OPTIMUM PLANNING OF MEDIUM HEAD HYDRO POWER PROJECTS

Ph. D. THESIS

By

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ROORKEE – 247 667 (INDIA)
DECEMBER, 2015

ABSTRACT

The energy demand of developing country is increasing day by day. To meet the growing energy demand, hydro power provides the reliable source of energy. Major demand of energy all over world in general and India in particular, is met by fossil fuel based power plants contributing to environmental related problems. Due to depleting sources of fossil fuels and growing environment concerns, the focus has shifted towards renewable source of energy which comprises of hydro power as major source of energy. India has total installed capacity of electricity power as 280 GW (15%). Out of which, 195 GW (70 %) is generated through thermal sources, 42 GW from hydropower resources and 37 GW (13%) is through renewable energy resources. Even though, total hydro potential in India is 148 GW, only 15.2% electricity supply is met using the hydropower and only 13 GW capacity is under construction. Thus, large portion of hydro power is still to be developed. In spite of various legal, regulatory, policy and other reforms, India is facing the energy shortage and peak shortage of 2.1% and 2.6% respectively and 33% of population in India, especially in rural areas, is not having access to electricity.

Most of the hydro power projects are located in hilly area. Only small percentage of hydro energy is available in the plain area on the existing water resources structures like barrages, irrigation canal falls, small dams etc. The hydro power projects are classified broadly as storage based and run of river type. The storage based projects require construction of dams submerging the upstream area while run of river projects utilise the water as available in the river by diverting or using in stream. Hydropower projects are classified by several ways. The classification based on installed capacity and working head are very common and used extensively. In India, hydro projects above 25 MW capacity are classified as medium and large and below 25 MW small. The classification of head and installed capacity vary widely from country to country. For the present study, low head is taken below 30 m, medium head from 30 to 300 m and high head above 300 m.

For harnessing the energy from hydro power projects, the selection of technology is carried out on the basis of head and discharge available at specific location. The low

head schemes are generally run of river projects located on flowing rivers, irrigation canal falls or low height dam projects. Medium head and high head schemes are generally located in hilly areas and may be run of river or storage based schemes. Literature survey reveals that most of reported studies were conducted to optimize either low head or high head Hydro Power (HP) schemes. Studies were also reported to optimize a different components of HP projects. Not much work has been reported for the optimization of medium head hydropower development. In case of low head HP schemes, due to large discharge, bigger size machines are used and contribution of electro mechanical works, in comparison of civil works, are more. For high head HP schemes, relatively small discharge is handled, thus, the size of machines is small and contribution of electro mechanical works, in comparison of civil works is less. While, in case of medium head hydro projects, the contribution of electro mechanical works and civil works are comparable.

Further, to estimate the power potential of any site, the details of head and discharge available at that site is required. The head available at any site can be obtained from the survey maps available /drawn of the area. Details of discharge are available often from government agencies but generally for bigger streams. The small or remote area streams are generally ungauged and hence discharge data for the hydropower development is not available. Hence, the present study has been carried out for optimum planning of medium head hydro power development with the following objectives:

a. Development of methodology for assessment of discharge at ungauged streams located in hilly area for hydro power development
b. Analysis of design aspects for civil works, selection of electro mechanical works and development of design correlations of these components
c. Development of methodology for optimum design of desilting tank for HP projects being critical for Himalayan areas.
d. Development of methodology for optimum design of penstock for HP projects contributing a significant cost component of civil works.
e. Development of cost correlations to estimate the cost of civil works and electro- mechanical works required for planning hydropower projects.

f. Optimum planning of hydro power layouts based on minimum generation cost using above said developed correlations of the works.

In order to achieve the above mentioned objectives, an attempt has been made to develop a methodology for the assessment of discharge of ungauged catchments using artificial neural network (ANN) for hydro power development in Himalayan region. For the study, a homogenous region in State of Himachal Pradesh of Indian Himalayan Region has been selected where catchments are fed by glacier, snow and rain. The parametric study has been carried to determine the optimum set of input data by training the network with different combinations of input parameters and determining the set having minimum error in prediction of discharge. The predicted discharge values have been compared with the discharge estimated by other methods and observed that discharge obtained by ANN is having minimum error of prediction.

Correlations for optimum design for the civil components of medium head projects have been developed. These components comprises of diversion structure (weir, barrage or dam), intake channel, desilting tank, head race conduit (pipe/tunnel/ channel), forebay tank, spillway, penstock, power house building and tail race channel. New approaches have been developed for the optimum design of desilting tank and penstock.

For the optimum design of settling basins, two new methods have been developed incorporating the effect of upstream and downstream transition portions. The first method is based on minimum vetted surface area of desilting tank. The second method is based on efficiency curves developed in this study for assessing silt removal efficiency of settling tanks. Both methods are found to provide similar results. The second method has been recommended for optimum design of desilting tank as it provides the design in first trial itself. The settling tanks for some hydropower projects have been designed using method recommended in this study and compared with existing desilting basins (design based on the available methods). It is observed that by adopting the newly developed method, either size of desilting tank reduces or silt removal efficiency of tank improves considerably.

For optimum design of penstock, a new approach has been developed under this study. The penstocks of hydro electric projects are generally designed based on minimizing the annual cost of penstock considering only friction loss in the pipe. In this new approach, total head loss comprising of not only friction loss but also other losses have been considered for minimizing the annual cost of penstock. The newly developed relation has been used for 21 hydro power projects with capacity ranging from 25 kW to 60 MW to find out the optimum diameter and compared with results obtained as per existing practice. By providing penstock diameter as per new method, though the penstock diameter has increased in the range of 3.31 to 14.31%, but resulted in the net saving in annual cost of penstock. The savings have been obtained from 0.613 % to 9.714% of penstock cost of the projects.

The design and sizing of the various components of civil structure works have been carried out based on the design guidelines and curves. The size of turbine is governed by runner diameter and specific speed which are based on the head and capacity of the units. The types of turbines considered under the medium head are Francis and Pelton. Based on technical feasibility, different alternatives of civil works and generating equipment considered for optimization are given below:

Diversion Structure	:	Trench Weir, Barrages and dam
Water conductor System	:	Channel, Steel Pipe, Tunnel
Settling Basin	:	with or without settling tank
Turbine	:	Francis, Pelton
Generator	:	Induction, Synchronous

For planning of hydropower projects, cost of the projects is evaluated to determine the techno-economic viability for taking investment decision. To compute the cost of civil and electro mechanical works, the cost curves and correlations based on the cost estimates of various projects with different capacity being executed in the country have been developed. Financial analysis has been carried out for cost optimization based on installation cost and generation cost.

To implement the methodology developed a stretch of a hilly glacier, snow and rain fed stream in the Himalayan region has been used to plan hydropower projects in cascade. Different layouts have been studied each comprising of one to five projects with installed capacity ranging from 70 to 110 MW and head varying from 98 to 706 m. It has been found that the layout having two reservoirs based projects (50 and 60 MW installed capacity) can generate maximum of 825 million units (MU) but at unit generation cost of INR 22.36 whereas the alternate with one barrage shall generate 370 MU at unit generation cost of INR 3.33. However this alternate requires construction of a very long penstock and is difficult to construct due to social and environmental concerns and has much low electricity generation. The alternate with 5 barrages provides 512 MU at unit generation cost of INR 4.89. In view of growing needs of electricity and affordability of such cost, the alternate with 5 barrages as run of river projects is found optimum.

It is expected that the developed methods shall be helpful in predicting the discharge of ungauged basins which is one of the important basic data for developing water infrastructure projects. The methodology employed for determination of the optimum installation of projects in cascade can be used by developers, policy makers and decision takers to plan their investments in such schemes. The financers may also use these correlations for appraisal of such schemes for financing.