International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 4 Ver. IV|| April 2018 || PP 22-25

Analysis of Principles of Determining Hydrological Characteristics for the Design Cross-Section of the Hydropower Plant

Paata Jokhadze[1], Aleksander Jokhadze[1]
[1](*Faculty of Informatics and Control Systems, Georgian Technical University, Tbilisi, Georgia)*
Corresponding author; Paata Jokhadze

Abstract: *The article reviews the problems associated with the principles of determining hydrological characteristics for the cross-section of water intake structures of Hydropower Plant (HPP) projects in Georgia. The case study of the projects was to determine the causes of a discrepancies between the actual values and the design values of the HPP parameters (Design Flow, Installed Capacity, Installed Capacity Factor, Average Annual Energy Production) of already implemented new HPP projects. Due to these discrepancies, the Payback Period of the project increases, the actual value of the Installed Capacity Factor (ICF) is less than its design value. Studies of existing projects have shown that the reason for this are those mistakes that were made in determining the main hydrological characteristics of the river for the project cross-section of the HPP.*
Keywords – *Data Sampling, Design Flow, Entire Assembly, Flow Duration Curve (FDC), HPP, Hydrological Data Time Series, Installed Capacity Factor (ICF), Run-of-River HPPs, Statistical Homogeneity.*

Date of Submission: 05-03-2018 Date of acceptance: 20-04-2018

I. Introduction

It is obvious that in most cases there is no initial hydrological data for the cross-section of the water intake structure of HPP, since it is unlikely that the location of the water intake structure and the existing Hydrometric Observation Station will be the same. For this reason, it is necessary to perform the conversion of the initial hydrological data from the selected Hydrometric Observation Station for the cross-section of the water intake structure of HPP. It should be noted that the validity of the data, obtained as a result of the conversion, mainly depends on the correct choice of the Hydrometric Observation Station, which must be selected, following a set of certain rules that are given in the normative documents. But this is only one of the factors ensuring the validity of the data during conversion, it is very important to apply relatively accurate conversion methods.

Studies of prospective HPP projects showed that designers made incorrect decisions when choosing conversion methods, the direct evidence of this is the revealed discrepancy between the actual values of parameters and the design values of parameters (Installed Capacity Factor, Average Annual Energy Production) of already implemented HPP projects.

II. Hydrological Data Conversion Methods

There are several methods for converting hydrological data, but they are not universal, and the application of each of them is possible only in certain cases. The basis of all methods is the principle of the ratio of drainage areas. Studies of HPP projects have shown that designers often used the following formula:

$$Q_{ungaged} = Q_{gaged} \cdot \frac{A_{ungaged}}{A_{gaged}} \tag{1}$$

Where: $Q_{ungaged}$ – Flow at the location of the water intake structure of HPP;
Q_{gaged} – Flow at the location of the selected hydrometric observation station;
$A_{ungaged}$ – Drainage area of the river at the location of the water intake structure;
A_{gaged} – Drainage area of the river at the location of the selected hydrometric observation station.

This formula is valid only in cases where the river flow rate (Flow Modulus) for both locations is equal, i.e. is a particular case that rarely occurs. It is easy to prove mathematically by the formulas for determination of flow rate:

$$q_{ungaged} = \frac{10^3 \cdot Q_{ungaged}}{A_{ungaged}} \tag{2}$$

$$q_{gaged} = \frac{10^3 \cdot Q_{gaged}}{A_{gaged}} \tag{3}$$

Where: $q_{ungaged}$ – Flow rate (liter/sec·km^2) at the location of the water intake structure of HPP;
q_{gaged} – Flow rate (liter/sec·km^2) at the location of the selected Hydrometric Observation Station.

If we assume that

$$q_{ungaged} = q_{gaged} \quad (4)$$

then

$$\frac{Q_{ungaged}}{A_{ugaged}} = \frac{Q_{gaged}}{A_{gaged}}$$

from last equation we obtain equation (1).

If for the particular case equation (4) is invalid, then the use of formula (1) is incorrect, since the conversion of hydrological data occurs with errors. For example: if the selected Hydrometric Observation Station is located lower in level than the water intake structure of the HPP, then the resulting values of the conversion will be less than the expected values, if the selected Hydrometric Observation Station is located higher in level than the water intake structure of the HPP, then the resulting conversion will be greater than expected values. This can be easily proved mathematically by considering the ratio of equations (2) and (3):

$$\frac{q_{ungaged}}{q_{gaged}} = \frac{Q_{ungaged}}{Q_{gaged}} \cdot \frac{A_{gaged}}{A_{ungaged}}$$

from which it follows that

$$Q_{ungaged} = Q_{geged} \cdot \frac{A_{ungaged}}{A_{gaged}} \cdot \frac{q_{ungaged}}{q_{gaged}} \quad (5)$$

As a rule, with a decrease in the average height of the catchment area, the flow rate decreases, an example of the dependence of the average height of the catchment on the flow rate for the Paravani River is given in Figure 1.

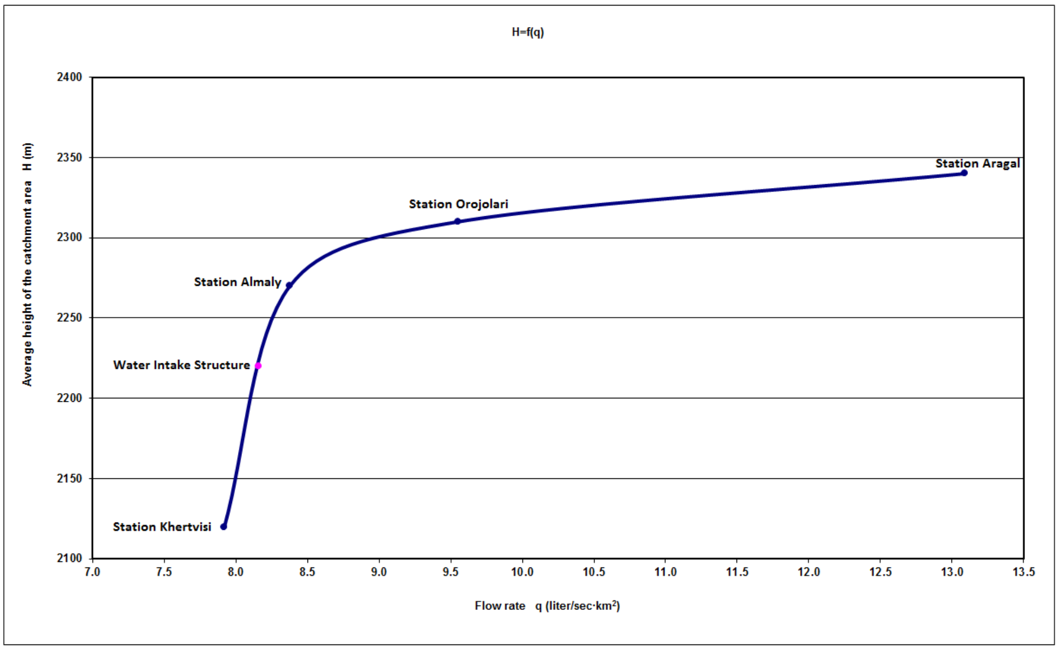

Fig. 1. Dependence of the average height of the catchment on the flow rate for the Paravani River

Thus, as can be seen from Fig. 1

$$\frac{q_{ungaged}}{q_{gaged}} > 1$$

if the selected Hydrometric Observation Station is located lower in level than the water intake structure of the HPP and

$$\frac{q_{ungaged}}{q_{gaged}} < 1$$

if the selected Hydrometric Observation Station is located higher in level than the water intake structure of the HPP.

The formula (5) is more precise and invariant with respect to the location of the selected Hydrometric Observation Station. Studies of prospective HPP projects showed that designers did not use this formula, which explains the discrepancy between the actual values and the calculated values of the HPP parameters.

Another method for converting hydrological data, which is often used in HPP projects in Georgia, is based on Dicken's empirical formula

$$Q_{ungaged} = Q_{gaged} \cdot \left(\frac{A_{ungaged}}{A_{gaged}}\right)^{n} \tag{6}$$

where n depend upon various factors, like Size, Shape, Location and Topography of Catchment Intensity, etc. It should be noted that, normally, the method is applied only if the drainage areas ratio is between 0.5 and 1.5. Despite these conditions, some designers in Georgia for all rivers take the value of n equal to 3/4 and ignore the limitation of the ratio of drainage areas, this leads to significant errors during the conversion of hydrological data, due to which the design parameters of the HPP do not correspond to the actual values.

III. Principles for Determining the Design Flow of HPP

Determining the design flow of HPP is one of the most important processes, especially for run-of-river HPPs. From the correct implementation of this process depends the reliability of such parameters of HPP as installed capacity, average annual energy production, the installed capacity factor, the cost of HPP project. The profitability of the project depends significantly on these parameters.

Unfortunately, in this part of the designing, we found incorrect approaches by the designers to determining the Design Flow of HPP. Basically, this is expressed in the identical approaches for run-of-river HPPs and for HPPs with reservoirs for seasonal regulation of discharges. The principle of operation of these two types of HPPs radically differ from each other and require different approaches during the selection of Design Flow.

In the case of run-of-river HPPs, excess water during periods of flood and residual water, the flow of which is less than the Minimum Technical Flow of the turbine for which the turbine cannot be started, continues to flow into the riverway bypassing the HPP, thus their potential is not used in energy production, and this potential is practically lost. For HPPs with a reservoir for seasonal regulation of discharges, this water accumulates in the reservoir and thus it is possible to use the potential of accumulated water as necessary, the potential of the river in such cases is used as much as possible, losses due to downtime of hydroelectric generating sets are automatically reduced to a minimum. During the selection of the Design Flow for these two types of HPPs, designers must solve completely different tasks. For HPPs with a reservoir, the main task is to optimize the discharge of water accumulated in the reservoir during season of regulation. In this case, the value of the Design Flow of the HPP depends mainly on the volume of the reservoir and can be increased in accordance with the volume of the reservoir. In any case, this value of the Design Flow is relatively greater than its value for run-of-river HPPs whose water intake structure is located on the same river and in the same cross-section of river.

The selection of the Design Flow should be carried out from the flow duration curve (FDC) of the available flows (available or net flows = flow of river - Environmental Flow), but not from FDC of river flows (see Fig. 2). Some designers make a mistake in this part of the design, as a result, the value of the selected Design Flow of HPP is greater than 10% of the average multi-year flow (this is the minimum rate of Environmental Flow in Georgia).

For run-of-river HPP projects the optimum Design Flow is usually close to the flow that is equal or exceeded about 30% of the time [1], but not less than 22%. This means that, to ensure profitability of the run-of-river HPP, it must operate at full capacity for a period of 110 days a year, but not less than 80 days (see Fig. 2).

For the HPP projects with a reservoir, the optimum Design Flow is usually close to the flow that is equal or exceeded about 18% of the time, but not less than 15%. This means that the HPP should operate at full capacity only at the flow of the river for 65 days a year, but not less than 55 days (see Fig. 2), the rest of the time, the HPP receives additional water from the reservoir.

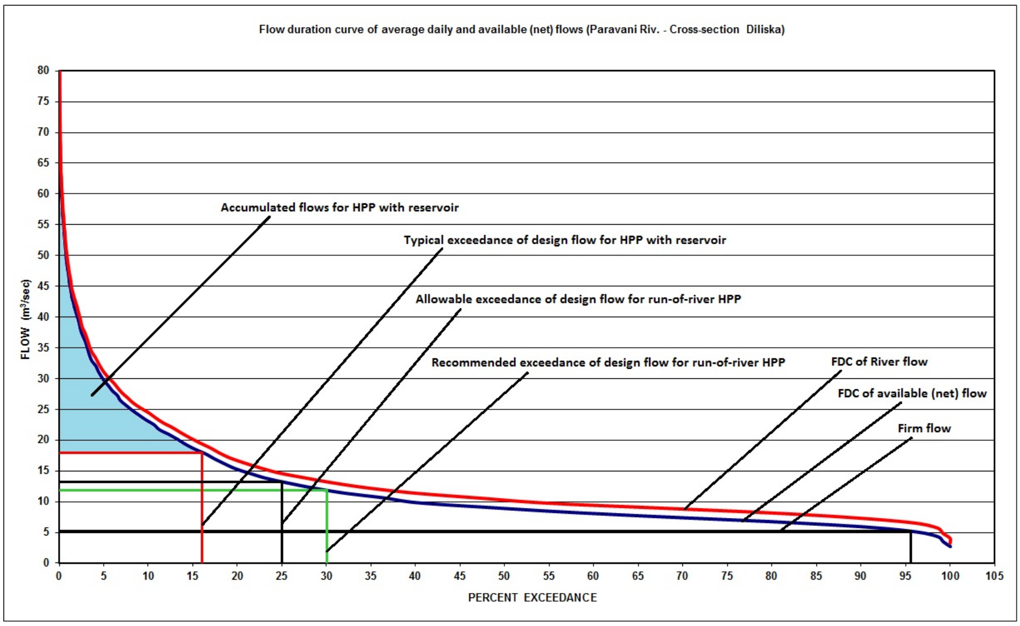

Fig. 2. Flow Duration Curve of average daily and available (net) flows (Paravani Riv. - Cross-section Diliska)

As can be seen from figure 2, the Design Flow of HPPs with the reservoir is much greater than the allowable value of the Design Flow for run-of-river HPPs, therefore, the same approaches for selecting the Design Flow for these two types of HPPs are unacceptable.

IV. Conclusion

In presented article, we discussed the mistakes made by some designers that we found in the part of determination of hydrological characteristics for the cross-section of water intake structures of HPP projects in Georgia. Also, in the part of determining the Design Flow of HPPs. Unfortunately, we should note that these mistakes were made not only by the designers of Georgian companies, but also by the designers of some well-known European companies, the reason for this is mainly the created image of the companies and the excessive self-confidence of the designers of these companies. On the other hand, the reason for this is the lack of information.

References

[1]. Retscreen®International, Clean Energy Decision Support Centre *Retscreen® Software Online Manual* (Minister Of Natural Resources Canada 1997-2004

Paata Jokhadze "Analysis of Principles of Determining Hydrological Characteristics for the Design Cross-Section of the Hydropower Plant" International Journal of Engineering Science Invention (IJESI), vol. 07, no. 04, 2018, pp 27-30