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Case Report

Technical/Economic-Environmental Comparison of the Exploitation of Part of the Hydro-Potential of the Mura River in Slovenia

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Annotation

Comparison between classic and alternative exploitation of hydro-potential on a section of the Mura River in Slovenia.

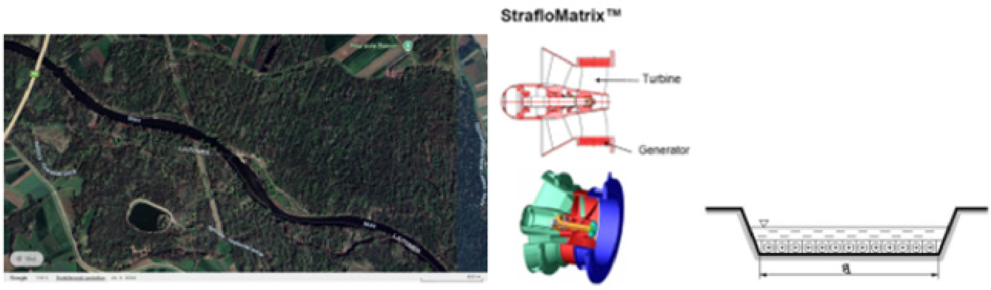
Keywords: Hydro energy; Kinetic turbines

Introduction

In Slovenia, the Mura River is the second most significant river potential. Therefore, the energy exploitation of the river is interesting because, in the next medium-term period, Slovenia must meet the requirements to reduce CO_2 emissions and increase the production of electricity from renewable energy sources, as well as reduce production from fossil fuels (from thermal power plants). The Mura River basin is located in the ecologically protected Natura 2000 area, which limits construction or setting up the necessary facilities on the riverbed for energy use. Therefore, we have set the goal of this article to evaluate an alternative energy use possibility for the Mura River, which is acceptable for the restrictions of the Natura 2000 rules and the surrounding organisms. We compare this solution with the classic principle of setting up a hydroelectric power plant with full river damming on a selected riverbed section. In the evaluations, we considered the economic and environmental aspects regarding the sustainable development of the Mura River basin region.

The Case Under Consideration

The selected section (Figure 1.a) runs three kilometres downstream of the “motorway bridge” over the Mura River. The fall of the riverbed is estimated at 1.11 ‰. The average annual flow is estimated at $160\, m^3/s$. From the satellite image (Figure 1.a), we estimate the average width of the river to be 81 meters. When calculating the flow rate, we consider the Manning coefficient for a poorly maintained earthen riverbed $n = 0.034$. The estimated mean flow velocity is $1.3\, m/s$. In this case, the height of the water in the trough is $1.6\, m$, and the cross-section of the channel is $1.3\, m/s$, which is taken in a simplified trapezoidal form. In this cross-section, the available volume of water is $375{,}000\, m^3$. During the duration of the average flow of 150 days per year (3600 hours/year), the estimated production is $6\, GWh$.



a) b) c)

Figure 1: Satellite image of a selected section of the riverbed of the Mura River (a), StrafloMatrixTM display of the turbine units' implementation b) and the placement of the units in a row at the bottom of the bed, width B=81 m (c); sources (a): Google Earth and (b) ANDRITZ-Hydro.

With an alternative approach, e.g., using the Matrix system, HydroMatrix, Treck, or other systems with small kinetic turbines that could be placed in a river bed, e.g., in thirty sections ($100\,m$ between transverse sections in the direction of the length of the canal - $3000\,m$), sixty units (60) each in a section, i.e., a total of one thousand eight hundred units (1800). Due to the average low water depth ($1.6\,m$), the kinetic part of the available hydro-energy potential is mainly used. Therefore, in each section, we should achieve one-thirtieth of the available production ($6\,GWh/year$) of the selected section of the riverbed without raising the water level, i.e., $0.2\,GWh/year$, which means that we would need $56\,kW$ of installed power in each section. That means each unit should reach $0.93\,kW$ of power (one-sixtieth of $56\,kW$). The free-flow rotor wind turbine principle can be used to calculate power for axial-type turbine rotors. Here, we must consider Betz's limit, which states that a maximum of $59\,\%$ of the available kinetic energy of the river current can be used technically. At the flow velocity $v = 1.3\,m/s$, we choose the rotor diameter of the turbine unit $D = 1.35\,m$, which determines the flow area of the unit $A = 1.43\,m^2$. The theoretical power of the unit will be as follows:

$$p_{e,th} = \frac{1}{2} C_p \rho A v^3 \tag{1}$$

where C_p is the Betz limit (0.59), ρ is the density of water ($1000\,kg/m^3$), A is the flow area, and v is the flow velocity. The unit's power calculated this way is $p_{e,th} = 948\,W$ or $0{,}95\,kW$, which is 2.2% more than expected ($0.93\,kW$). Suppose we decide to place the turbine units in the form of a StrafloMatrix design, which means placing the coated rotors of the units in a row. In that case, we can expect a slightly higher power of the unit, at least 10%, or $1.05\,kW$, which is sufficient to cover the electrical losses of the electro-generator. Today's modern generators reach over $90\,\%$ efficiency.

According to the classic approach, by raising the dam water by $2\,m$, we increase the total height of the water to $3.56\,m$, and the estimated dam water volume would increase $855{,}000\,m^3$, which would enable medium production at the same duration ($150\,days/year$), too $30.6\,GWh$. To achieve this annual production, installing an axial turbine with a power of $8.5MW$ or two with a power of $4.25\,MW$ would be necessary.

Comparison of alternative vs classic layout

From an economic point of view, the alternative solution of energy exploitation of the three-kilometres section of the Mura River using the classic approach is strikingly less effective than the annual production. The classic layout requires only one or at most two aggregates (or turbine units), which means much easier installation, maintenance, and management. Furthermore, the classic layout requires the construction of a larger dam on the riverbed, which is, therefore, naturally more expensive and demanding than the alternative layouts, of which there are more (30 sections). Therefore, maintaining alternative energy utilization of energy water potential is also more demanding and expensive.

From an environmental point of view, the fact that it requires a larger concrete dam structure, which is a significant intervention in the environment, stings in the case of the classic layout. Even more so will be the fact that the flood area increases practically up to the anti-flood embankments, which in this particular case are placed eighty meters from the banks of the riverbed on both sides of the riverbed. That means that the flood area of the classic layout is three times larger compared to the alternative approach, which practically maintains the water flow within the natural riverbed. On both sides of the riverbed, protected areas of sensitive animal and plant habitat - floodplain wetlands - would be flooded. That is probably why the classic version is unacceptable for ecologists, environmental activists, and environmentalists.

Conclusion

The present comparison shows that the more environmentally acceptable layouts of structures for exploiting the hydro-potential of river flows are significantly more expensive, not in layout, but more in terms of reduced production. The profitability of alternative layouts is therefore questionable, but the price of environmental protection is one that we must pay to preserve the environment.

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