Planning and Design of Small Hydro Power Station on D/S of Low Head Weir (Kolhapur Type)

Rajendra Amgonda Patil [1], Amanulla Liyakatalli Mulla[2]

[1,2]*Textile & Engineering Institute, Ichalkaranji, India*

Abstract - *India is facing a serious problem of shortage of power. It is necessary to generate as much power as possible by using renewable source of energy viz. hydropower and also to minimize the transmission losses by generating power by using locally available resources. During the past couple of decades large hydro power development has been constrained by number of facts viz. environmental issues, resource crunch, long gestation period, inter state or inter-national water dispute etc. Small hydros, free from above problems substantially, are increasingly gaining attention of planners and developers. The growing interest in the development of small hydro projects has resulted in evaluation of existing irrigation systems with regard to their suitability for hydro power development. Mainly low head weirs are potential for such development. In Maharashtra state, (India) a number of low head weirs (Kolhapur Type) have already been constructed for irrigation purpose. Water is stored upstream of weir and supplied to irrigation by pumping. From some weirs water is continuously released to downstream side and power potential is available at some of these K. T. weirs. A small hydro power project is therefore planned downstream of K. T. weir on Krishna river at Bahe in Sangli district of Maharshtra state. A detailed survey of the river bed is carried out. On downstream side of the weir river bed is having a gentle slope and at a distance of 200 m from weir a fall of 9.5 m is available. At 50 m on the downstream of the weir the river naturally gets divided in two parts by formation of an island. A small discharge flows from north side of the island. While the major river flow takes place through the south portion, a small hydro power station is therefore proposed to be located in the north side of island. River normally in floods for four monsoon months. It is not possible to get any differential head between u/s and d/s of K. T. weir for power development during this period. The power station can therefore be run only for 8 months in a year. At the present site 7 m net head and 19 cumec design discharge is available. By using this 1 MW power can be generated. The scheme consists of planning and designing of following elements with cost economics.*

Key Words: Hydropower, Generation, weirs, KT weir, *irrigation systems, power station.*

1. INTRODUCTION

Uncertainties about availability of future fuels have greatly renewed interest in the utilization of renewable resources in general and Small Hydroelectric sources in particular, the world over. Every drop of circulating water above mean sea level have potential energy inherent in it by virtue of its position.

The power demand of far flunge areas can best be met by harnessing the local streams/canal falls through construction of small Hydro power stations, rather than extending transmission lines to these areas.

There is variety of types of generating equipment's available catering to the needs of small hydro development. There is no restriction on the rate of discharge or the head that can be gainfully utilized. There is wide choice for selection of the equipment depending upon the requirements of site conditions, maintenance, efficiency and overall economics.

1.1 Selection of Site

In Maharashtra State a number of Kolhapur Type (K.T.) weirs have been constructed for irrigation purpose. Water is stored upstream of the weir and supplied to irrigation by pumping. For some weirs water is continuously released to downstream and power potential is available for generation.

There exists a cascade of K.T. weirs on Krishna River. Out of these, one weir is selected for proposal of construction of a Small Hydro station. Following are typical salient features at this site:

- The discharge through K.T. weirs range from 1 cumec to 60 cumec during 8 months (October to June every year).
- Good transportation facilities are available up to the K.T. weir site by road.
- Land on both the banks of the river is under sugarcane cultivation and for irrigation river water is used which is delivered to the field by installing pumping units on the banks. Electrical energy generated with the help of the proposed Small Power Station can therefore be very conveniently supplied to satisfy these power demands.
- Proposed Site is about 10 km from a Town Islampur in Sangli District of Maharashtra, which is a business center.
- National Highway No. 4 is about 10 kms from the proposed site therefore transportation is easy and fast.

- (f) A railway station exists at about 8 kms from the proposed site.
- (g) RCC pipe manufacturing facilities are available at a distance of 25 kms from the proposed site.
- (h) Within 15 kms circle there are 3 sugar industries. Therefore, the site is developed and power demand is ever increasing

2. Proposals

A detailed survey for L-Section and block leveling of the riverbed (north side of the island) is carried out from the K.T. weir to 250.00 m chainage and contour plan is prepared. A critical study of this contour plan indicates possibility of two alignments. On further study one of these two alignments, which gives minimum length, and therefore minimum cost of penstock is finalized. Due to shorter length of penstock, head loss is also less. For this alignment powerhouse is nearer to the island and is easily approachable from it. Existing K.T. weir is situated at a distance of 15 m upstream of the road bridge. The spacing between the piers of the road bridge is 13.00 m. The excavation of trenches for penstock below the bridge in between two piers will therefore pose no problem during construction.

From the L-Section along the penstock it is found that 9.5 m gross head (static head) is available which is expected to give a net head of about 7.0 m.

2.1 Design Discharge

From second week of June to end of October, every year, river is flooded hence it may not be possible to get any useful head for power development. Therefore, it is assumed that power station can be run only from November first week to June first week i.e. approximately for 215 days in a year.

The existing weir is constructed for purely irrigation purpose and discharge is further released through weir to downstream side for irrigation. These discharges vary from 1 cumec to more than 58 cumecs. From this information Flow-Duration curve is obtained.

It is a general practice to design such small schemes on a 50% dependability of flow. From this graph for 50% dependability a discharge of 19.25 cumec seems to be available. Therefore, Design Discharge is taken as 19 cumec.

2.2 Weir

For the proposed small power project, weir already exists. It is of Kolhapur Type (K.T.) weir. The few salient features of this are as follows:

Table 1: Salient Features of K.T.Weir

(a)	River Bed R.L.	:549.40 m above M.S.L.
(b)	F.S.L.	:551.00 m above M.S.L.
(c)	Maximum Depth at F.S.L.	:1.80 m
(d)	Length of the Weir	:356.00 m
(e)	No. of Openings	:60
(f)	Width of the Opening	: 2.00 m
(g)	Storage Capacity above still	:17.85m.cum (629.93 m.cft)
(h)	Gross Capacity	:29.16 m.cum (1029 m.cft)
(i)	Year of completion	:1977
(j)	Cost of the Scheme	: Rs. 14,59,916 (1977 price).

2.3 Intake Structure

The intake is designed to withdraw flow from the forebay as efficiently as possible with minimum vorticity or no vorticity. The hydraulic design of intake structure has to be planned in such a way that the cost is minimum and maximum quantity of locally available material can be used. Submergence of 2 m for the penstock entrance provided to prevent air entertainment at the penstock entrance.

A sliding gate is placed at the start of the penstock so that penstock can be drained for repairs and maintenance purpose. To prevent debris entering in to the waterways trash-racks are provided.

At the site, hard rock is exposed in the riverbed and sides, but some silt is likely to get carried by river water. Desilting chamber (catch-pit) is therefore provided as a part of intake structure on the upstream of gate of the capacity of about 50 cubic meters. For desilting of catch pit, flow in the intake can be stopped by fixing needles or bulkheads in the slots provided in the K.T. weir.

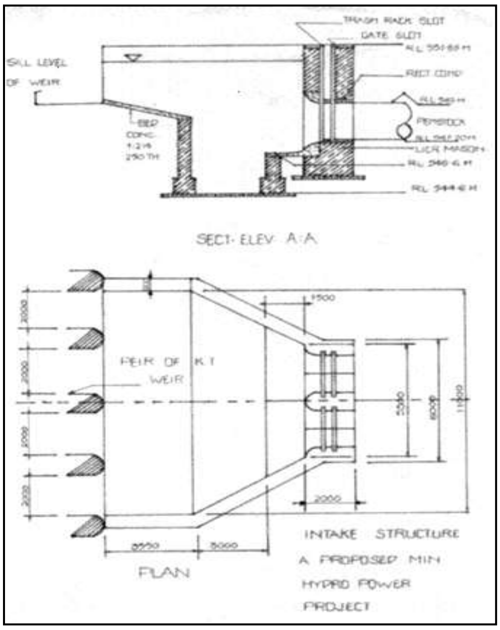

Figure 1: Intake Structur1

2.4. Penstock

Penstock is designed to provide the required flow for the hydroelectric plant. Energy loses in the penstock are calculated as per flow though a closed conduit. Alternatives for penstock pipes of various materials such as R.C.C. and Mild Steel and either one or two numbers of pipes are studied to achieve a workable as well as economical solution before taking a final decision.

For such type of the projects with small head, net head over the turbine assumes importance. Net head is calculated by subtracting losses between intake structures to Tail Race from the Gross head. Amongst the many parameters governing, head loss at various locations along the penstock, the main factor that governs major head loss is friction to the flow through the penstock. Therefore, while deciding the material of penstock and its diameter main aim is to minimize this friction loss. Different diameters and different numbers of steel and R.C.C. pipes are tried. For these alternatives, head losses and costs are worked out. That combination which gives reasonable head loss with minimum cost is selected.

From these studies following two alternatives appear to be promising.

Table No.2: Penstock Alternatives

	HF (m)	Cost (Rs.)
(i) 2,500 mm dia R.C.C. pipe, One in Number	1.395	2308921
ii) 1,800 mm dia R.C.C. pipe, Two in Number	1.563	2381796

Here former is better than latter as head loss and cost, both are less. However, considering site conditions the second alternative is chosen as there is no approach road in the riverbed and this may pose transportation problem for larger diameter pipes. Therefore, the "1,800 mm diameter R.C.C. Two in Number" are selected as Penstock for the proposed Small Hydro Scheme.

2.5 Y-Piece

From the intake total discharge is carried by 2 R.C.C. penstocks of diameter 1,800 mm. There are four turbines; therefore, these two penstocks are bifurcated into four branches. For this M.S. Y-Piece of diameter 1,800 mm One No. branched in 1,600 mm diameter two nos. To select the included angle between the Y-Piece legs different alternatives are studied and 60o angle for Y-Piece gives a reasonable solution.

2.6 Net Head

Having decided to use penstock of R.C.C. pipes 1800 mm diameter 2 numbers, all possible head losses from intake structure to tail race are calculated. From this net head is calculated as follows:

Net Head = FBL - TWL - Losses.

Where, FBL = Fore Bay R.L. = 551.00 m

TWL = Tail Water R.L. = 541.50 m.

Total Losses = 2.112 m

Net Head = 551.00 - 541.50 - 2.112

= 7.388 m.

2.7 Installed Capacity

Two major factors are required for assessment of power potential viz. the discharge available in the stream and the head that could be exploited. There are no hard and fast rules for determining the power potential of the small hydro project. It is influenced by local considerations.

Power = C x 9.81 x Q x H (kW)

Where, Q = Discharge in m3/sec = 19 m3/sec

H = Net Head = 7.388 m

C = Coeff. of generation considering Overall generating unit Efficiency = 0.85

Power = 0.85 x 9.81 x 19 x 7.388 = 1170.5 kW.

Therefore, the total Installed Capacity of this power project is 1170 kW. Say 1100.

2.8 Selection of Hydro Mechanical Equipments

In large size conventional Hydro Power Stations, the Hydro Mechanical Equipment is 'Tailor made' with a view to suit site conditions and to work with maximum efficiency. However, in case of Small Power Stations this logic has to be changed. The equipment manufacturer Standardize their designs for a few different categories of duty points for the machines and to make small project viable one has to select machines available from this standard list. Keeping this logic in view the size and number of machines to be adopted is required to satisfy the following conditions:

(i) The machines should be identical which minimizes maintenance problems and reduces the cost of spares.

(ii) The numbers of machines have to be so selected that within the working range of head and discharge these should give maximum power output with permutations and combinations of numbers of machine to suit the discharge available at a particular time.

In this particular situation it is proposed to use 4 identical units of equal capacity.

In the months of monsoon i.e. from June to September power station has to remain flooded. To avoid damage to the equipments, it is very necessary to select the type of machinery such that everything is enclosed in the conduit.

For the proposed hydropower project Bulb Turbines are selected. It is preferable to select smaller runner dimensions, having higher specific speed. Due to the smaller runner diameter, weight of the unit becomes less and such unit can be accommodated within the penstock diameter itself. The selection is done from the literature available for standardized equipments.

Table No.3: Turbine & Generator Specifications

Turbine:		
Type	:	GD002-WP-100-4 units
Blade angle:		+ 5o
Head	:	6.4 m
Discharge:		5.073 m3/sec
Output	:	281 kW
Rated speed:		375 rpm
G.D.	:	Tubular with Fixed lade
002	:	Runner Type
W	:	Horizontal Shaft
P	:	Bulb Unit
100	:	Runner diameter 100 cm. (1.00 m)
Generator:		
Type	:	SFG 250-16
S	:	Hydro Turbine driving
F	:	Generator
G	:	Tubular
250	:	Rated Power 250 kW Capacity
16	:	16 Poles

From the literature it is clear that this turbine can work efficiently for varying head, ranging from 4.5 m to 6.4 m. Also it can work efficiently for discharges ranging from 4.671 cumec to 5.073 cumec.

Thus, by adopting four such units of Bulb Turbine it is possible to generate maximum power equal to 4 x 281 = 1,124 kW, when discharge is sufficient to run 4 units.

When the discharge reduces gradually it will also help to generate power by running either 3 or 2 or 1 unit at a time dependent upon the discharge available.

2.9 Power House (Civil Structure)

Powerhouse is situated in the riverbed itself and more than 4 months in the year it will remain flooded. Therefore, arrangement made here is very simple. Both turbine and generator are enclosed in the conduit. Other control equipments are kept above HFL. There is no special powerhouse structure. It is as if pipe lines (penstocks) are laid in trenches. Size of the total space required is 16.00 m x 27.00 m. Trenches of 4.00 wide and 2.8 m depth are excavated and 300 mm thick p.c.c. 1:2:4 is laid at bed. Mild steel pedestal at an interval of 4.00 m are fabricated and embedded in the p.c.c. for supporting horizontal penstock. During floods these trenches are covered by placing precast R.C.C. slab panels of the size 2.00 m x 2.00 m on the trenches.

Weight of each individual panel and also the machinery is not too large and can be conveniently handled by a small size crane resting on tripod stand and a chain pulley block unit. This will result in considerable economy.

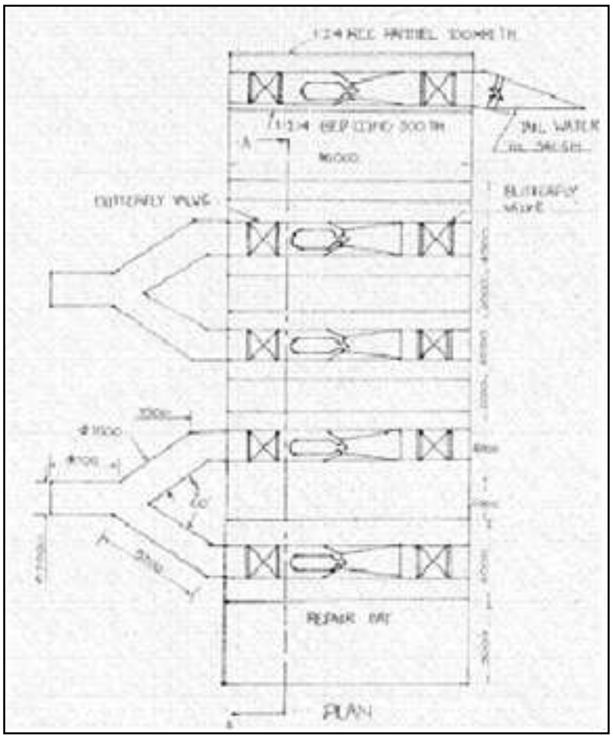

Figure No.2: Layout of Mini Hydro Power Plant

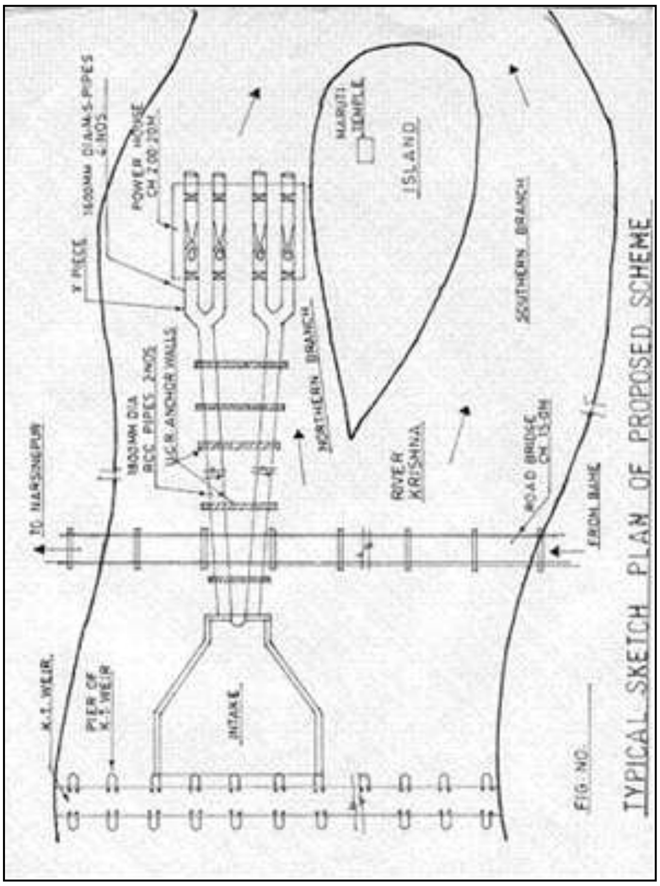

Figure No. 3: Typical Sketch Plan of Proposed Scheme

2.10 Cost Estimate & Economics

Cost estimates for the various elements are worked out in detail and total cost of the project is Rupees 6.8 Crores Only.

Cost per kW:

Total cost of the Project	=	Rs. 10.725 Crores
Installed Capacity	=	1100 kW.
Cost per kW	=	Rs. 97500

Number of Units (kWh) generated and Load Factor:

Dependent upon the flow available in the river during different periods the total annual generation (kWh) that would be possible 43, 43,000 kWh.

The total kWh generated considering that all 4 units run for 215 days would be that could be 58, 00,000 units.

Load Factor = 75%.

Benefit Cost Ratio is 2.00.

3. CONCLUSIONS

From the studies it is seen that by investing Rs. 10.725 Crores one can generate about 1100 kW power. Cost per kW is Rs. 97500/-, this is somewhat more than cost per kW for conventional hydropower project of larger capacity. But for small hydropower project, usually total capital investment is very small and problems of land acquisition, submergence, rehabilitation, deforestation, impact on environment will not be present.

A comparison of the cost of civil structures to cost of Hydro-Mech Electrical equipment shows that the ratio is 10:90 i.e. 10% of the total cost of the project. (Because cost of the weir is not included in it as it is already constructed for irrigation purpose). For the other civil structures use of locally available material can be made. Also, no special type of material or technology is required for planning, designing and construction of civil structure.

The Cost-Economics of the scheme indicates that B.C. ratio is 2.00.

In Maharashtra State, K.T. Weirs exist at many sites and it would be worthwhile to examine the possibility of hydropower development at every such site when the country is facing acute power shortage.

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