Assessment of small hydropower potential for the Olanesti River using advanced software techniques

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Abstract. The assessment of small hydropower potential for rivers is essential for the Renewable Energy Sources Directive implementation, in order to identify and analyze opportunities for new small hydropower developments. As the Water Framework Directive requirement is the non-deterioration of the status of the river water bodies, the aspects regarding the consistency of a flow regime downstream hydropower plant and the environmental objectives are important. The paper presents a case study, the Olanesti River (Romania), using software techniques dedicated to the assessment of small hydropower potential. The hydropower potential of the river was assessed considering the heads based on the Digital Terrain Model and the mean flow. In addition, the environmental flow was considered for the installed capacity assessment, in order to cope with the Water Framework Directive requirements. The harnessed hydropower potential, the optimal distance between the water intake and power plant location, their optimum positions along the river sector, installed capacity and electricity production, calculated at an average lifetime, are the outcomes of the software. The applicability of the tool might be extended on a regional scale in order to support the decision making authorities, taking into account the increasing demand for energy as well as the environmental issues.

1. Introduction
One of the major challenges for the European Union refers to how we can ensure energy security with competitive and “clean” energy taking into account the increasing global energy demand and the uncertain future regarding the access to the energy resources.

The vision of European energy policy corresponds to the concept of "sustainable development" and refers to the following:

- consumer access to energy at affordable and stable prices;
- sustainable development of production, transport and consumption of energy;
- security of energy supply;
- reducing of emissions of greenhouse gases.

The Directive 2001/77/EC of the European Parliament and Council on the promotion of electricity produced from renewable energy sources on the single energy market was the first concrete action of...
the European Union in order to achieve the objectives committed by the ratification of the Kyoto Protocol on reducing the greenhouse gas emissions.

The main directions of action of the Directive 2001/77/EC were:
- increasing the use of renewable energy within the electricity production,
- setting a target on the electricity consumption produced from renewable energy sources,
- appropriate procedures for financing the investments in renewable energy sector,
- simplification of administrative procedures on the projects implementation that harness the renewable energy sources.

In 2009, the European Commission issues the new Directive 2009/28/CE on the promotion of the use of energy from renewable sources, amended by Directive 2013/18/EU, which main objective establish that for each Member State, 20% from the total internal gross consumption of energy must be produced from renewable energy sources until 2020 [1].

The main objective must be transposed in the individual objectives for each Member State, taking into consideration the national particularities: energetic potentials, the existing level of the energy production from the renewable energy sources and the energetic mix (the RES-E rate from the total internal energy production of each Member State: hydropower, solar, wind, thermal etc.).

The national objective for Romania, according to Directive 2009/28/CE, is the following: “24% from the total internal gross consumption of energy must be produced from renewable energy sources until 2020”.

In order to implement the RES-e Directive 28/2009/EC on promotion of the use of energy from Renewable Energy Sources, the need to evaluate the hydropower potential of water courses in Romania is highlighted.

The facts that: the hydropower potential is a renewable resource, the small hydropower plants (SHP) locations generate a low environmental impact (at local scale), and the depletion of conventional energy sources at an accelerated rate, are the main prerequisites for the promotion of the SHP development.

In order to implement the RES-E Directive 28/2009/EC on promotion of the use of energy from Renewable Energy Sources one must take into account the provisions of the Water Framework Directive 60/2000/EC. In this context, a hydrological regime consistent with the achievement of the environmental objectives of the Water Framework Directive (ecological flow) should be considered downstream hydropower plant.

2. Materials and methods

The paper presents a case study, the Olanesti River (Romania), using Vapidro-Aste software technique dedicated to the assessment of small hydropower potential of a river sector, identifies the potential locations for new small hydropower plants developments and takes into consideration the environmental flow necessary for ensuring the aquatic ecosystems protection.

The VAPIDRO-ASTE software has been produced by RSE S.p.A in the frame of the SEE HYDROPOWER project, financed by the South East Europe Program and the Research Fund for the Italian Electrical System [2].

2.1. The ecological flow determination

The method to determine the ecological flow (environmental issue) was elaborated by the National Institute of Hydrology and Water Management (NIHWM) in 2015 in order to support the implementation of the Water Framework Directive 2000/60/EC in Romania and to fulfill its requirements related to water quality and quantity necessary to the aquatic ecosystem protection [3].

The Olanesti River (Figure 1) is located in the south-central part of Romania within the Olt River Basin.

The river sector analyzed to assess the harnessed hydropower potential of the Olanesti River, about 30 km length, is located upstream Vladesti Reservoir up to the river springs.
The approach of the method to determine the ecological flow is the following:
- the need for a full range of natural variability in hydrological regime for aquatic ecosystem,
- mean flow provides habitat for fish fauna,
- more water during the periods of reproducing fish.

The ecological flow is dynamic having monthly variability, one value for each month it means 12 different values/year (Figure 2). The ecological flow takes into account the natural variability of the flow regime.

The main condition of this method is that the twelve monthly values for each year must be higher than the salubrious flow ($Q_{95\%}$ - minimum monthly mean flow with 95% probability of occurrence).

In this case study on the Olanesti River, the values used for the ecological flow are the following:
- the ecological flow for dry season ($Q_{e1} = 0.26$ m$^3$/s), which was computed as a mean of the 6 monthly values for dry season;
- the ecological flow for wet season ($Q_{e2} = 0.32$ m$^3$/s), which was computed as a mean of the 6 monthly values for wet season.

Figure 1. Olanesti River – tributary of the Olt River
2.2. The technical and economical data

The technical and economical data used by Vapidro-Aste software as input data are the following:
- Digital Terrain Model (with a 30 m grid cell);
- the mean flow for the 1970-2011 period at the Olanesti-Bai Hydrometric station both for the dry season \( Q_1 = 1.292 \text{ cm/s} \) and the wet season \( Q_2 = 1.035 \text{ cm/s} \);
- the ecological flow for the dry season \( Q_{e1} = 0.26 \text{ cm/s} \) and the wet season \( Q_{e2} = 0.32 \text{ cm/s} \);
- the hydropower plant’s lifetime – 30 years;
- the total cost of the water works – 5000 Euro/kW of installed capacity [4];
- the selling price of energy – 0.0425 Euro/kWh [5];
- the selling price of the Green Certificates (GC) – 40 Euro/GC [6] and there are issued two green certificates (GC) for each MWh produced for the first 15 years of functioning according to the present law.

The economical data (the interest rate, the price of the built water works on km) and the financial data (the price of the GC, of the produced electricity, of the mechanical and electrical equipments, maintenance cost etc.) that were used as input data were obtained from the websites of the Romanian competent authorities in the specific fields of activity: ISPH Project Development [4], Romanian gas and electricity market operator [5], Romanian Energy Regulatory Authority [6]; and transformations in the measurement units and RON (Romanian coin) to Euro conversions were performed according to the Vapidro-Aste requirements.

2.3. Presentation of the Vapidro-Aste software main steps performed for the study case

The Vapidro-Aste software menu allows the user to select the appropriate method for calculus and perform the simulation in order to assess the hydropower potential of the river sector. The selected method takes into account the national regulations, climatic conditions (dry and wet seasons) and environmental issues (ecological flow).

In the present study case, the selected method from the software menu uses two multiannual mean flows for each section of calculus (hydrometric station), one value for dry season and one value for

Figure 2. The ecological flow at the Olanesti hydrometric station located on the Olanesti River
wet season, the corresponding values for the ecological flow to dry and wet season and presents the construction of a small hydropower with derivation (Figure 3).

First step after selecting the appropriate method is the ecological flow determination and entering the GIS data required by the software and then the Vapidro-Aste calculates automatically the river network associated to the interesting area.

For the next steps, the user selects the river sector where to calculate the potential hydropower production, inputs the hydrological data, the technical and economical data required by the software and in the end the model is able to determine the optimal hydropower exploitation scheme considering the financial parameters.

Therefore, the results obtained using Vapidro-Aste software consist of GIS maps, tables and graphics that can be exported in different formats for the interpretation and provide the final conclusions.

3. Results

The case study in the paper presents a simulation of the hydropower potential assessment of the Olanesti River, \( L = 41 \) km according to the Cadastral Water Atlas of Romania [8], for the river sector from the upstream of the Vladesti Reservoir to the Olanesti River springs.

The Olanesti River Basin \((S = 237 \text{ km}^2)\) is located in the south-central part of Romania within the Olt River Basin, in the North-West of the Oltenia region within the Căpățânii Mountains from the Oltenia Sub-Carpathians.

The analyzed river sector is 30 km long and the calculus is performed for the hydrological data registered at the Olanesti-Bai hydrometric station within the 1970 – 2011 period.

The results obtained using the Vapidro-Aste software for the assessment of small hydropower potential for the Olanesti River are the following:

- the installed capacity of the small hydropower plant is 978 kW;
- the electricity production computed on an yearly average functioning duration of 3900 hours/year is 3,818 MWh/year;
- the average lifetime of the small hydropower plant (SHP) is 30 years;
- GIS maps and graphical representation of:
  - the installed capacity variation on the analyzed river sector (Figures 4 - 5);
  - the electricity production variation on the analyzed river sector, computed on the average lifetime of 30 years (Figures 6 - 7);
  - the identification of the optimal locations for the water intake and the power plant (Figures 8-9).
Figure 4. The GIS map of the installed capacity variation on the Olanesti River for the analyzed river sector

Figure 5. The graphical representation of the installed capacity variation on the Olanesti River for the analyzed river sector
Figure 6. The GIS map of the electricity production variation on the Olanesti River for the analyzed river sector, computed on the average lifetime of 30 years.

Figure 7. The graphical representation of the electricity production variation on the Olanesti River for the analyzed river sector, computed on the average lifetime of 30 years.
Figure 8. The Vapidro-Aste optimization procedure on the analyzed river sector for the identification of the optimal locations of the water intake and the power plant based on installed capacity.

Figure 9. The identification of the optimal locations for the water intake and the power plant based on installed capacity on the Olanesti River for the analyzed river sector.
4. Conclusions
The hydropower potential on the Olanesti River for the analyzed river sector of about 30 km length was assessed considering the heads based on the Digital Terrain Model and the multiannual mean flow for the dry and the wet seasons. In addition, the environmental flow for the dry and the wet seasons was considered for the installed capacity assessment, in order to cope with the Water Framework Directive 60/2000/EC requirements.

The harnessed hydropower potential, the optimal distance between the water intake and power plant location, their optimum positions along the river sector, installed capacity and electricity production, calculated at an average lifetime, the cost-benefit analysis and the payback time are the outcomes of the Vapidro-Aste software and represent important specifications for potential investors.

In the presented case study, the results obtained with Vapidro-Aste revealed the maximum installed power on the analyzed river sector is 978 kW which corresponds to a distance of 4000 meters from the water intake to the power plant and for a mean head of 60-70 meters. The mean electricity production is about 3818 MWh/year and is computed for an operation time of the hydropower plant of 3900 hours/year.

In order to respect the RES-e Directive 28/2009/EC and the Water Framework Directive 60/2000/EC provisions, a periodical hydropower assessment of the rivers which includes the ecological issues is required.

The periodical assessment of the river’s hydropower potential is needed also due to the technological progress, modifications of the river flows, changes of the economical conditions, discovery of other alternative energy sources etc.

The applicability of the software might be extended on a regional scale in order to support the decision making authorities, taking into account the increasing demand for energy as well as the environmental issues.

References
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