ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 15, March 2017

MICRO HYDEL POWER PLANTS AT THE TOE OF EXISTING DAMS

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Abstract: Micro hydel power plant is a type of hydroelectric power plant that typically produces 5kw to 1000kw of electricity using the natural flow of water. This project aimed at finding the possibility of a micro hydel power plant at the toe of existing dams. The water that is drained out from the reservoir through scour outlet pipe during the monsoon is used to harness electricity. The study area of our project is at the dam toes of Idukki district. Among 9 dams in Idukki, we selected Kallarkutty and Ponmudi as our site due to the presence of scour outlet pipe. Geological, seismic and spillage features of our selected dam supported the feasibility of our power plant. From the available head conditions, we adopted Francis and Kaplan turbine for the design purpose and from the available velocity, penstock is designed considering all the losses that can occur. It is proved from our result that a considerable amount of current can be produced from this water which is being wasted during rainy season. Thus installation of this power plant leads to be an ultimate solution for the power failure faced by India.

I. INTRODUCTION

The global electricity generation has more than double in the past two decades due to increasing economic development. These difficulties are continuously increasing, which suggest the need of technological alternatives to assure their solution. One of these technological alternatives is generating electricity as near as possible of the consumption site, using renewable energy sources that do not cause environmental pollutions, such as wind, solar, tidal and hydro-electric power plants.

Hydro-electric power is a form of renewable energy sources which comes from flowing water. When the water is falling by the forces of gravity, its potential energy converts into kinetic energy, this kinetic energy of the flowing water turns blades or vanes in a hydraulic turbine, the form of energy is changed into mechanical energy. The turbine turns the generator rotor which then converts this mechanical energy into electrical energy and the system is called hydro-electric power stations. Hydropower provides 17% of electricity demand of the world from an installed capacity of about 730 GW. However, economic and environmental factors seriously restrict the exploitation of hydropower through conventional large capacity projects.

Among all the renewable energy resources, small hydropower, which is defined by different plant capacities in different countries, is considered as one of the most promising sources. The contribution of SHP is about 1%–2% of the Dam toe low head schemes being planned on the existing low height dams mainly meant for irrigation systems have established hydrology and are free from geological and discharge uncertainties. Water availability in rivers is not the same throughout the year and the maximum availability of water is in the rainy season, which lasts for 3–4 months a year. Dams are constructed to store this seasonal water for flood mitigation, irrigation, and drinking needs. When water flows from dam outlets under pressure, due to the water level difference between upstream and downstream of the dam, there is a possibility of power generation. These schemes are known as dam toe hydropower schemes.

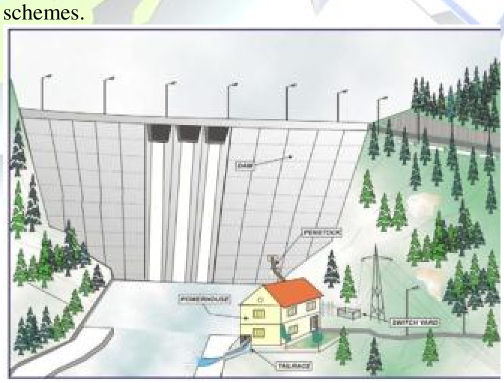

Fig 1: Schematic of a typical dam toe SHP scheme

II. SCOPE

A micro hydel residential plant is by its very nature located near a reliable water stream and therefore it can provide electricity to off-

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grid homes uninterruptedly. Down streaming water is probably the most cost-effective energy source for off grid power generation.

Micro hydel power is generated through a process that utilizes the natural flow of water. With no direct emissions resulting from this conversion process, there are little to no harmful effects on the environment. Adding to the potential economic benefits of micro hydel power plants are efficiency, reliability, and cost effectiveness. These can be continuously operated day and night and under any wind conditions (not like solar plants or wind turbines) and every day. Seasonal changes however can be anticipated (more water during the winter season and the monsoon season, less water during the summer season). Micro-hydel plants only divert a small fraction of the stream and they don't need a water storage pool. Therefore, the environmental damage that accompanies the large scale hydro plants is not duplicated by the micro-hydro dam-less electric plants.

Micro hydel systems are limited mainly by characteristics of the site. The most direct limitation comes from small sources with minuscule flow. Likewise, flow can fluctuate seasonally in some areas. Lastly, though perhaps the foremost disadvantage is the distance from the power source to the site in need of energy. This distributional issue as well as the others is key when considering using a micro hydel system. Even though the micro hydel plant requires low maintenance, with years some of the pipe run might be covered with vegetation and the access to the pipe might be difficult; keeping the vegetation off is an extra effort that might require the hiring of labourers and equipment. [3] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

III. LITERATURE REVIEW

Literature review is an integral part of any project. It is an evaluative report of information found in the literature related to the selected area of study. The review describes, summarizes, evaluates and clarifies the project. It gives a theoretical base and help in determining the nature of study. A number of journals were collected and the journals which were related to our topic were studied. The journals referred have been summarised below:

S. K. Singal, et.al. (2010) summarizes the importance of micro hydel power plant. The most important aspect of a micro hydel project is that it encourages sustainability. In a study carried out in India it has been estimated that it has been estimated that a potential of 15000 MW exists in small hydropower range, out of which only 2045 MW has been installed so far.

ZeinaBitar,et.al. (2015) conducted a study on different designs of HPP and alternatives of installed power were proposed and considered in order to choose technically and economically optimal solution. To compare and evaluate alternatives, in this study we take into consideration calculation of total energy produced. Calculation includes also cost of civil works, mechanical and electrical works, operation and maintenance and cost off investment. As result of this study the best alternative to be installed in mini HPS is chosen. The hydraulic losses for this type of project are also found to be considerably less than the hydroelectric projects.

Saurabh Sangalet.al (2013) provides a review on the selection of hydro turbine for hydroelectric project. To harness the potential, new turbines have been developed and commercially available. For the cost effective and efficient project, we need to study the optimal selection of hydro turbine.

Sarala P Adhauet.al (2009) outlines in detail the economic analysis and application of micro hydel power plants. The objective of this paper is to present one of the major criteria which are cost that gives rise to economic analysis which has been done suggesting some measures to be taken to reduce the cost. It also considers the environmental aspects into account. The study has been done in the village of Bhimgarh.

IV. METHODOLOGY

This study includes feasibility study, data collection, design of trash rack, penstock, turbine and power station for the micro hydel plant in Kallarkutty and Ponmudi dam.

V. FEASIBILITY STUDY

A number of dams in the Idukki district were considered out of which we selected the kallarkutty dam and Ponmudi dam as they had the most apt conditions that was required for our project. Sufficient spillage and the availability of a scour pipe were the main criteria. For the purpose of feasibility study we approached the KSEB and obtained the details of the Kallarkutty and Ponmudi dam. Details about the dam body, amount of daily spillage and other details were collected from the KSEB. We had successfully visited the 9 dams of Idukki and found out the study area of our project.

STUDY AREA 1: KALLARKUTTY DAM

The location of the dam is at latitude 9.95412 north and longitude 77.1295 easts. Kallarkutty dam is a masonry gravity dam. Length of dam is 182.88m. The spillway structure has five bays; Size of the gate is 10.97mx6.40m. There is one lower level outlet provided in the dam. It is stated by the project authorities that the dam was constructed during 1961 and spillway designed for a flood of 1982.4 m3/sec.

It is the reservoir of the Neriamangalam Hydroelectric Project and is constructed across the Mudirapuzha river which is a major tributary of the periyar river. The dam is constructed in the downstream side of the tail race confluences of the Sengulam and Panniyar Power stations. The tail water of the upstream projects viz. Pallivasal, Sengulam and Panniyar power stations leads to this reservoir. This reservoir is the downstream- most one in the Mudirapuzha basin. The spill from the upstream reservoirs Kundala, Mattupetty, RAHaedworks, Anayirangal, Ponmudi and Sengulam also reaches this reservoir. The water from the Kallarkutty reservoir is diverted through a water conductor system to the Powerhouse of

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Neriamangalam HEP located on the bank of Periyar. After generating power, the water is released to Periyar river.

DAM SPECIFIC DETAILS (collected from DRIP, KSEB)
(i)Dam Features:
a) Latitude at dam site: 9058'48'' N
b) Longitude at dam site: 7705'' E
c) Type: Masonry
d) Length of dam at Top: 182.88m
e) Width of dam at top: 6.1m
f) Height above deepest foundation level: 45m
g) Volume content of dam (103 m^3): 40
h) Energy dissipation arrangement: Hydraulic Jump type stilling basin
(ii)Reservoir features:
a) Catchment area at the dam site: 730.38 km^2
b) Maximum water level(m): 456.90
c) Full Reservoir level(m): 456.6
d) Minimum Draw down level(m): 438.90
e) Sill level of scour sluice:429.8 m
f) Spillway crest level:450.2 m
g) Dead storage level(m): 438.90
h) Deepest foundation level: 414.5 m
i) Live storage capacity: 6.43 mm^3
j) Gross storage capacity: 6.8 mm^3


Fig 2: Kallarkutty dam

STUDY AREA 2: PONMUDI DAM

Ponmudi dam is located in the Idukki district. It is constructed at Ponmudi across the river Panniyar in the year 1961. The location of the dam is 9057'37'' N and 7703'27'' E. The project is in Mudirapuzha basin of Periyar river basin. The water from the Ponmudi reservoir is diverted through a water conductor system to Panniyar Power station (30MW) located on the left bank of Mudirapuzha river, after generating power, the water is released to Panniyar river itself.

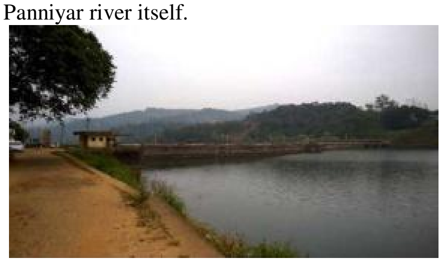
Fig 3: Ponmudi dam

DAM SPECIFIC DATA
(i)Dam features
Type: masonry gravity
Length of dam at top: 288.8m
Width of dam at top: 6m
Height above the deepest foundation level: 57.6m
Volume content of the dam (103 m^3): 181
Main spillway arrangement:
Type of spillway: ogee
No. of bays: 3
Type of gate: radial
Size of gate: height 6.4m width 10.97m
Energy dissipation arrangement: hydraulic jump type stilling basin
(i) Reservoir features
Catchment area dam site: 221.75km^2
Maximum water level: 708.66m
Full reservoir level: 707.75m
Minimum drawdown level: 676.65m
Dead storage level: 676.65m
Live storage capacity: 47.4Mm^3
Gross storage capacity: 51.54 Mm^3
Reservoir spread area at FRL: 2.78 km^2
Spillway crest level: 701.35m
Sill level of scour sluice: 661.5m

VI. DESIGN

For this project to be successful we should be able to find out the type and number of turbines which will provide maximum output with the available spillage.


Fig 4: Turbine selection chart based on head and flow rate (source: Hydraulic machines by Jagadish Lal)

A. SELECTION OF TURBINE FOR KALLARKUTTY DAM

The turbine selection is the first phase of the project which will look at developing the network technology requirements. We assume a net head of 20m considering the gross head and losses. A curve denoting percentage of flow vs discharge is being plotted from which discharge at 50% is taken as the design discharge. Here we obtained a value about 12.086m^3.

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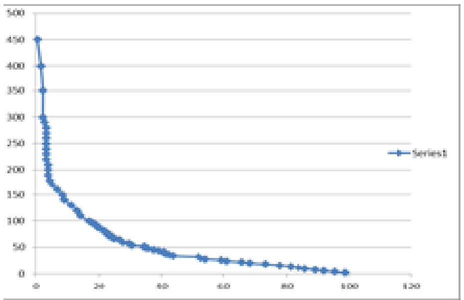

Fig 5: curve of Kallarkutty dam

From the obtained head and discharge values we selected Kaplan turbine for kallarkutty dam with the help of figure 4.

B. SELECTION OF TURBINE FOR PONMUDI DAM

We assume a net head of 40m considering the gross head and losses. A curve denoting percentage of flow vs discharge is being plotted from which discharge at 50% is taken as the design discharge. Here we obtained a value about 7.69m^3.

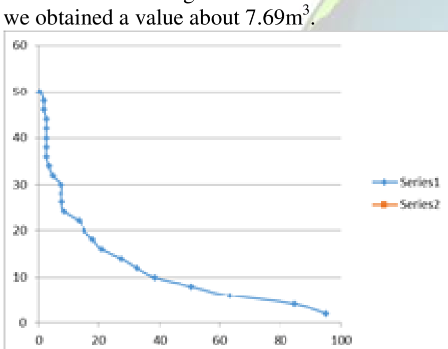

Fig 6: curve of Ponmudi dam

From the obtained head and discharge values we selected Francis turbine for kallarkutty dam with the help of figure 4.

C. TRASH RACK

Trash Screens and Trash Racks are designed to capture floating and submerged debris within water way systems. Typically made from aluminium and stainless steel. A trash rack is used to capture debris whilst allowing the water to flow. The Trash Screen is a storm water device that collects and retains rubbish while letting water flow uninterrupted.

For Kallarkutty dam, the diameter of the scour outlet pipe is 2.5m. With this diameter we calculated the area of cross section, and the area of trash rack allotted is taken as 30% of the calculated area. Here we obtained an area of 1.224m^2

For Ponmudi dam, the diameter of the scour outlet pipe is 2m. With this diameter we calculated the area of cross section, and the area of trash rack allotted is taken as 30% of the calculated area. Here we obtained an area of 0.942m^2

D. PENSTOCK

Penstock is a conduit or tunnel connecting a reservoir/forebay to turbine housed in powerhouse building for power generation. It withstands the hydraulic pressure of water under static as well as dynamic condition. The penstock material may be mild steel, glass reinforced plastic (GRP), reinforced cement concrete (RCC), wood stave, cast iron and high density polyethylene (HDPE) etc. However, in most of the cases, mild steel used for penstock due to wider applicability and availability.

For kallarkutty dam area is available near the outlet so we assumed the length of penstock as 10m. Using the diameter of the scour outlet pipe we calculated the area. From fig 5 obtained the discharge and using both these values calculated the velocity of flow as 3.01m/s. As per the manual on planning and design of small hydroelectric schemes clause 6.1.8, the maximum velocity in the penstock may not exceed 5m/sec. Since the obtained value is less than the permissible limits the design is safe.

Thickness of penstock, t =Pd/fs

Where Internal Pressure P=wh

For ASTM-A-537-yield point stress=3500kg/cm2

Substituting these values, we obtained the thickness of penstock as 1.42mm. Since minimum thickness of penstock for handling and stress at erection is 8mm, we provide a steel penstock of thickness 8mm.

For Ponmudi dam area is available near the outlet so we assumed the length of penstock as 10m. Using the diameter of the scour outlet pipe we calculated the area. From fig 5 obtained the discharge and using both these values calculated the velocity of flow as 2.9m/s. As per the manual on planning and design of small hydroelectric schemes clause 6.1.8, the maximum velocity in the penstock may not exceed 5m/sec. Since the obtained value is less than the permissible limits the design is safe. we obtained the thickness of penstock as 1.14mm by using the same equation above. Since minimum thickness of penstock for handling and stress at erection is 8mm, We Provide a steel penstock of thickness 8mm.

E. TURBINE

A turbine converts the flow and pressure energy into mechanical energy. Turbines are basically of two types i.e. Reaction & Impulse and Depending upon the head of the available water further divide in three categories i.e. High, Medium & Low head. According to site specification (i.e. head and flow) we choose the turbine to use in mini- hydro power plant

As mentioned earlier from fig 3, Kaplan turbine is found to be the most appropriate corresponding to the head and flow for Kallarkutty dam.

From the standard equation prescribed by KSEB we found out a Kaplan turbine of capacity 2MW is to be installed.

Power = 8xQxH

Runner dia,Dg=60x(2gH)0.5ku /πN

Where ku is the speed ratio which can be obtained from fig 6 of IS12800 (part 1) and the specific speed Ns calculated is 310rpm.By substituting all these values in the runner diameter equation we obtained the diameter as 1.5m.

For Ponmudi dam, from fig 3, Francis turbine is found to be the most appropriate corresponding to the head and flow.

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From the standard equation prescribed by KSEB we found out a Kaplan turbine of capacity 1.5MW is to be installed. Speed ratio which can be obtained from fig 6 of IS 12800 (part 1) is 0.56 and the specific speed Ns calculated is 210rpm.By substituting all these values in the runner diameter equation we obtained the diameter as 1m.

F. POWER HOUSE

A power station also referred to as a power plant or powerhouse and sometimes generating station or generating plant, is an industrial facility for the generation of electric power. Most power stations contain one or more generators, a rotating machine that converts mechanical power into electrical power. Power is captured from the gravitational force of water falling through penstocks to water turbines connected to generators. The amount of power available is a combination of height and flow.

The power factor is taken as 0.90 and the generator output is obtained as 1500KW. The outer diameter of the generator barrel is provided as 6.15m and the total length of power house is obtained as 19m. The width of the power house is calculated by addin generator diameter plus 0.50m clearance on upstream side plu 1.5m for approaching draft tube manhole plus 2m clearance on downstream side plus 1.5m for pressure relief valve which is equal to 12m. The height of the power houe is obtained as 18m by considering the ceiling height and the hook level. Hence the final size of the power house is (19x12x18) m.

VII. CONCLUSION

India is rich in water sources still we are facing power shortages daily; this is not actually due to the lack of water but due to insufficient knowledge or non-implementation of new technologies. The idea that we had presented here can ultimately lead to the usage of such wasted water to decrease power problems. The results that we had concluded are:

•The feasibility study was carried out in the 8 dams of Idukki district
•It was found that the Kallarkutty and Ponmudi dams had the sufficient spill and head for installation of a micro hydel power plant at the dam toe. Based on the spill, the turbine to be installed was selected.
•The prime components of the power plant were designed.
•It was thus concluded that the project has got future scope in many more such dams and installation of such projects can give significant contributions towards meeting the current energy demand

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