HYDROLOGICAL INVESTIGATIONS AND ANALYSIS FOR HYDROPOWER PROJECTS

Ph.D. THESIS

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ABSTRACT

Energy is an essential requirement that is directly related to the development, economic growth and welfare of a nation. In case of developing countries, increase in the power consumption and energy demand mirrors the increasing development rate. To meet the increased energy demand and overcome the dependability on the fossil fuel based energy sources lead to the development of renewable energy sources. Energy sources ranging from non-renewable sources such as coal, lignite, natural gas, oil, hydro and nuclear power to viable renewable sources such as wind, solar, small hydro, agricultural and domestic waste are available. Among these energy sources, hydro power plants is the most substantial one because of reliable, sustainable and emission less power generation.

India is a developing country with diversified power consumption patterns. To meet such an increasing demand for power, massive addition to the installed energy generation capacity is required. The electricity sector in India had an installed capacity of 280.33 GW as of October 2015. Non-renewable power plants constitute 87.55% of the installed capacity, while renewable power plants constitute the remaining 12.45% of total installed Capacity. Hydro power projects are generally categorized in two segments i.e. small and large hydro. In India, hydro projects up to 25 MW station capacities have been categorized as small hydro power (SHP) projects and projects more than 25MW are considered as large hydro.

Even India has vast hydro power potential, though it is difficult to harness the available potential. The main reason behind this problem is the availability of the stream flow discharge data. The available data are not enough for planning; as water resources project planning requires about 30 years of discharge data or most of the hydropower sites are remotely located and ungauged.

To solve the problem related to the length of the data availability, stream flow prediction approach is helpful. Prediction models can be applied to the observed data to extend the length of the discharge time series. Stream flow

forecasting is a challenging task due to the complexity of hydrological systems. Improving the quality of stream flow forecasting has always been an important task for researchers and hydrologic forecasters. There is no single stream flow forecasting method that provides optimum forecast results under all circumstances. Major goal of prediction models is to generate synthetic stream flow sequences that are statistically similar to the observed stream flow sequences. The second problem with the development of hydropower project is the unavailability of the stream flow data or ungauged catchment.

The problem related to the availability of the insufficient stream flow data can be solved by using efficient prediction model as found in the literature. Another problem for ungauged sites can be figured out by regionalization of flow duration curve. Literature review reveals that prediction and regionalization related approach show some drawbacks. It is found that lot of earlier studies were conducted on the prediction of stream flow, however less work is reported for the application of these prediction models for estimation of hydropower potential. In case of ungauged sites, earlier studies suggested application of regionalization of flow duration curve, however the uncertainty associated with the parameters was rarely considered. Based on literature survey, the following gaps are identified.

(i) There is lack of application of prediction models for estimation of hydropower potential, where sufficient length of data is not available. For successful and sustainable power potential study, sufficient amount of data is required.
(ii) Application of regionalized flow duration curve methods to estimate discharge at the ungauged sites for hydropower potential analysis is rarely employed in the earlier research.
(iii) Regionalized models lack accuracy, because of the uncertainty associated with the parameters used in the regionalization process. Very few researchers worked on the uncertainty analysis of the regionalized flow duration curve.

India has large hydropower potential, as there are many river basins. It has been found that one of the river basin in India i.e. Narmada river basin has large potential for large and small hydro power projects. The major obstacle in hydropower development is the availability of discharge data for the identified potential sites in this basin. Based on the literature review and the gaps identified, it is found that lot of research has been conducted in the area of prediction in ungauged basins (PUBS) however, the uncertainties associated with these methods is seldom talked about. To harness the available hydropower potential, prediction analysis, regionalization of flow duration curve (FDC) and uncertainty analysis for regionalized flow duration curve development is required. Keeping this in view, the present study is carried out with the following objectives:

(i) Analysis to find out appropriate stream flow prediction model in the selected study area.

(ii) Development of the regional flow duration model to estimate stream flow at ungauged sites.

(iii) Testing the performance of developed regionalized flow duration models.

(iv) Evaluation of the reliability of developed regional flow duration curve (RFDC) for its application to un-gauged sites.

(v) Estimation of hydropower potential by using developed regionalized FDC at ungauged sites.

In order to achieve the above mentioned objectives, an attempt has been made to develop a methodology of hydrological analysis for hydropower development in the Narmada river basin. This work is divided broadly in to three parts. In the first part, analysis of the discharge data for normality condition has been carried out. The best fit ARIMA model selection criteria is Schwarz criterion (SBC) and the affirmation of the selection of parsimonious is carried out by residuals analysis. Residuals of the selected ARIMA model are tested for independence, homoscedacity and normality. Prediction from ANN approach requires Max-Min transformation, so data are fed into the model in the form of transformed series. Training, testing and validation ratio is found as 50:25:25 by trial and error method. Next prediction model applied is X-12-ARIMA i.e. seasonalized adjustment prior to the application of ARIMA. Another prediction model that applied is Thomas-Fiering model i.e. regression based model. The best prediction model is selected on the basis of performance criteria. These performance criteria are root mean square error (RMSE), coefficient of determination (R^2) and Nash-Sutcliffe Efficiency (NES).

In the second stage, regionalization of flow duration curve is carried out. Three regionalization models i.e. dimensionless flow estimation model, normal reduce variate flow estimation model and multiple linear regression model are applied. The performances of the selected models are estimated on the basis of percentage absolute error. Initially the models are tested for the same sites which were used for the model development. The results are found satisfactory. Further, these models were validated for three other sites which were not used in the model development and the results were found satisfactory. The model validation process is conducted to make sure that regional flow duration curve models are working in good order for the spatially different sites.

After the successful validation, the next stage is the uncertainty analysis. As this model is developed for the ungauged sites, there might be some uncertainties associated in the developed regional models. Majorly these uncertainties are related with the parameters selected for development of regionalized flow duration models. To estimate these uncertainties, Bootstrap resampling method is employed. According to the validation results and uncertainty analysis, dimensionless flow estimation method is found successful for application. Using this method, hydropower potential is estimated at four ungauged sites. From the above study, following conclusions are drawn.

(i) ARIMA, X-12-ARIMA, ANN and Thomas-Fiering models are analysed for stream flow prediction and found that the performance of the ANN is the best and less erroneous for stream flow estimation at higher dependable flow and can be used for ungauged sites.

(ii) For development of regionalized flow duration model, three models were analysed. Method 1: Dimensionless flow estimation model and Method 3: Stepwise multiple linear regression model has been found better than the other model i.e. Method 2: normal reduce variate flow estimation model based on the highest performance and the least error. Hydropower potential estimation shows that Method 1 has error from 0.05% to 80.10%, Method 2 has errors from 2.42% to 421.47% and Method 3 has error from 0.01% to 14.65%.

(iii) Uncertainties of the above mentioned three models were estimated using Bootstrap resampling method. Performance of the dimensionless flow estimation method is lying in the range of 0.1%-33% and stepwise linear regression methods performance is lying in the range of 0.1%-24%, so these models are found efficient; while the normal reduce variate method that has error in the range of 33%-99%, thus not found efficient.

(iv) Uncertainty associated with the hydropower potential estimation ranges from 2%-25% for Method 1, 85%-99% for Method 2 and for Method 3, the uncertainty is lying in the range of 1% to 8%. Thus uncertainty is found more by using Method 2 based on the data of seven sites used for model development. Further, uncertainty analysis was carried out by using 3 different sites which were not used for model development and found that the error for Method-1 is 1.35% to 56.8%, for Method-2 is 1.20% to 147.80% and for Method-3 is 24.06% to 94.66%. Thus Method-1 Dimensionless flow estimation model is found appropriate for development of regionalized flow duration model.

(v) The developed regionalized flow duration model was used for estimation of hydropower potential of four sites in the Narmada basin.

For assessment of power potential on ungauged hydropower sites, the prediction of stream flow is essential. The regional flow duration model developed for the Narmada river basin can be used by the hydropower developers for estimation of hydropower potential in this area. The methodology developed for flow prediction can be used for other river basins by the hydropower developers.