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Technical and environmental analysis of SHP in RET Screen: A case study of power production at Machai/Mardan

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ABSTRACT

Pakistan's economy is directly affected by Power conjuncture causing energy failure on regular basis for long duration and shut down of industrial units causing social disorganization. Because of population growth and need in economy advancement it's estimated that national electricity demand will continue to grow at 10 % per annum. The environmental impacts associated with hydroelectric developments that incorporate water storage (typically larger in size) are mainly related to the creation of a water storage reservoir. The RET Screen International Clean Energy Project Analysis Software addresses a number of renewable energy electricity generating technologies. The four most widely applied technologies are Wind energy, photovoltaic, small hydro and biomass combustion power technologies. The energy available from a hydro turbine is proportional to the quantity of water passing through the turbine per unit of time and the vertical difference between the turbine and the surface of water at the inlet (i.e. head).

Keywords: *RET Screen, Small Hydro, Hydro Turbine, Shut Down, Industrial Units*

1. INTRODUCTION

Small Hydro varies between 2.5 and 25MW, but the widely accepted value is 10MW.In industrial terms mini-micro-Hydro refers to schemes below 2MW and 500kw. [1] Generation from Small Hydropower plant at Mardan/Machai using hydrology data of upstream location was possible through RET Screen Energy Model as shown in Fig 1.

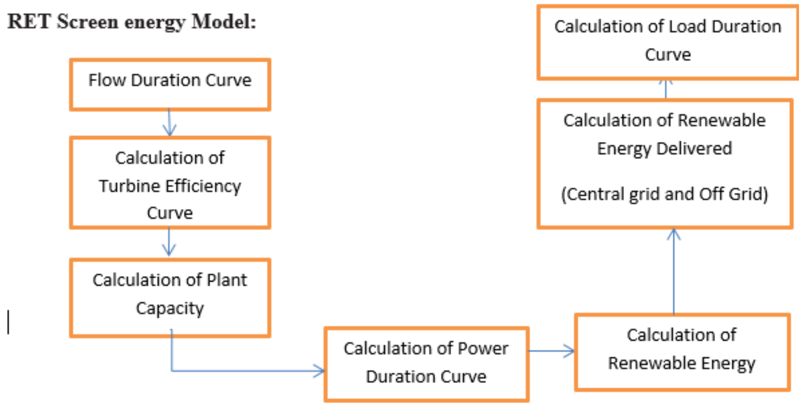

Fig: 1 RET Screen: A Small Hydropower Energy Model Flowchart

Hydrology: As shown in Fig 2 hydrological data are specified as a flow-duration curve. For Machai project which is a run of river project Located at Latitude: 34°37'38.27" N and 71°59'23.78" E. Hydrology method is "Specific Run Off" used in conjunction with the RET Screen Hydrology database.

Flow Duration Curve: In Modeling Machai HPP in RET Screen the Hydrology data was utilized in MS-Excel to draw the Flow duration Curve. Hydrology Data of 313 values in Cumec (m^3/sec) of Machai Canal Located in District Mardan and percent exceedance were calculated based on Rank Function.

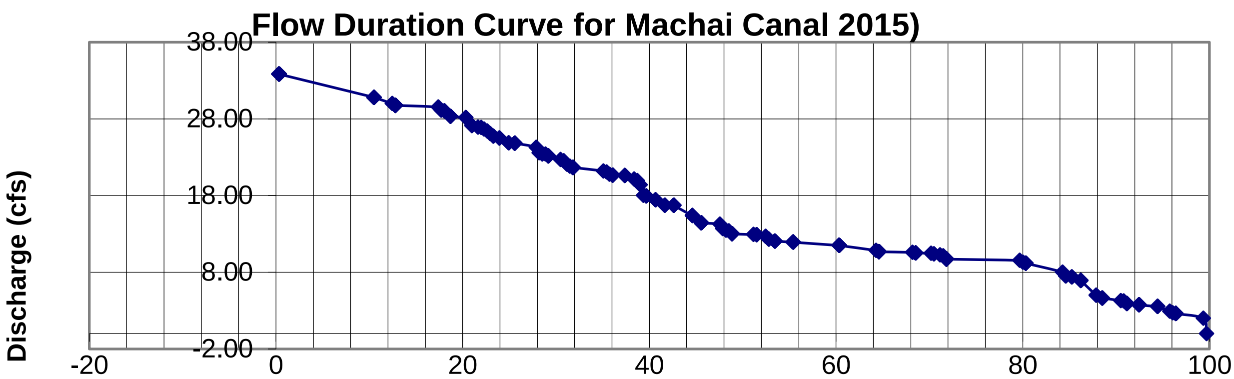

Fig 2:Percent of time that indicated discharge was equaled or exceeded

The Flow duration Curve is expressed in Normalized form i.e., relative to the mean flow. The mean flow is calculated as: $\bar{Q}$=RAD. Where *R* is the specific run-off and *AD* is the drainage area.

Flow Duration Curve was drawn in Excel based on Logarithmic Scale. Normalized values calculated in MS-Excel were put in built in Table form in RET Screen. Each value of Machai Canal Flow put in RET Screen gave Kaplan Turbine Efficiency.

2. KAPLAN TURBINE EFFICIENCY

Kaplan or Propeller Turbine along with adjustable blades designed specifically for head ranging from 10m to 70m and output from 5 to 200MW.RET Screen Energy Model, Hydro Turbine Type Kaplan for Design flow Value of 40cumecs, head Value 8.1m and corresponding flow values for the given Normalized flow values in table gave Kaplan turbine Peak Efficiency 96% and Efficiency at design Flow as 95.5%.

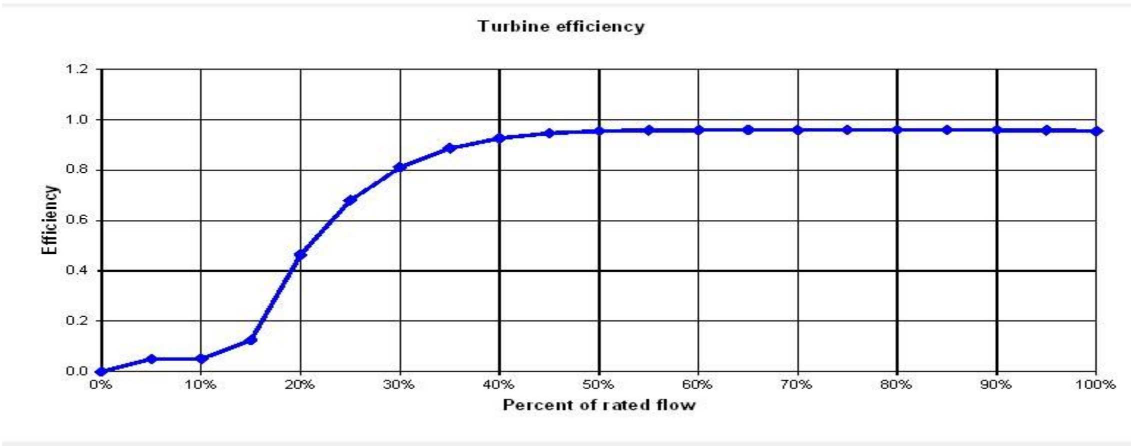

Fig 4: Calculated Efficiency Curve for Kaplan Turbine Head: 7m Design Flow: 40m^3/sec

The flow at peak efficiency was 30 Cumec for the power output of 2.679MW. Maximum hydraulic losses were 5% and miscellaneous losses 2%.the available flow adjustment factor was 1.0.and Availability was 94%.

Kaplan Peak Efficiency is calculated with this formula: *Q p* □□0.75Q_d

Power Available as a Function of Flow:

Power available from Small Hydropower Plant at any available flow Q is given by the following equation:

$$P=p\,Q\,g[Hg-(Hhydr + Htail)]\; et\; eg\;(1-ltrans)(1-lpara) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots1$$

H_{hydr},H_{tail} are Hydraulic losses and tailrace effect respectively related to flow Q and e^t is turbine efficiency at design flow since e_g is generator efficiency l_{trans} transformer losses.

Hydraulic losses are calculated with this formula:

$$H_{hydr}=\frac{Hg}{Hhydr,max}=\frac{Q2}{Qdes} \qquad \ldots\ldots\ldots\ldots\ldots\ldots2$$

Where *lhydr,max* is the maximum hydraulic losses specified by the user, and *Qdes* the design flow.

$$H_{tail}=H_{tailmax}\,\frac{(Q-Qdes)2}{(Qmax-Qdes)2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots3$$

Equation (2) is applied only to river flows that are greater than the plant Design flow (i.e. when $Q > Q_{des}$) .[5]

Plant Capacity:

Plant Capacity is calculated with the help of the following equation

$$P_{des} = p\, Q_{des}\, g[H_g - (H_{hydr} + H_{tail})]\, e_{t,des}\, e_g\, (1 - l_{trans})(1 - l_{para}) \quad \ldots\ldots\ldots\ldots\ldots\ldots 4$$

Where *Pdes* is the plant capacity and *et,des is* turbine efficiency at design flow.

Power Duration Curve: The flow values in Cumec 313 are utilized in the following equation to calculate power:

$$P_{des} = p\, Q_{des}\, g[H_g - (H_{hydr} + H_{tail})]\, e_{t,des}\, e_g\, (1 - l_{trans})(1 - l_{para}) \quad \ldots\ldots\ldots\ldots\ldots\ldots 5$$

These 313 values of available flow are utilized in calculating FDC and corresponding values of power obtained from above equation are used to calculate the Power duration curve.

Fig 4: Power and Flow duration Curve

The residual *flow Qr* is specified by the user and must be subtracted from all values of the flow-duration curve for the calculation of plant capacity, firm capacity and Renewable energy available.

Design flow is defined as the maximum flow that can be used by the turbine. The available flow is defined as:

$$Q'_n = \max(Q_n - Q_r, 0) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Small hydro plant capacity factor:

The annual capacity factor *K* of small hydro power plant is a measure of the available flow at the site and how efficiently it is used. All small hydropower Plants are designed on the basis of a capacity factor of 70% to 80%.

$$Plant\ Capacity\ Factor, K = \frac{Actual\ energy\ produced}{Max.\ energy\ that\ could\ have\ been\ produced}$$

$$= \frac{\text{Average Demand}}{\text{Plant Capacity}}$$

The RET screen energy Model of Machai HPP based on the Hydrology data gave a value of capacity factor of 57% for a plant capacity of 2.679MW which is much closer to the practical limit.

3. GREENHOUSE GAS (GHG) EMISSION REDUCTION ANALYSIS MODEL

The RET Screen Greenhouse Gas (GHG) Emission Reduction Analysis Model found in the *GHG Analysis* worksheet of the RET Screen Software helps the user estimate the greenhouse Gas emission reduction (mitigation) is potential of a proposed clean energy projects.

In Pakistan the GHG emission factor for Small Hydropower specifically for Machai HPP is 0.43 i.e. tCO_2/MWh is 0.43.

CO_2 emission is calculated on the basis of installed capacity and consumer demand. Two periods in carbon di-oxide emission viz, operation and construction has a great influence. [3]The SHP potential is round about more than 100GW. China being a world leader in Hydropower has developed 15 GW of SHP alone [4]. Reduction of carbon dioxide emissions by SHPs depends on their annual power generation, installed capacity, time usage and electricity emission factor [2].The electricity exported to grid by 2.679MW Machai HPP is 13,254MWh. The total GHG emission tCO_2 is 5699.3.

Base case electricity system (Baseline)

Country - region		GHG emission factor (excl. T&D) tCO2/MWh	T&D losses %	GHG emission factor tCO2/MWh
Pakistan	Oil (#6)	0.430		0.430

☐ Baseline changes during project life

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission tCO2/MWh	GHG emission tCO2
Electricity	100.0%	13,254	0.430	5,699.3
Total	100.0%	13,254	0.430	5,699.3

Proposed case system GHG summary (Power project)

Fuel type	Fuel mix %			Fuel consumption MWh	GHG emission tCO2/MWh	GHG emission tCO2
Hydro	100.0%			13,254	0.000	0.0
Total	100.0%			13,254	0.000	0.0
Electricity exported to grid	MWh	13,254	T&D losses 10.0%	1,325	0.430	569.9
					Total	569.9

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission tCO2
Power project	5,699.3	569.9	5,129.4		5,129.4

Net annual GHG emission reduction 5,129 tCO2 is equivalent to 1,166 Acres of forest absorbing carbon

The GHG emission reduction analysis of Machai HPP shows that the area of forest in acres absorbing carbon di oxide is equivalent to 1,166.with the construction of Machai HPP the forest area i.e. the number of trees absorbing CO_2 will be increased occupying area in acres of 1,166.this analysis shows the environmental friendliness of Machai HPP.

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	5,699.3	569.9	5,129.4		5,129.4

Net annual GHG emission reduction 5,129 tCO2 is equivalent to 1,166 Acres of forest absorbing carbon

With the construction of Machai HPP the net annual GHG emission will be reduced by a value of 5,129 and the Liters of gasoline not consumed will be equal to 2,203.789

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	5,699.3	569.9	5,129.4		5,129.4

Net annual GHG emission reduction 5,129 tCO2 is equivalent to 2,203,789 Litres of gasoline not consumed

The recycling rate of waste in tonnes will be equivalent to 1,769.

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	5,699.3	569.9	5,129.4		5,129.4

Net annual GHG emission reduction 5,129 tCO2 is equivalent to 1,769 Tonnes of waste recycled

The Net annual GHG emission reduction will be equivalent to 5,129 and people reducing energy use by 20%.

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	5,699.3	569.9	5,129.4		5,129.4

Net annual GHG emission reduction 5,129 tCO2 is equivalent to 5,129 People reducing energy use by 20%

The Hectares of forest absorbing carbon will be equivalent to 472.

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	5,699.3	569.9	5,129.4		5,129.4

Net annual GHG emission reduction 5,129 tCO2 is equivalent to 472 Hectares of forest absorbing carbon

4. CONCLUSION

Cascade Studies for the hydropower projects is being proved extremely useful in exploitation of available hydropower potential to its maximum possible limits. In Khyber Pakhtunkhwa, about 142 hydropower project sites, with a total capacity of 24736 MW have been identified having high, medium and small heads. Out of these, 19 projects are in operation, 27 projects are under implementation in the public sector and 11 projects are under implementation in the private sector which is mainly run-of-river schemes with small daily pondage for peaking.

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