Proc. of the International Conference on 'Advances in Mechanical Engineering', December 15-17, 2008
S.V. National Institute of Technology, Surat – 395 007, Gujarat, India

Investigations and Development of Small Hydropower Project in Gujarat – A Case Study

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Small hydropower projects can provide a solution for the energy problems in rural, remote and hilly areas as well as along the canal systems, where extension of grid in unfavorable. There exist a potential of around 187 MW in 287 projects in different parts of the Gujarat state, of which only 7 MW has been tapped so far. Efforts shall be made to harness the balance potential by setting up small hydropower projects based on river/canal/dam through private/state/joint sector participation. In the present study, the small hydro scenario in India and Gujarat has been reviewed. The power potential available at the Nadiad branch canal in Gujarat State has been evaluated. The canal has a design discharge of 85 m^3/s and there exists a fall of 2.47 m at a chainage of 33,800 m on it. It has been estimated that there exist a potential of 800 kW at this site and a small hydropower project can be installed on the left bank of the canal. Various civil and hydro-mechanical components have been designed and cost estimation has been carried out. Based on the study it is found that the development of this site is techno-economically feasible considering government subsidy and clean development mechanism benefit available for such projects.

1. INTRODUCTION

Power is the engine of growth of any developing economy. Consumption of electrical energy is universally accepted indicator of progress in the agricultural, industrial and commercial sectors, as also of the well being of the people of the state. No major economic activity can be sustained without adequate and reliable supply of power. It plays a critical role in employment generation, regional development and poverty eradication.

In the present context of power shortage it is crucial to recognize the ways and means of harnessing energy which are renewable, eco-friendly and non-fossil in nature. Over the last two and half decades, the Government of India along with state governments has been promoting Renewable energy in the different sectors like industry, agriculture, transport, commercial and domestic through many fiscal and financial incentives. Attempts have been made to generate power through Renewable energy sources such as solar, wind, small hydro and biomass.

Hydropower represents the use of water resources towards inflation free energy due to absence of fuel cost. It contributes to around 750 GW of electricity in the world, which satisfies around 22% of the world's energy demand. In many countries it is the main source of power generation, e.g. Norway: 99%, Brazil: 86%, Switzerland: 76% and Sweden: 50% [1].

India is blessed with many rivers, natural streams, canal networks and mountains offering tremendous hydro potential of large, small, mini and micro hydropower. The rural areas in India are subjected to inadequate, poor and unreliable supply of energy services. Small hydropower projects can provide a solution for the energy problems in rural, remote and hilly areas as well as along the canal systems, where extension of grid is unfavorable.

In this paper, the present energy scenario in India and Gujarat state has been reviewed. Brief introduction of SHP and Indian perspective concerned with SHP has been discussed. Current status of SHP in Gujarat state has been presented. The details of canal network in Gujarat have been briefly described. Techno-economic aspects for the development of canal based small hydropower project on Nadiad branch canal in Kheda district of Gujarat state are presented.

2. POWER SCENARIO IN INDIA

India has been experiencing a large gap between demand and supply of electricity. In spite of 8 to 10% annual growth in power generating capacity there exists a power shortage of 7%, which exceeds 13% in peak demand periods [2].

India needs to sustain 8-10% growth rate of energy over the next 25 years to get rid of poverty and meet the human development goals. This would require, at least, enhancing primary energy supply by 3-4 times and the electricity supply by 5 times of the current level. Power generation capacity would need to be increased to 800 GW in year 2031-32 from the current installed capacity of around 139 GW [3]. Of the total installed capacity, share of thermal is 66%, hydro is 26%, nuclear is 3% and other renewable is around 5%. In India, the contribution of hydropower has been declining since 1963. The hydro share fell from 50% in 1963 to around 26% in 2008. For grid stability, the ideal hydro-thermal mix ratio is 40:60 [1].

In view of rising fossil fuel prices due to growing energy demand & limited resource availability as well as increased attention towards global warming, it has became essential to identify the different energy options which are renewable and environmentally benign in nature. Fortunately, India is blessed with many rivers & canals, long coastal areas, large amount of animal and cattle population as well as many regions receive reasonably good amount of solar energy showing enormous potential of hydro, wind, biomass & biogas and solar energy. The current status of various renewable energy sources in India is given in Table 1 [4].

Table 1: Renewable energy sources in India

Sr. No.	Renewable Energy Source/System	Estimated Potential (MW)	Installed Capacity as on 31 March 2008 (MW)
1.	Wind Power	45195	8757.00
2.	Bio Power (agro residues and plantations)	16881	606.00
3.	Bagasse cogeneration	5000	800.00
4.	Family-type biogas plants	120 lakh	39.94 lakh
5.	Small Hydropower (up to 25 MW)	15000	2141.00
6.	Energy recovery from waste	2700	55.25
7.	Solar water heating system	140 million m^2 collector area	2.30 million m^2 collector area
8.	Solar photovoltaic system	50 kW/km^2	120 MW_p
9.	Solar cookers	-	6.20 lakh

3. SMALL HYDROPOWER

Different countries are following different standards to distinguish between large and small hydro. In India, hydropower stations up to 25 MW capacity are called Small Hydropower (SHP) Projects. Further, SHP projects are classified as micro, mini and small hydro depending on the station capacity up to 100 kW, 101 to 2000 kW and 2001 to 25000 kW respectively [5]. Three different layouts which are most commonly used in SHP are run-off-river, canal based and dam-toe based scheme.

The potential of SHP in the country is over 15,000 MW, of which only 2141 MW from 645 sites have been tapped so far. The current status of SHP in India is given in Table 2 [6]. The Ministry of New and Renewable Energy (MNRE), Government of India is responsible for the development and deployment of SHP in the country. To promote the SHP projects in India, MNRE provides subsidy for the installation as well as renovation and modernisation (R&M) of SHP projects. Also, the Clean Development Mechanism (CDM) under the Kyoto

Protocol to United Nations Framework Convention on Climate Change (UNFCCC) provides an opportunity for the power sector to earn revenue through the reduction of greenhouse gas emissions (GHG), particularly carbon dioxide (CO2).

Table 2: Small hydropower scenario in India

Overall potential below 25 MW	Over 15,000 MW
Identified potential	14,294 MW (5,403 sites)
Installed capacity	2141 MW (645 projects)
Under construction	1,233 MW (349 projects)
Capacity addition during 2002-2007	Over 500 MW
Target capacity addition – 11^{th} Plan (2007-2012)	1400 MW
Policy announced for private sector development	18 states

4. SMALL HYDROPOWER SCENARIO IN GUJARAT

The Government of Gujarat has given highest priority to the development of power sector. The scope for small hydropower projects in rivers and canals of Gujarat is relatively less. However, efforts shall be made to harness 100% of the available potential by setting up of small/mini/micro projects based on river/canal/dam through private/state/joint sector participation. There exists a SHP potential of around 187 MW in 287 projects in different parts of the state, of which only 7 MW through 2 SHP projects have been tapped so far. The details of identified and existing SHP projects in Gujarat are given in Tables 3 & 4 respectively [7].

Table 3. Identified SHP potential in Gujarat

Run off River		**Dam Based**		**Canal Based**		**Total**	
No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)
22	43.55	1	14.00	264	128.82	287	186.37

Table 4. Existing SHP projects in Gujarat

S. N.	**Name of Project**	**District**	**Unit Capacity (no. x kW)**	**Total Capacity (kW)**	**Net Head (m)**	**Design Discharge (m^3/s)**	**Year of Commissioning**
1.	Ukai Left Bank Canal Power House	Surat	2x2500	5000	18	34	1987-88
2.	Panam Mini Hydro Electric Project	Panchmahal	2x1000	2000	12	20	1993-94

Gujarat has quite fertile land with average rainfall varying between 14 to 45 inches per annum in different parts of the state. To support the agriculture sector, the state has a well-developed irrigation system in the form of different canals and dams. There exist more than 184 major and medium irrigation schemes in the state [8]. The energy available in the flowing water can be utilized for electricity generation at the falls of the canals and thus the existing irrigation infrastructure can serve the dual purpose of meeting the irrigation and energy requirements of the state.

5. DEVELOPMENT OF SHP IN GUJARAT – A Case Study

Investigations have been carried out for the development of SHP project in Gujarat state. For the present study, the Nadiad branch canal has been considered for the development of SHP project which is a branch canal of Mahi main canal. The Mahi canal emanates from Mahi river at Wanakbori weir in Balasinor taluka of Kheda district in Gujarat.

The weir diverts the flow of Mahi river to the Mahi main canal which is 73.6 km long with design discharge capacity of 8200 cusecs. Six branch canals emanate from the main canal at different chainages have total length of 223 km, the details of branch canals are given in Table 5.

Table 5. Details of branch canals of Mahi main canal

S. N.	Name of Branch Canal	Chainage
1.	Shedhi Branch Canal	23,878 m (78,320’) w.r.t main canal
2.	Nadiad Branch Canal	40,850 m (1,34,000’) w.r.t main canal
3.	Cambay Branch Canal	35,854 m (1,17,600’) w.r.t Nadiad branch canal
4.	Limbasi Branch Canal	11,036 m (36,200’) w.r.t Cambay branch canal
5.	Petlad Branch Canal	54,854 m (1,79,920’) w.r.t main canal
6.	Borsad Branch Canal	69,878 m(2,29,200’) w.r.t main canal

On Nadiad branch canal, at a chainage of 33,800 m there exists a fall of 2.47 m height and the design discharge of the canal is 85 m^3/s. To evaluate the potential available at this site, the site has been visited and detailed data were collected from Mahi irrigation Circle, Nadiad. The different data collected are discharge data for the period between 1997 and 2007, details of fall structure, longitudinal and cross sectional details of the canal etc. These data have been analyzed critically and flow duration curve is prepared as shown in Fig. 1[9].

View of Nadiad branch canal and fall

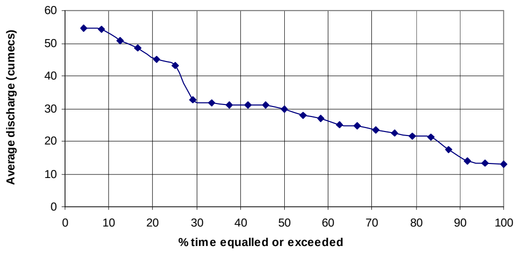

Figure 1. Flow-duration curve

5.1 Installed Capacity and Number of Units

The gross head available correspond to depth of fall is 2.47 m, accordingly the net head has been worked out as 2.3 m. Based on the net head available and discharge considered from flow-duration curve, power potential and energy available are worked out considering turbine, gearbox and generator efficiency as 88%, 95% and 94% respectively. Based on optimum energy generation, installed capacity of 800 kW has been found most suitable at a rated discharge of 45.12 m^3/s. The annual average energy generation is worked out as 4.59 Million Units at 65.43% load factor.

Single turbine of 800 kW capacity will be cheaper from the initial cost point of view. However, the discharge does not remain constant round the year and in case of single unit there are chances of running turbine at part load as well as total loss of power generation during maintenance and shutdown. Considering these facts, 2 units of 400 kW each have been proposed for the project.

5.3 Selection of Turbine

There are various components in the hydropower plant, but turbine is the most critical component because it directly affects the overall performance of the whole power plant. According to Indian Standards the overall dimensions of the power house, spacing between the turbines, space for the service bay etc. depends on the turbine diameter. Keeping in view these factors as well as low capacity of the project, while selecting the turbine greater considerations have been given to initial cost of the turbine, cost of civil works and indigenous availability. Correspond to specific speed (746.45 metric) of the turbine; different turbines considered for the current installation are horizontal Kaplan (tubular) turbine, vertical Propeller turbine and vertical Semi Kaplan turbine with siphon intake.

Among these turbines, horizontal shaft Kaplan turbine is having higher part load efficiency due to variable runner blades but it is costliest. Whereas, Propeller turbine is suited for the site having almost constant discharge because of fixed runner blades. On the other hand, vertical Semi Kaplan turbine with siphon intake operates on the siphon principle i.e. the valve of intake flume chamber is closed and kept water tight and vacuum is created by a vacuum pump, which enables water to enter in the flume chamber and energize the runner. It has the advantage that machines can be easily shut down by breaking the vacuum. The intake and draft tube gates are not required and the power house is also compact, thus reduces the overall cost of the project. Considering these facts, 2 no.s of vertical Semi Kaplan turbines with siphon intake of 400 kW capacity, having adjustable runner blades and fixed wicket gates have been proposed for the Nadiad small hydropower project.

5.3 Other Components

The other major components include civil work components like cross regulator, power channel, power house, tail race channel, approach road etc. and electro-mechanical components like gear box, generator, governor etc. The power house is proposed on the left bank of Nadiad branch canal, considering land availability. The typical layout of canal based project is shown in Fig.2.

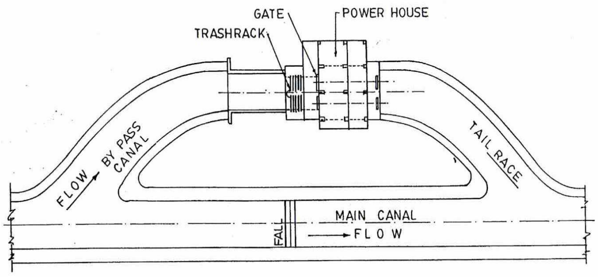

Figure 2. Typical layout of canal based project

As the capacity of the project is relatively less all the components are designed/selected from economy point of view. To regulate the flow of water from Nadiad branch canal towards power house gated cross regulator is proposed on the existing fall to take the advantage of existing fall structure and hence to achieve saving in cost. To lead the water towards power house from Nadiad branch canal power channel has been proposed on the left bank of NBC. The rated discharge for power generation is 45.12 m^3/s, however, power channel has been designed for 50 m^3/s discharge considering 10% overrating of the turbine. Similarly, on downstream of the power house tail race channel of 50 m^3/s capacity has been proposed to discharge the water back to NBC.

The runner diameter of turbine has been worked out as 2.87 m. Correspond to this diameter and following IS 12800 (Part 3):1991 the dimensions of power house have been worked out. Accordingly, the power house building of size 20.0 m×10.5 m×26.0 m height has been proposed to accommodate two machines of 400 kW each, auxiliary equipments etc. To facilitate handling of equipments during the erection and maintenance periods, one electrically operated traveling (EOT) crane of 10 tones capacity has been proposed. The longitudinal section of power house is shown in Fig. 3 [9].

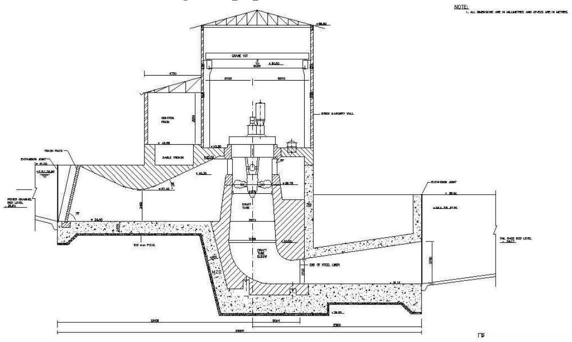

Figure 3. Longitudinal section of power house

If synchronous speed of generator is more, number of poles of the generator are less and hence generator is cheaper i.e. speed of the generator shall be kept as high as possible. Thus in present case gearbox (speed increaser) has been proposed which will increase the speed from 86 to 430 rpm, which will result in reduction in size of generator and hence the cost. To govern the speed against load variations two numbers of computerized PLC based digital electronic governors have been proposed. Two numbers of vertical shaft synchronous generators of 400 kW each, 3 Phase A.C., 50 Hz frequency have been proposed.

Detailed cost estimations have been carried out based on the rates prevailing in the area. Based on capital investment, maintenance cost, various expenditures and revenue generation; the cost per kWh has been worked out and it is found that, the cost of generation from the scheme is about Rs 3.89 per kWh without any financial assistance and Rs 2.94 per kWh with MNRE subsidy and CDM benefit at 65 % load factor.

6. CONCLUSIONS

Canal based schemes are reliable in terms of geology and hydrology. Moreover, they are easily approachable as they are in plain areas. Also, they do not have problem of power evacuation, as they are near the load centres. These schemes are associated with advantages such as low gestation period, simple layout, no submergence and rehabilitation problems and practically no environmental problems. One such potential site on Nadiad branch canal in Gujarat state has been investigated and details for the development small hydropower project have been worked out. It has been found that there exist a potential of 800 kW on this site and power house can be constructed on the left bank of the canal. Based on the study it is found that the development of this site is techno-economically viable considering government subsidy and CDM benefits available for such projects.

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