Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 117 (2017) 163–171

Energy Procedia

www.elsevier.com/locate/procedia

1st International Conference on Power Engineering, Computing and CONtrol, PECCON-2017, 2-4 March 2017, VIT University, Chennai Campus

Design of 15 kW Micro Hydro Power Plant for Rural Electrification at Valara

Prawin Angel Michael[a], C.P.Jawahar[b1]

[a] Department of Electrical and Electronics Engineering, Karunya University, Karunya Nagar, Coimbatore - 641 114, India
[b] Department of Mechanical Engineering, Karunya University, Karunya Nagar, Coimbatore - 641 114, India

Abstract

There is a fast depletion of renewable sources that was used in the past for the generation of electricity and the difficulty in reachability of the grid supply to the remote villages was a big challenge faced. The best possible remedial measure in this scenario is to make use of the natural resources available to generate electricity. In an endeavourance towards this end, the paper has been formulated for the electrification of valara village in Idukki district of Kerala, India. Valara is a kind of locality in which there is a tribal settlement of about 120 families that do not have privilege of electrical energy supply. The present work focus on the preliminary studies carried out at the site for the development of a complete micro hydro power plant which focuses on three main folds such as technical as well as economical feasibility studies, design of civil works and selection of electro mechanical components. The results of the study reveal that there is a huge potential at the site to develop a micro hydro power plant which would meet the energy demand of the tribal settlement and thereby improving their living condition.

Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.

Keywords: discharge; energy; head; hydro; renewable

1. Introduction

1* Corresponding author. Tel.: +91 422 2614144 fax: +91 422 2615615
E-mail address: cpjawahar@gmail.com

1876-6102
Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.
10.1016/j.egypro.2017.05.119

Energy is the backbone for the growth of a nation [1]. India's demand for electrical energy is growing rapidly, while its electrical energy system is struggling with severe shortage to supply the same [2]. Renewable energy technologies play an important to narrow down the shortage. In order to diversify the country's power generation mix, the Government of India, has issued several national policies to promote their further development [3,4]. Among the renewable energy source, small hydro power contributes 13% of the total grid-connected power generation, thereby constituting second largest grid-connected system after wind power, as per the report by Ministry of New and Renewable Energy. India is endowed with a vast and viable hydro potential for cleaner power generation. Due to its abundant availability, it can be utilized effectively to reduce the gap between the energy demand and supply. Development of small hydro power plants rapidly is one of the important assignment in the policy announced by the Ministry of Power. Such kind of power plants is quite possible wherever water resources are available and where power is to be provided to remote areas away from the grid. Kerala state has huge untapped potential for small hydro power generation. Small, mini and micro hydro power plants play an important role in electrifying the rural parts [5-8].

1.1 National Status Review

For more than 100 years the commissioning of hydro projects are in existence. Right in 1897 at Darjeeling the first SHP was commissioned with a capacity of 130 kW. In 1902 at Chambal and in 1911 at Jubbal 40 kW and 50 kW power was generated at the plants respectively. The statistics says that till independence there was 1362 MW energy available in the country generated by the hydro power projects .50 years after independence the power generation measured upto 85,019 MW. All the above mentioned plants was commissioned by Government sectors and few public sectors but the major awareness of SHP was developed in late 90’s [9-15]. Due to the emerge of SHP at the end of August 2014 the power generation reached around 20,000 MW only by SHP with more than 15,000 MW potential remains unexploited.

1.2 International Status Review

Off the total potential available in the world, the potential generation of hydro counts to 19%.The hierarchy of the largest producers of power using hydro as the resources are China followed by Japan, Italy and Brazil. The target potential at the end of 2015 by Europe was 300 MW [16]. Statistics says that 28.9 MW potential is available in west Bengal (Hussein and Raman, 2010) of which 50 kW is by micro hydro power plant [17]. In Canada there are still potentials identified which are capable of generating high potentials [18]. Srilanka and Bangladesh has a potential of 97.4 MW [19] and 10 kW [20] respectively.

2. Small Hydro Power Technology

The schematic of a small hydro power plant (run-of-river type) is shown in Fig. 1. The basic

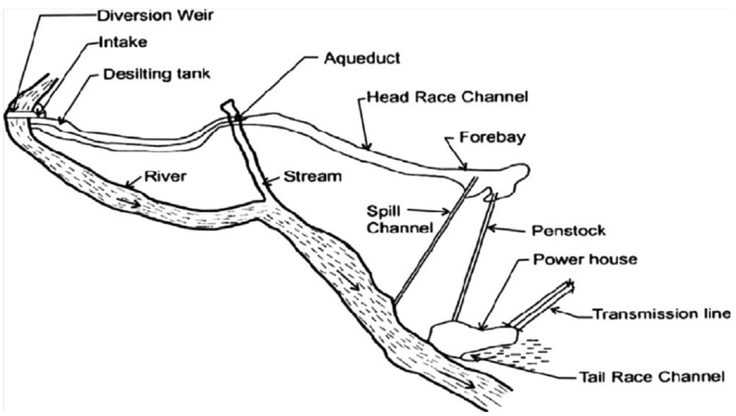

Fig. 1. Schematic of a small hydro (run-of-river type) power plant [21]

components are weir, desilting tank, penstock, turbine, generator and controls [22]. Water from the river is diverted through an intake at the weir, which also controls the water flow. Water then enters a desilting tank where, if any impurities are removed in it. A forebay tank is located between the intake and penstock, to store water. Water from the forebay tank is transported to a turbine through a pipe termed as penstock. The turbine converts the potential energy of the water into mechanical energy. The mechanical energy is then converted into electrical energy with the help of a generator. The power produced at the turbine shaft is determined using the following relation

$$P = \rho \eta g Q H \tag{1}$$

where

g - acceleration due to gravity (m/s^2)
H - head (m)
P - power (W)
Q - discharge (m^3/s)
ρ - density of water (kg/m^3)
η - overall efficiency of turbine, generator and gear box (80 to 90%)

3. Site Investigation

3.1 Topographical Survey

The project site Valara is located in the Adimali Grama Panchayat of Idukki district in Kerala. The site is located at a distance of 14 Km from Adimali. The site is connected by road from Kothamangalam to Adimali. The site is very near to the main road. The stream is a seasonal one, but it has more discharge in rainy season because of its large catchment. The catchment of Valara waterfall is located between 10°18′36″N latitude and 76°29′45″E longitude. About 70% of the catchment area is under dense mixed forest and rest of the area is utilized for human settlements and cultivation of rubber, cardamom, tapioca, areca nut and coconut. The catchment of Valara was identified using the top sheet and it is about 63 Km^2. The head of the water fall is 80 m and it is situated at an elevation of 460 m from mean sea level. During the survey, the possible location for weir, forebay tank, penstock, turbine, power house were also identified.

3.2 Geological Survey

The rock exposures along this stream have been studied in details. The rock type is found to be pyroxene granulite. It is a massive, grano blastic, measocratic rock composed of plagioclase, potash feldspar, hornblende and biotite. The general rock type is charnockite. A good portion of the Western Ghats is made up of this rock. In the Travancore area the rocks are well foliated and show intrusive relationship with peninsular gneiss. They are highly garnetiferous as compared to the charnokites of North Kerala, where garnet is absent. About 80% of the proposed site has an exposed rock presence.

3.3. Socio-economic Survey

A tribal settlement of about 120 families is there within a radius of 3 Km from where the stream is located. Most of the tribal live in concrete type of houses and few of them in thatched roof houses. Most of the houses have two rooms and few of them have 3 or 4 rooms. The tribal interact with each other in their local language Malayalam. The tribal settlement depends on the forest for their livelihood. They do not have access to electricity and use kerosene for lighting purposes.

3.4 Climate

The area is subjected to two monsoons, namely the south- west (June-August) and the north- east (October-November), the former contributing to 75% of the annual rainfall and the latter 30%. The average annual rainfall of the region is estimated at around 440 cm based on data available from the nearby station at Munnar. The temperature in the area varies between 15.2°C and 25°C, the minimum is during the winter season (November-January) the range between 0°C and 10°C and maximum during the summer season (February-May). The average annual humidity of the area is of the order of 57%.

3.5 Land Use

About 70% of the catchment area is under dense mixed forest and rest of the area is utilized for human settlements and cultivation of rubber, cardamom, tapiocca, arecanut and coconut. A comparison with other catchment in this region indicates that the open jungle forest of the catchment is the main factor contributing to the summer flows in Deviyar River.

3.6 Village Layout and Type of Houses

Valara is a small village/hamlet in Adimali Taluk in Idukki District of Kerala State, India. It comes under Neriamangalam Panchayat. It belongs to Central Kerala Division. It is located 21 km towards North from District head quarters Painavu, 198 km from state capital Trivandrum. There are around 120 tribal community residing near the valara falls. Most of the houses are of concrete type. Few thatched roof houses also exist. Most of the houses have two rooms and few of them have 3 or 4 rooms.

3.7 Energy Requirement

3.7.1 Domestic load

On preliminary survey with the local people and authorities, for 120 houses; the domestic load considered as 2 numbers of 11 W CFLs, 1 number of 50-120 W fan and a mobile charger load of 10 W.

CFLs: 2 x 11 x 120= 2640 W or 2.64 kW
Fan Load: 1 x 50 x 120=6000 W or 6 kW
Mobile Charger Load: 1 x 10 x 120=1200 W or 1.2 kW

Total = 2.64 + 6 + 1.2 = 9.84 kW

3.7.2 Public lighting load

Number of lights = 20
Type of load = 18 W CFL
Lighting hours = 4
Total load = 18 x 20 W = 0.36 kW

3.8 Power House Installation Capacity
3.8.1 Installed capacity

Assuming the losses in the power house and line to be 10% and taking 20% future growth as 20 %, the power house installation capacity is worked out below
Domestic load = 9.84 kW
Public lighting = 0.36 kW
Future load growth = 0.2 x (9.84 + 0.36) = 2.04 kW
Power house consumption and line losses = 0.1 x (9.84 + 0.36 + 2.04) = 1.22 kW
Total load = 9.84 + 0.36 + 2.04 + 1.22 = 13.46 kW = 15 kW (say)

3.8.2 Energy consumption per day

Considering 6 hours for domestic lighting, 10 hours for other domestic loads, 4 hours for public lighting, the energy consumption per is calculated as follows
Domestic lighting = 2.64 x 6 kWh = 15.84 kWh
Other domestic loads = 7.2 x 10 kWh = 72 kWh
Public lighting = 0.36 x 4 kWh = 1.44 kWh
Power consumption and line losses = 0.1 x 15 = 1.5 kWh
Total = 90.78 kWh

4. Techno Economic Analysis
4.1 Available power facilities

Electricity is not available for the 120 tribal families and they are employing kerosene for lighting purposes. Utilizing the hydro resources to produce power will uplift the life of the tribal settlement in Valara.

4.2 Duration of flow

With the details collected on the discharge data between January 2009 and December 2013 of Valara stream, which is seasonal, the flow duration analysis has been done.

75% = 0.151 m^3/s
50% = 2.257 m^3/s

4.3 Energy potential

To determine the energy potential at the site, discharge data are required. The discharge data was collected between January 2009 and December 2013 of Valara stream, the flow duration curve which depicts the variation of time with discharge [9] has been plotted and it is shown in Fig. 2.

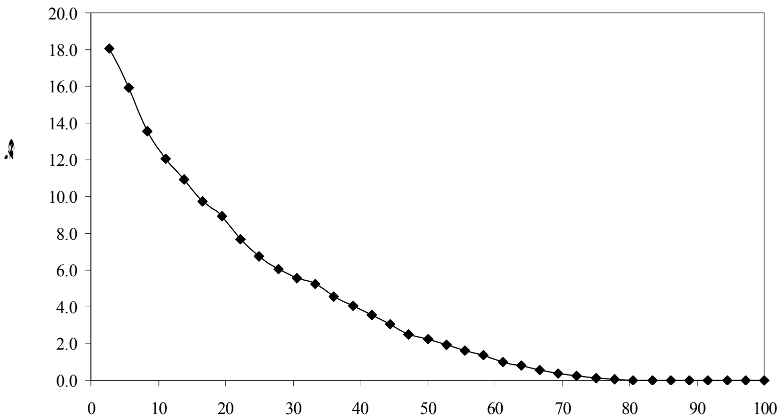

Fig. 2. Flow duration curve

To determine the discharge available for generation of electrical energy, the discharge is reduced to 80% to account for various losses.

Table 1. Energy potential

S.No	% of Time	Average(m3/s)	Flow Available(m3/s)	Head (m)	Power (kW)
1	2.78	22.549	18.039	80	7928.09
2	5.56	19.923	15.939	80	7004.86
3	8.33	16.949	13.559	80	5958.96
4	11.11	15.059	12.047	80	5294.61
5	13.89	13.705	10.964	80	4818.64
6	16.67	12.160	9.728	80	4275.39
7	19.44	11.165	8.932	80	3925.50
8	22.22	9.640	7.712	80	3389.34
9	25.00	8.473	6.779	80	2979.07
10	27.78	7.550	6.040	80	2654.43
11	30.56	6.927	5.542	80	2435.51
12	33.33	6.587	5.269	80	2315.82
13	36.11	5.674	4.539	80	1994.98
14	38.89	5.086	4.069	80	1788.26
15	41.67	4.462	3.569	80	1568.70
16	44.44	3.816	3.053	80	1341.78
17	47.22	3.160	2.528	80	1110.87
18	50.00	2.821	2.257	80	991.88
19	52.78	2.424	1.939	80	852.13
20	55.56	2.039	1.631	80	717.00
21	58.33	1.712	1.370	80	601.93
22	61.11	1.238	0.990	80	435.23
23	63.89	0.983	0.787	80	345.66
24	66.67	0.666	0.533	80	234.09
25	69.44	0.480	0.384	80	168.63
26	72.22	0.351	0.281	80	123.36
27	75.00	0.189	0.151	80	66.44

28	77.78	0.090	0.072	80	31.81
29	80.56	0.000	0.000	80	0.00
30	83.33	0.000	0.000	80	0.00
31	86.11	0.000	0.000	80	0.00
32	88.89	0.000	0.000	80	0.00
33	91.67	0.000	0.000	80	0.00
34	94.44	0.000	0.000	80	0.00
35	97.22	0.000	0.000	80	0.00
36	100.00	0.000	0.000	80	0.00

It is inferred from Table 1 that a discharge of 0.072 m^3/s can produce 31.81 kW (when flow is available during 78% of the time) which is about twice the load requirement. Hence, one unit of 15 kW is proposed.

5. Design of Civil Works

The civil works comprises of forebay tank, spillway, penstock and power house. The dimensions of the fore bay tank are 3 m length, 2.3 m width and a depth of 1.25 m. The diameter and length of the penstock are 0.22 m and 120 m respectively and it can carry a discharge of 0.072 m^3/s at a velocity of 2.5 m/s. The layout of the power house building has been worked out on the basis of IS code and size of power house building shall accommodate control panel and other auxiliaries. The size has been fixed as 10 m x 5 m x 3 m. All the design calculations were carried out as per the standards used in the construction of micro hydro plant.

6. Selection of Electro Mechanical Equipment

6.1 Turbine

Specific speed is the parameter based on which the turbine is selected. The specific speed (N_s) of a turbine is given by

$$N_s = NP^{1/2}H^{-1.25} \quad (2)$$

where

H - head (m)
N - speed (rpm)
N_s - specific speed
P - power (kW)

For 80 m head, 15 kW power and a speed of 1500 rpm, the specific speed is about 21. From Table 2, for a specific speed of 21, cross flow turbine is suitable.

Table 2. Selection of turbine

S.N	Type of Turbine	Specific Speed
1	Pelton	12 - 30
2	Turgo	20 - 70
3	Crossflow	20 - 80
4	Francis	80 - 400
5	Propeller and	340 - 1000

6.2 Synchronous generator

Generator is coupled with the turbine to produce electrical energy. The 3 phase, 50 Hz synchronous generator selected has a capacity of 15 kW at 415 V and its speed is selected to be 750 rpm, the network selected will be a star connected , brushless excitation , air cooled.

7. Financial Analysis

The total project cost is estimated as Rs.60 lakhs; out of which Rs.35 lakhs for civil works, Rs.12 lakhs for electro mechanical works, Rs.5 lakhs for transmission and distribution and Rs.8 lakhs for other expenses. The cost of installation is Rs.4 lakhs/kW and the cost of generation is Rs.8.06/kW and Rs.12.04/kW at a load factor of 90% and 60% respectively as inferred from Table 3.

Table 3. Cost of generation

S.No	Item	Cost (Rs.lakhs)
1	Total project cost	60.00
2	Annual working expenses	2.31
3	Interest @ 12% on total project cost	7.20
4	Total annual expenses	9.51
5	Annual generation at power house (Lakh Units)	
	(i) @ 90% load factor	1.18
	(ii) @ 60% load factor	0.79
6	Cost of generation per kWh (Rs.)	
	(i) @ 90% load factor	8.06
	(ii) @ 60% load factor	12.04

8. Conclusion

A 15 kW micro hydro power plant has been designed for rural electrification at the valara site in the state of Kerala. The site has huge potential for developing the same. The proposed micro hydro power plant is found to be technically and economically viable and it not only meets the energy demand of about 120 tribal families in the locality but also improves their living standard as the operation and maintenance of the plant would be managed by them.

Acknowledgement

We would like to thank the Centre for Water Resources Development and Management, Kerala and Dr. E. J. James, Director, International Affairs, Karunya University, Coimbatore, for their kind help and support in collecting the data during the field survey. We would also mark a note of gratitude to Mr. Anil Assistant Director, the Energy Management Centre, Kerala for all his timely suggestions and encouragements.

References

[1] Capik M, Yılmaz AO, Cavusoglu I. Hydropower for sustainable energy development in Turkey: the small hydropower case of the eastern black sea region. Renew. Sustain. Energ. Rev. 2012;16:6160-72.

[2] Understanding energy challenges in India: policies, players and issues, International Energy Agency, Paris, 2012.

[3] Schmid G. The development of renewable energy power in India: which policies have been effective? Energ. Policy 2012;45:317-26.

[4] Sharma NK, Tiwari PK, Sood YR. A comprehensive analysis of strategies, policies and development of hydro power in India: special
emphasis on small hydro power. Renew. Sustain. Energ. Rev. 2013;18:460-70.
[5] Yuksek O, Komurcu MI, Yuksel I, Kaygusuz K. The role of hydro power in meeting Turkey's electric energy demand. Energ. Policy 2006;34:
3093-103.
[6] Dursun B, Gokcol C. The role of hydro electric power and contribution of small hydro power plants for sustainable development in Turkey.
Renew. Energ. 2011;36:1227-35.
[7] David Kilama Okot. Review of small hydropower technology, Renew. Sustain. Energ. Rev. 2013;26:515-20.
[8] Raja Singh R, Thanga Raj Chelliah, Pramod Agarwal. Power electronics in hydro electric energy systems. Renew. Sustain. Energ. Rev.
2014;32:944-59.
[9] Adhau Adhau SP, Moharil RM, Adhau PG. Mini-hydro power generation on existing irrigation projects: case study of Indian sites. Renew.
Sustain. Energ. Rev. 2012;16:4785-95.
[10] Bhattacharya SC, Jana C. Renewable energy in India: historical developments and Prospects. Energy 2009;34:981-91.
[11] Naidu BSK. Small hydro in India: environmental friendly alternative energy Source. TERI Inform Monitor on Env. Sci. 1997;1:81-93.
[12] Nautiyal H, Singal SK, Varun Sharma A. Small hydropower for sustainable energy development in India. Renew. Sustain. Energy Rev.
2011;15:2021-7.
[13] Saxena P, Kumar A. Hydropower development in India. Proceedings of the International Conference on Hydraulic Efficiency
Measurements, India. 2010.
[14] Nouni MR, Mullick SC, Kandpal TC. Techno-economics of micro-hydro projects for decentralized power supply in India. Energ. Policy
2006;34:1161-74.
[15] http://www. arizonaenergy.org
[16] Punys P, Pelikan B. Review of small hydropower in the new member states and candidate countries in the context of the enlarged European
Union. Renew. Sustain. Energ. Rev. 2007;11:1321-60.
[17] Mohibullah M, Radzi AM, Hakim MLA. Basic design aspects of micro hydro power plant and its potential development in Malaysia.
Proceedings of the Power and Energy Conference, Malaysia, 2004.
[18] Ranjitkar G, Jinxing H, Tung T. Application of micro-hydropower technology for remote regions. IEEE EIC Climate Change Tech. 2006;1-
10.
[19] Fernando S. An assessment of the small hydro potential in Sri Lanka. Energ. for Sust. Dev. 2002;6:95-98.
[20] Wazed MA, Ahmed Shamsuddin. Micro hydro energy resources in Bangladesh: a Review. Australian J. of Basic and Appl. Sci. 2008;2:
1209-22.
[21] Singal, SK., Saini RP., Raghuvanshi CS. Analysis for cost estimation of low head run-of-rivers small hydro power schemes. Energ. for
Sustain. Dev. 2010;4:117-26.
[22] Guide on How to develop small hydropower plant. European Small Hydro Association, 2004.