annual streamflow [6]. These regions were expected to affect 11–14% (for RCP2.6 and the shared socio-economic pathway (SSP1, SSP2, SSP4) and 41–51% (RCP8.5–SSP3, SSP5) of the world population by the 2080s.

In this research, the hydropower potential was estimated and benefit cost analysis was performed for Simly dam site, Islamabad, Pakistan, for years 2016-20. Since the dam stores water for filtration plant, which is fulfilling the drinking water needs of Islamabad city, two scenarios were checked simultaneously for hydropower development. First one was the use of reservoir inflows considering no storage, while in the second scenario, the flows going to filtration plant were taken into account for hydropower generation. The results were plotted between flow and power duration curves for both the scenarios. The total annual revenue was calculated and compared with the annual cost. The project proved quite fruitful if structured.

2. Methodology

2.1 Experimental Program

Simly dam is located 30 KM east of Islamabad, extended between 33°43’08” N latitude ranges and 73°20’25” E longitude ranges (Figure 1). It is a small embankment dam, constructed on Soan river majorly used for drinking water supply to Islamabad, and for irrigation purposes. The reservoir is fed by the water of natural springs and melting snow from Murree hills. It was constructed by CDA (Capital Development Authority) [12, 13]. The main features of the dam are given in Table 2.

Table 2: Salient Features of Simly Dam. [12, 14]

Height	80 m
Planning Begun	1962
Expected Completion	1972
Completed [14]	1983
Length	313 m
Volume of Dam	1, 977, 000 m^3
Spillway	Ogee Type
Capacity of Spillway	34, 405 m^3/sec
Total Capacity	35, 463, 000 m^3
Active Capacity	24, 669, 000 m^3
Inactive Capacity	10, 793, 000 m^3
Surface Area	1.7 KM^2
Catchment Area	153 KM^2
Maximum Length	11.2 KM

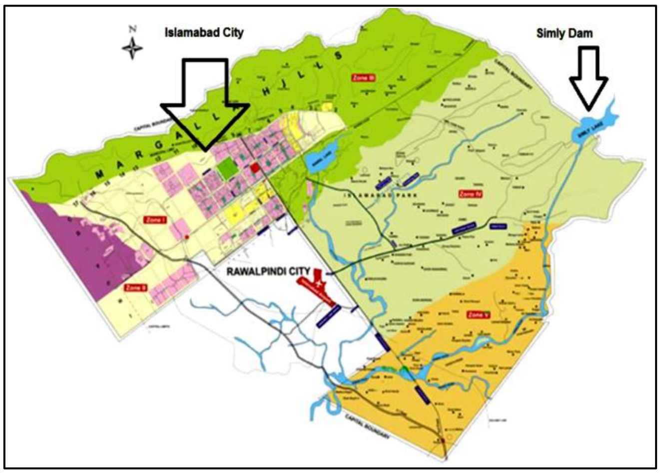

Figure 1: Simly dam layout with Islamabad city [11]

2.2 Description of Dataset and its Analysis

The average daily data for reservoir levels, inflows, evaporation losses and outflows for filtration plant for year 2016-20 was obtained from Resident Engineer (RE) office, WAPDA, Islamabad. The data was then averaged to monthly values (Figure 2, 4) to use it for the hydropower potential estimation. The hydropower potential was estimated using equation 1.

$$Available\ Power = \eta\gamma QH \qquad (1)$$

Where ŋ is the plant efficiency which was assumed to be 80 % [11], γ is the specific weight of water which was taken as 9810 N/m3, Q is the flow in m3/sec and H is its potential head in meters at any specific discharge.

The evaporation losses were deducted from the inflows to convert them to net inflows before using them in calculations. The first scenario was comprising the use of reservoir inflows for potential estimation i.e., considering the project as run of the river case. For the second scenario the flows received by filtration plant were considered. The total KWHs for a month were calculated from equation 2.

$$Total\ KWHs\ for\ a\ Month = No.of\ Days \times No.of\ hours\ in\ one\ day \times Power\ in\ KW \qquad (2)$$

Total annual revenue was estimated by multiplying the total no. of annual KWHs by per KWH commercial rate of electricity. The turbine to be installed was then chosen on the basis of maximum head and discharge. The size and cost of turbine and penstock pipe was checked from the websites of various vendors. The installation cost, operation and maintenance cost were also estimated the same way.

3. Results and Discussion

The estimation of hydropower potential for the first scenario, where the run of the river condition was adopted, yielded maximum 2.57 MW (Figure 3) of power which is for the month of August that is quite similar to those estimated by [11]. The values are clearly depicting the potential of small hydropower plant [2]. This case produced a base power value of 0.148 MW (Table 3) i.e., the plant will be working as mini hydropower plant [2] for very low flow season. Similarly, maximum no. of KWHs were also generated in the month of August. Total no. of annual KWHs, when calculated, the value reached to 40115888.48 KWHs. This power turned into an annual revenue of PKR. 377.3 million (2.3 million USD) if this electricity is sold to household population (rate of 1 KWH = PKR. 9.406/-). While it generated an annual revenue of PKR. 1.02 billion (6.4 million USD), if offered to commercial areas (rate of 1 KWH = PKR. 25.654/-) considering the second option, the maximum power was noted as 0.82 MW (Figure 5) in the month of September. As the obtained value is than 1 MW therefore the plant will be considered as mini hydropower plant [2].

The firm power was perceived as 0.517 MW (Table 5) conforming the operation of plant as mini hydropower scheme throughout the year [2]. The total no. of annual KWHs in this scenario came out to be 5784406.216, which can generate a revenue of PKR. 54.4 million (0.3 million USD) on household basis and PKR. 148 million (0.9 million USD) for commercial use. The detailed comparison of both the scenarios is performed in the next section of benefit cost analysis.

Table 3: Calculations of hydropower potential for run of the river scenario

Months	Days	Net Inflows (m^3/s)	Net Head (m)	Power (MW)	No. of KWHs
1	31	0.899	63.7	0.45	3.3×10^5
2	29	1.326	63.4	0.66	9.5×10^5
3	31	2.202	64.9	1.12	24.5×10^5
4	30	1.129	67.6	0.59	17.4×10^5
5	31	0.29	66.1	0.15	5.5×10^5
6	30	0.60	63.8	0.30	13.1×10^5
7	31	3.543	62.2	1.73	88.5×10^5
8	31	4.729	69.2	2.57	150.5×10^5
9	30	1.353	71.4	0.75	49.8×10^5
10	31	0.321	70.0	0.17	12.9×10^5
11	30	0.295	68.0	0.15	12.6×10^5
12	31	0.287	65.8	0.14	13.0×10^5

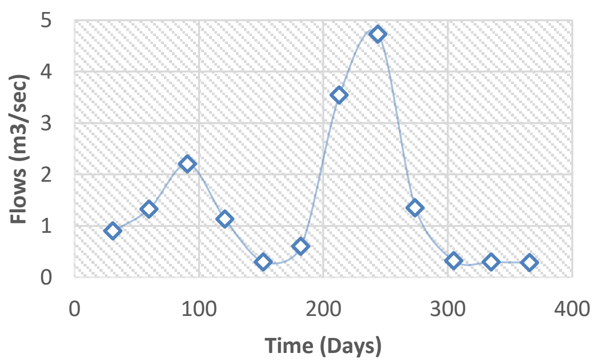

Figure 2: Flow duration curve for run of the river scenario

3.1 *Benefit Cost Analysis*

The maximum head of water at the dam site was less than 80 m therefore Kaplan turbine with horizontal shaft arrangement was recommended for benefit cost analysis. The

Table 4: Benefit Cost Ratios (BCRs) for various scenarios

Scenario	Market	Benefit (PKR Million)	Costs (PKR Million)				BCR	Remarks
			Turbine	Penstock	Installation, operation and Maintenance	Total		
Run of the river	Household	377.3	92.6	0.528	640.4	733.5	0.51	Not OK
	Commercial	1029.1	92.6	0.528	640.4	733.5	1.40	OK
Filtration plant storage	Household	54.4	37.2	0.528	640.4	678.1	0.08	Not OK
	Commercial	148.3	37.2	0.528	640.4	678.1	0.22	Not OK

maximum flow was 4.72 m^3/sec therefore one unit of Kaplan turbine with flow range 0.5-5 m^3/sec was chosen from the website given in methodology section. Similarly, five units of penstock pipe each with length 12 m, diameter 8-120 inch and thickness 4.5 to 25.4 mm were chosen randomly for the sake of safety factor. The installation cost, operation and maintenance cost were also selected from the same website as listed in Table 4.

For the case of run of the river plant, the household scenario will be difficult initially, but after one year it would also start giving positive response i.e., benefit cost ratio will be greater than 1 for higher years. Second scenario proved very fruitful as compared to all with Benefit Cost (BC) ratio as 1.4 which will be the most appropriate solution. However, the supply of electricity should only be given to commercial sectors.

The BC ratio for the filtration plant scenario is very low which shows that these scenarios are less advantageous, however, if constructed they will start giving benefit after few years of project completion. The study conducted by [11] used the supply lines flows for power generation., It was quite significant that, by using turbine at start of water supply lines, consuming the pressure of water supply pipe, the power generation can reach up to 2.04 MW. This way almost double amount of electricity can be generated by using both the scenarios.

4. Conclusion

Small but continuous addition to power production is very much fruitful. Keeping in view per capita consumption of electricity of Islamabad for year 2016 the Simly dam hydropower project can fulfil 1/6 of power demand of people living there

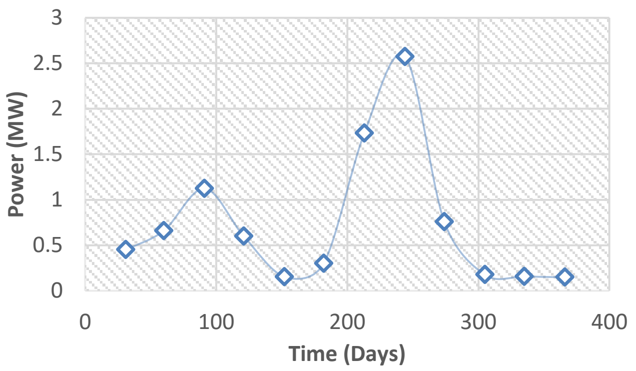

Figure 3: Power duration curve for run of the river scenario

The benefit cost analysis encourages that the run of the river development should be started as early as possible as the initial benefits and costs in this scenario are in positive direction. The value of 2.57 MW for this scenario looks very small, but the availability of many of such types of hydel generation sites can be very useful to fulfill the local power demands. After the successful operation of run of the river

Table 5: Calculations of hydropower potential for filtration plant storage scenario

Months	Days	Outflow (m^3/s)	Net Head (m)	Power (MW)	No. of KWHs
1	31	1.037	63.7	0.52	3.8×10^5
2	29	1.168	63.4	0.58	4.0×10^5
3	31	1.013	64.9	0.51	3.8×10^5
4	30	1.236	67.6	0.65	4.7×10^5
5	31	1.279	66.1	0.66	4.9×10^5
6	30	1.318	63.8	0.66	4.7×10^5
7	31	1.256	62.2	0.61	4.5×10^5
8	31	1.387	69.2	0.75	5.6×10^5
9	30	1.477	71.4	0.82	5.9×10^5
10	31	1.452	70.0	0.79	5.9×10^5
11	30	1.211	68.0	0.64	4.6×10^5
12	31	1.284	65.8	0.66	4.9×10^5

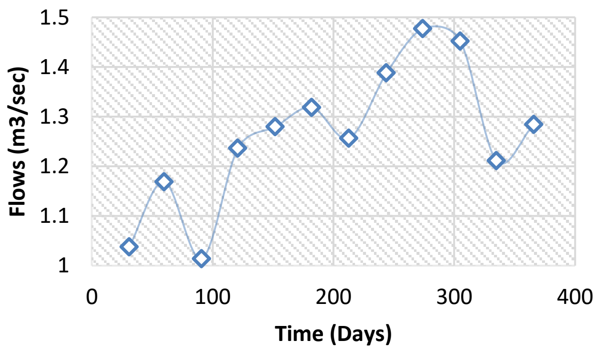

Figure 4: Flow duration curve for filtration plant storage case

case, storage situation may be adopted on later stages. Installation of turbines at the start of various water supply lines from the filtration plant could be the most appropriate option to utilize the hydraulic energy of water in supply lines.

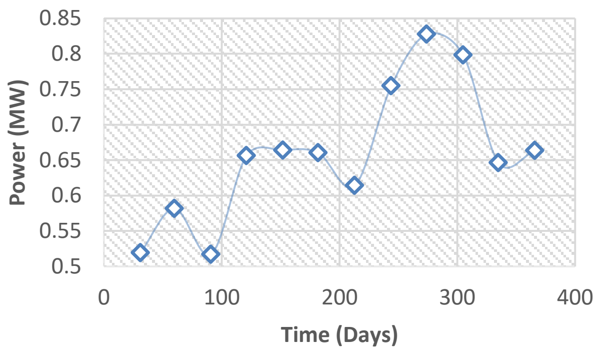

Figure 5: Power duration curve for filtration plant storage case.

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