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COMPARATIVE ANALYSIS OF THE HYDROPOWER CHARACTERISTICS OF A SMALL HYDROPOWER PLANT

Attila OLAH [1], Albert Titus CONSTANTIN [1], Marie-Alice GHIȚESCU [1]

Abstract: The paper presents the possibility of building a micro-hydro power plant on a given site, a different variant compared to the actually realized/designed situation. The work thus analyses the hydropower characteristics in comparison for the two situations. In the end, the conclusions drawn, taking into account the proper functioning of the existing small hydropower plant, lead to the development of thinking in order to realize MHC's, mountain streams with low multiannual average flows.

Keywords: small hydropower plant, hydropower optimization, fish passes

1. GENERAL DATA

The hydropower development designed on the Nirajul Mare river is composed of a derivation-type Small Hydropower Plant and is carried out along the Nirajul Mare river on a sector of approx. 6.1 km long, between elevations 934maSL - 655maSL (with a total gross head of 279 m) includes only one (1) small hydropower plant, having only one (1) catchment.

The purpose of the investment is to capitalize the hydropower potential of the Nirajul Mare river, county. Mureş, on the water course sector from the confluence of Nirajul Mare river with Tigla watercourse, up to the confluence with Little Niraj watercourse.

The main characteristics of the hydropower development are:

- Water catchment PN1
- Water supply culvert PN1-MHC N2
- Small Hydropower Plant MHC N2

Constructive description of water catchment PN1:

Water intake PN1 is located on Nirajul Mare river, downstream of confluence with Ţigla stream, at elevation level of 934.50maSL. The area of Nirajul Mare River Basin at this elevation is 16.8km^2, the multiannual average flow of 0.383 m^3/s, the baseline flow 0.08 m^3/s, $Q_{5\%}$ = 36 m^3/s and $Q_{1\%}$ = 67 m^3/s, according to the hydrological study developed by the NATIONAL INSTITUTE OF HYDROLOGY AND WATER MANAGEMENT.

The Nirajul Mare River presents a longitudinal profile of relative balance, the average slope being 1.2%, the sinuosity coefficient 1.36 and the average altitude is 520 maSL.

The water intake was dimensioned for the transit of an installed flow of 0.75 m^3/s, taking into account the multiannual average flow. It develops upstream reservoir with the role of loading/compensating basin (V=91 m^3).

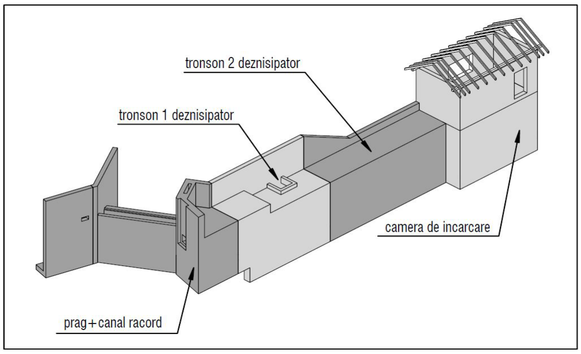

Figure 1. Water intake PN1

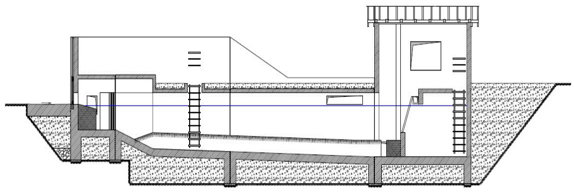

Figure 2. Water Intake cross-section PN1

Water supply culvert connects the catchment and the hydropower plant, it is proposed to be under the existing road or in the river's floodplain.

Table 1.

Reach	Diameter (mm)	Length (m)
Water supply culvert PN1-MHC N2	700 mm/ PAFSIN/underground	6100 m

Small Hydropower Plant MHC N2 characteristics:

The hydropower plant MHC N2 is located on the right bank of Nirajul Mare river, in a non-flooding area at the flow rate with a 5% probability of appearance on the water course, having an elevation of ±0.00 = 655.00 maSL. The turbinated flow is 0,75 m^3/s, the are of the catchment is about 39 km^2, and the design and verification flows are $Q_{5\%}$ =55 m^3/s and $Q_{1\%}$ = 101 m^3/s, according to the hydrological study developed by the National Institute of Hydrology and Water Management.

[1] Politehnica University of Timisoara, Hydrotechnical Department, Spiru Haret Street, no. 1A, 300022, Timişoara, Romania, attila.olah@student.upt.ro, albert.constantin@upt.ro

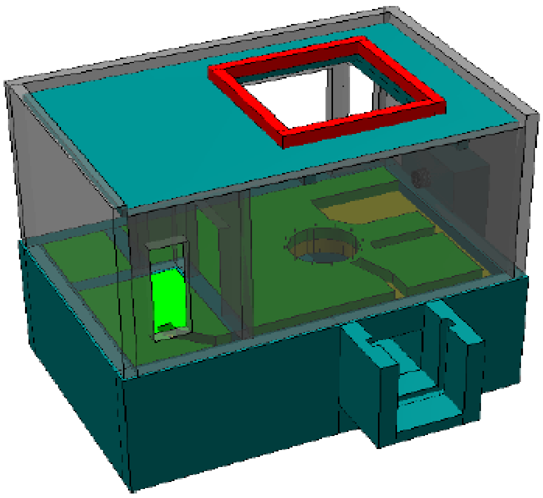

Figure 3. Small Hydropower Plant MHC N2.

Table 2.

Installed flow	No. of turbine	Type	Installe d power	Energy production
(m^3/s)			KW	MWh
0.750	1	Pelton	1582	4030

Flow measurement:

The turbinated flows produced by MHC N2 are monitored by mounting a flow meter on the supply pipe of MHC N2. The servitude flow is highlighted and monitored with the help of an ultrasonic flow meter mounted at the entrance to the by-pass channel.

2. COMPARATIVE HYDROENERGY PARAMETRES

2.1 SMALL HYDROPOWER PLANT WITH ONE HEAD

The hydropower parameters are analysed for the existing situation in the field, finally determining the power installed at the generator, respectively the annual electricity.

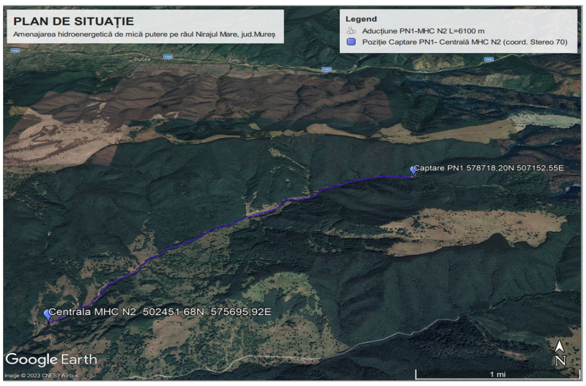

Figure 4. Culvert route: from intake to hydropower plant

Figure 5 shows how to choose the turbine for the existing situation, dictated by the head and installed flow. It is found that the turbine chosen must be a PELTON turbine.

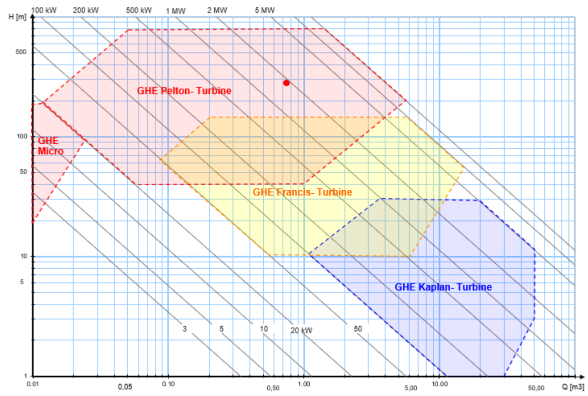

Figure 5. Turbine Type Selection MHC N2.

Taking into account the hydrological data of the location, respectively the surface of the reception catchment, the cumulative flow curve is drawn (figure 6.), respectively the multiannual average flow is determined, and further used to establish the necessary (installed) flow:

$$Q_i = k_i * Q_m \qquad (2.1)$$

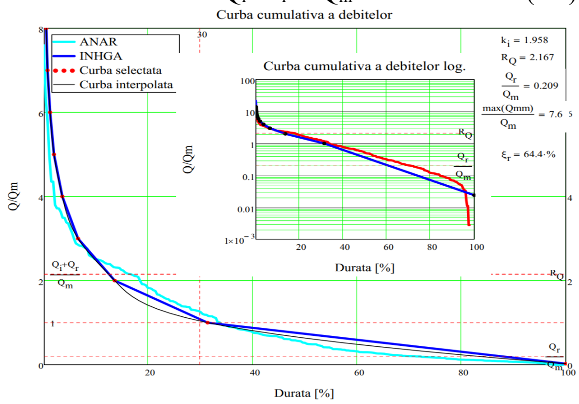

Figure 6. Cumulative flow rate curve

Taking into account these data, by imposing a 700 mm diameter intake pipe, the longitudinal pressure losses are obtained, and finally the net head at the turbine (figure 7) and, depending on this, the net power. (figure 8)

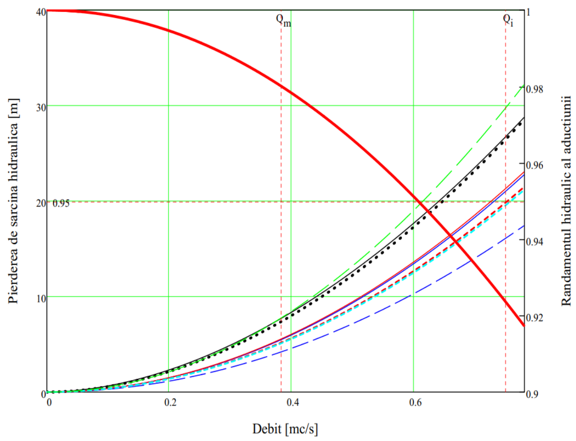

Figure 7. Hydraulic head losses

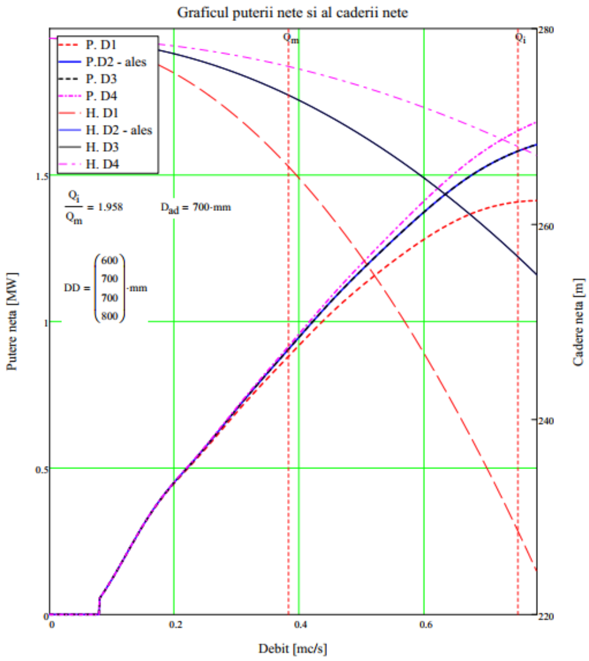

Figure 8. Net power as a function of net head

Finally, the hydropower characteristics of the MHC for this version are:

1582 kW – power at the gernerator

5121 MWh – annual average energy

1256334 EURO – total cost of the hydropower installation, 4 years and 3 months – investment recovery time.

2.2 SMALL HYDROPOWER PLANT WITH TWO HEADS

Dividing the initial route into two subdivisions with a first head of 200m, respectively the second head of 79m, leads to the imposition of a PELTON-type turbine at the first plant, respectively a FRANCIS turbine at the second plant (figure 10).

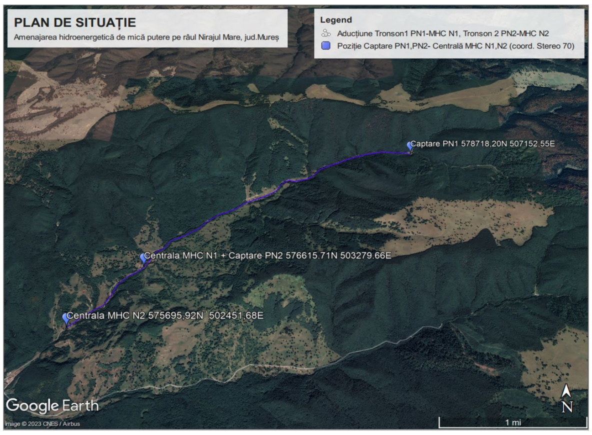

Figure 9. Culvert MHC route, with two heads

Under the conditions of the same existing hydrological data at the location, with the observation that at the second intake, in addition to the engineered flow from the first section, we also have the input of the hydrographic basin between the two intakes, at the second plant we will have an installed flow of 1.002 m^3/s.

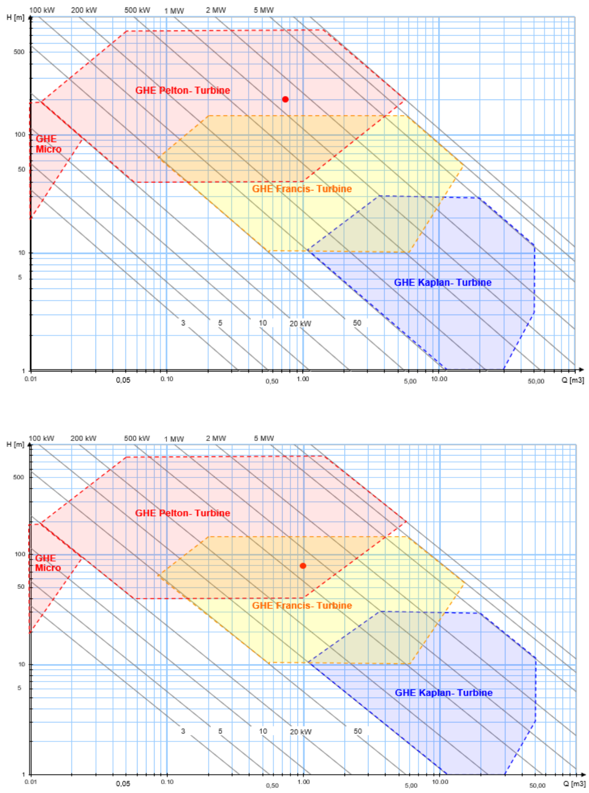

Figure 10. Turbine Type Selection for 2 hydropower plants

The net head is calculated on each section separately, and by summing up the longitudinal load losses, on the two sections we find that they are 25.48m, in the initial situation the load losses are 21.36m.

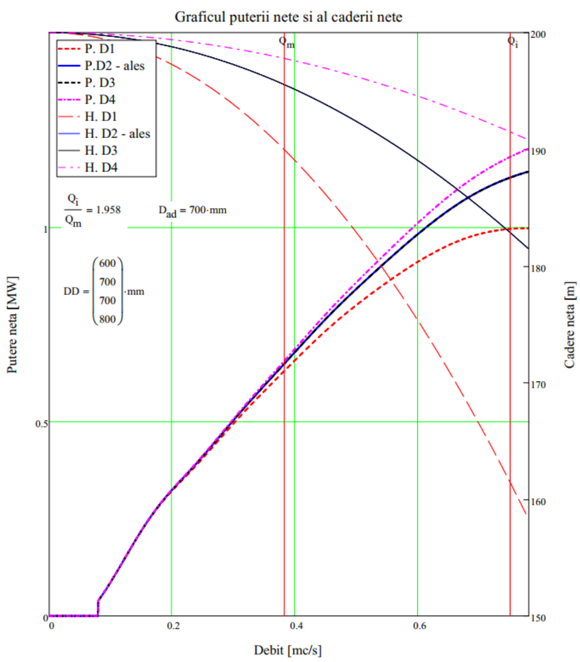

Figure 11. Net power as a function of head across reach 1

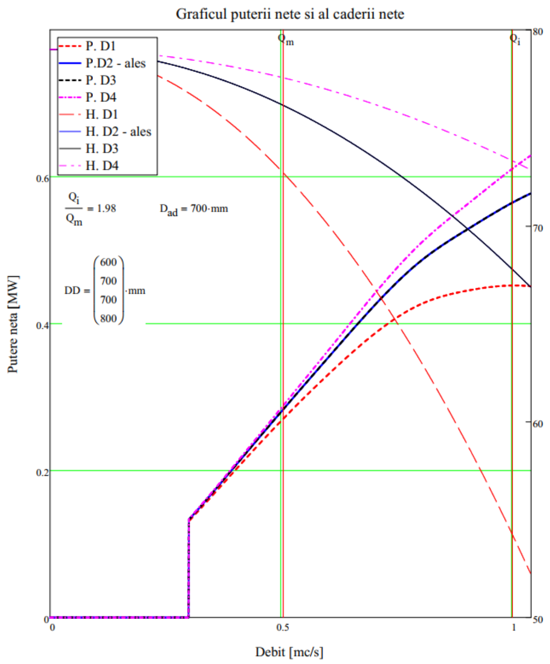

Figure 12. Net power as a function of head across reach 2

Finally, the hydropower characteristics of the MHC for this version are:

1692 kW – power at the generator

5366 MWh – annual average energy

1798968 EURO – total cost of the hydropower installation, 5 years and 4 months – investment recovery time.

3. FLOW TRANSITION ANALYSIS THROUGH FISH PASSAGE

The operation of the MHC is conditional on ensuring the easement flow on the water course, between the catchment and the hydropower plant. The flow recorded by the fish passage is analysed from the exploitation data, in two significant calendar months, situations that can be frequently encountered in practice: February or June.

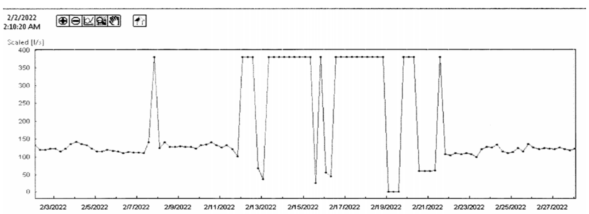

Figure 13. Flow through the fish passage: February 2022

From the graph with the flow through the fish ladder related to February 2022, it is found that in four days (February 13, 15, 16, 19) the easement flow condition downstream of the intake threshold is not met (Qs = 80 l/s), that is, on many days of February, a flow through the fish ladder greater than Qs = 80 l/s (11 days) is registered. Similarly corresponding to June 2022, it was found that the permanent servitude flow downstream of the catchment is ensured (Qs= 80 l/s), this value being even exceeded by registering higher values: between 120 - 160 l/s.

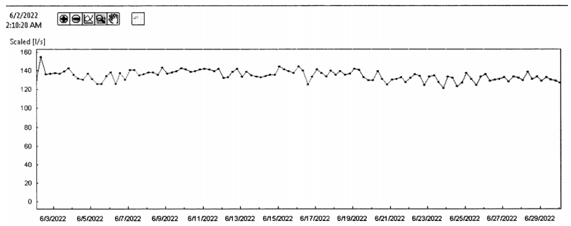

Figure 14. Flow through the fish passage: June 2022

The two representations in figure 13-14 exemplify the existing situations on the mountain watercourses, where in certain periods of the year, by arranging the catchment thresholds correlated with the actual hydrological situation of the location area, we have ensured the ecological flow for the survival of the fauna and aquatic ichthyofauna, and not in other periods.

4. CONCLUSIONS

It is found that in option 1, the existing one, is obtained an installed power at the generator of P = 1582 kW, compared to option 2, with two hydropower plants with two different heads, where an installed power of P = 1692 kW is obtained. At the same time, the annual energy produced in S.E.N. is 5366 MWh in option 1, compared to 5121 MWh according to option 2.

As an explanation of the energy surplus, the 2nd option with two power plants capitalizes on a larger hydrographic basin area for PN2 intake, by arranging the PN2 intake, immediately downstream of the MHC N1 power plant. The river basin input is transposed through an installed flow higher than that of the second plant, which is also the reason why the installed power becomes higher in option 2 than in option 1.

The advantage of option 2, with two reaches, is the possibility of obtaining electricity, when one of the plants is stopped for maintenance (overhaul), while the other is still working. In option 1, case of a single failure with a single MHC power plant, if it is operated for maintenance, no electricity is produced at all during that period.

As a disadvantage, due to the need to build two hydropower plant buildings (option2), compared to a single hydropower plant (option1), the investment costs are higher in option 2 (1,798,968 Euro) than in option 1 (1,256,334 Euro), which also leads to an increase in the investment recovery time (5 years and 4 months - against - 4 years and 3 months)

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