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Turnu Magurele – Nicopole Hydropower Development for Increase Electricity Production from RES in Romania and Bulgaria

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Abstract

In the framework of EU Strategy for the Danube Region, pillar 1, Energy efficiency and renewable energy sources, is provided the elaboration of global measures plan for sustainable hydropower development of Danube River and its tributaries. Turnu Magurele – Nicopole hydropower development on the Danube River, a common Romanian and Bulgarian project, was born almost 50 years ago but is extremely actual, on the borderland between energy and social benefits and environmental issues. The paper presents this project and some considerations related to its pros and cons.

Keywords: Electricity production; Danube River, Hydropower; RES.

1. Introduction

Danube River is the second largest river of Europe, after Volga, with a length of 2860 km, flowing from an altitude of 1078 MASL toward Black Sea, crossing 10 countries [1]. Its river basin, with 800,000 km^2, covers lands from 19 countries [2].

In the upper part, the mountainous areas of the Danube basin, are located hydrotechnical works, as dams, while most navigation canals, dykes and irrigation networks concentrate on the lowlands along the central and lower Danube [3]. The building of large dike systems for flood protection started in the 16th century in Hungary; old networks of drainage and irrigation systems exist in all basins, mainly in Serbia and Romania. The first major Danube regulation works started in 1830 in Upper Austria; the first Danube hydro dam was built in 1927 at Vilshofen (lower Bavaria). Today, hydropower utilization and energy production vary substantially from country to country, the total installed capacity of hydropower plants in the Danube River Basin is 29.2 GW.

The largest hydropower development (HPD) on the Danube River is Iron Gates I Hydropower and Navigation System, located at km 943 and was designed and executed in collaboration between Romania and Serbia [4]. The construction of the Iron Gates I system began on 1964, the objective is symmetrical to the Danube axis and consists for each part of: a hydropower plant (HPP) with six Kaplan turbines, one lock and a spillway with 7 fields.

At both the HPP and the lock, over the past 15 years, refurbishment programs have been carried out which have led to an increase in the installed capacity from 175 to 194.4 MW per unit in the plant, totalizing 1166 MW and an annual electricity production of 5.24 TWh/a in the average hydrological year, which represents about 10% of the Romanian electricity production. In addition, the plant provides almost half of the Romanian technological system services.

Around 80 km downstream Iron Gates I, at km 863, is located the Iron Gates II Hydropower and Navigation System on the Danube in the Ostrovul Mare area of Romania and was also designed and executed in collaboration with Serbia. The construction of the Iron Gates II system started in 1977, the objective has a non-symmetrical configuration, the Danube being hammered into two fronts (the main one is the main Danube arm and the second one on the Gogosu arm). The objective consists of a central power plant with 16 Bulb type units (8 for each part put into operation between 1984 and 1986), two additional plants (functional since 1994, the Romanian one, and the Serbian one since 2000) three locks (two on the Romanian side and one on the Serbian side) and two spillway dams (the Romanian one on the Gogosu arm, the Serbian one in the main barrage front). The Romanian HPP has after refurbishment 251.2 MW and a mean electricity production of 1.24 TWh/a.

Located on the secondary side of the Danube, there is an additional Romanian HPP, Gogosu, which has 2 bulb type units, with an installed capacity of 54 MW which will reach 62.8 MW after retrofitting.

Many scientific papers were dedicated to Iron Gates I or II HPDs. Most of the papers are dedicated to the ecological issues resulted by the creation of the Iron Gates reservoirs as: emerging contaminants in sediments [5], heavy metal storage in sediments [6, 7], studies related to aquatic biota

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[8], silica retention [9, 10, 11], retention of sediments and nutrients [12], studies of fish population evolution [13].

Other papers are dedicated to technical issues regarding the HPPs operation as increasing the electricity production [14], use of bottom outlets for flood transit [15] or demonstration of safe operation of Iron Gates HPDs [16].

Recent papers are related to new techniques to evaluate the landscape [17] or simply to social issues as the public perception regarding protected areas in Danube River basin [18]. One of the most important papers is related to the sustainable management of the Danube River basin in the area of the three Iron Gates HPDs [19]. The presented methodology can also be applied for every other HPD on the Danube River.

The aim of the paper is to present a third hydropower development on the Romanian sector of the Danube River, this time to be realized together with Bulgaria. The situation is changed related to the first two HPDs because of the very strong environmental constraints.

2. Turnu Magurele – Nicopole hydropower development

The first evaluation of rivers hydropower potential in Romania was published in 1929, [20] and then, 4 years later, results were published this time in very detailed manner, with assumptions and calculations for all rivers, interesting from hydropower point of view, and with sketches representing hydropower developments on these rivers [21]. All these hydropower developments are today realized and with only some slight changes.

Regarding the Danube River only the cataracts sector, between Romania and the former Yugoslavia, today Serbia, was considered. The proposal was to realize three HPPs with maximum heads of 6.3, 9.1 and 8.8 m and installed capacities of 240, 300 and 330 MW, respectively. Those are today "covered" by only one HPD, Iron Gates, totalizing a head of 27 m and an installed capacity of around 2300 MW.

In addition, downstream Iron Gates I was built Iron Gates II with a bit more than 251 MW installed capacity at km 863.

The site of the works for the hydrotechnical node was established in Varna in 1972 at km 581 [22]. On April 5, 1978, in the presence of the party and state leaders of the two countries, the construction works of the Turnu Magurele – Nicopole HPD were inaugurated.

Between 1978 and 1983, the Romanian side carried out works worth 267 million lei on its bank. During the period from 1977 to 1980, the Bulgarian side carried out some site construction works in Belene and the site of the hydrotechnical node. At the end of 1980, the Bulgarian side announced that it could not continue the execution of works for the Turnu Magurele – Nicopole HPD due to internal economic and conjunctural considerations. It was decided at a high level to draw up an analysis of the efficiency of the works of the HPD, which was carried out in 1981, leading to different conclusions: the Romanian side considers efficient work on both sides, while the Bulgarian side considers that the work on his shore is not effective at that time.

A brief description of the main data describing Turnu Magurele – Nicopole HPD is [22]:

- use the hydropower potential of the Danube on the area between HPD Iron Gates II (km 863 on the Danube) and km 581 where it will be the hydrotechnical node location;
- the reservoir has a length of approx. 282 km: length of the Romanian - Serbian sector: 17 km and length of the Romanian - Bulgarian sector: 265 km;
- the slope of the Danube is about 4 cm/km;
- retention elevations analyzed: 29.5; 30.75 or 32 MABSL (meters Above Baltic Sea Level); the normal retention level was established at 30.75 MABSL;
- gross head: 9.1 m;
- the tributaries on the left bank: Jiu and Olt, and on the right bank Timoc (the border between Serbia and Bulgaria), Lom, Ogosta, Iskar, Vit, Osam.

In figure 1 is presented the situation plan of HPD Turnu Magurele – Nicopole.

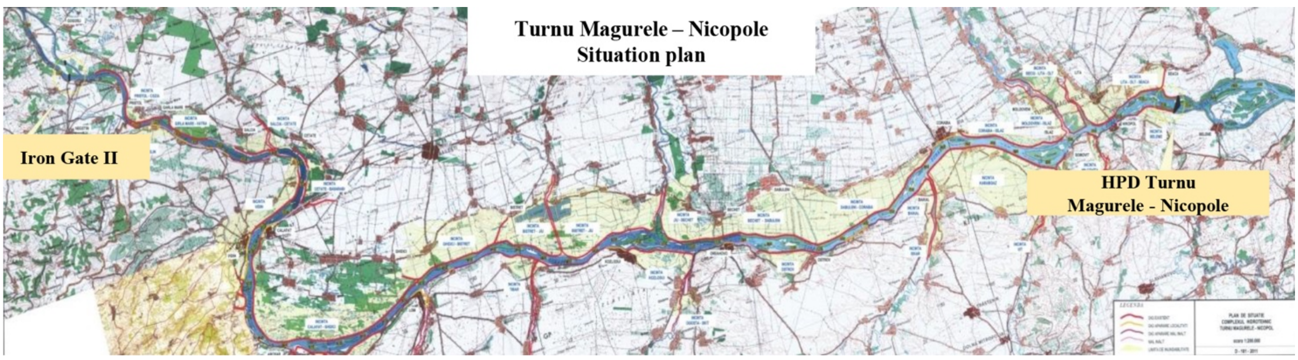

Fig 1. HPD Turnu Magurele – Nicopole, situation plan.

Year of last design documentation is 1993. In figure 2 is presented the longitudinal section of the dam of Turnu Magurele – Nicopole HPD.

The hydrotechnical node comprises on each shore a plant and a lock. Both spillway dams are located on Ostrovul Pavel, on the left bank. Land dams provide river barriers and the shoreline. On both banks there are works for the defense of settlements and riparian lands, drainage systems and other hydro-melioration works.

Regarding the parameters for the entire HPP, both parties, there were established the following data [23]:

- the installed flow is 11,020 m^3/s; it corresponds to an installed coefficient of 1.7 as the mean flow of Danube River in that cross section is 6,500 m^3/s;
- the installed capacity is 840 MW in 24 hydropower units;

- this correspond to an annual energy production of around 4.432 TWh/a if the average time use of installed capacity is considered 5300 h/a.

It must be mentioned that energy production at HPD Iron Gates II after the realization of HPD Turnu Magurele – Nicopole diminishes by approx. 480 GWh/a due to the raise of the downstream level.

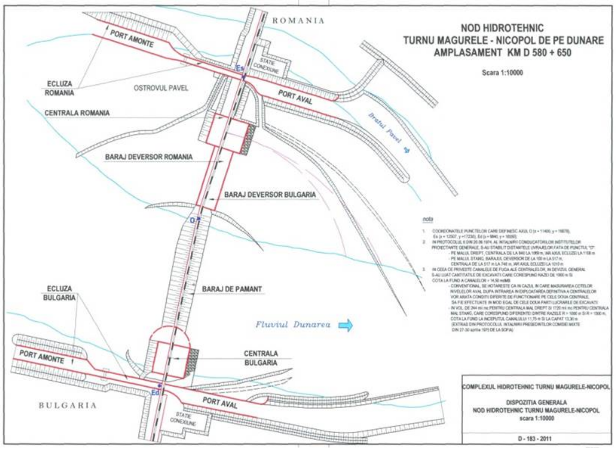

Fig 2. HPD Turnu Magurele – Nicopole: the dam, longitudinal section.

In figures 3 to 5 are presented sections through a spillway, through the closing embankment dam and through a hydropower unit of HPD Turnu Magurele – Nicopole.

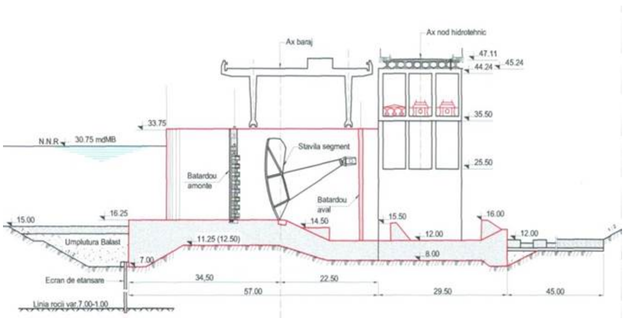

Fig 3. HPD Turnu Magurele – Nicopole, section through a spillway.

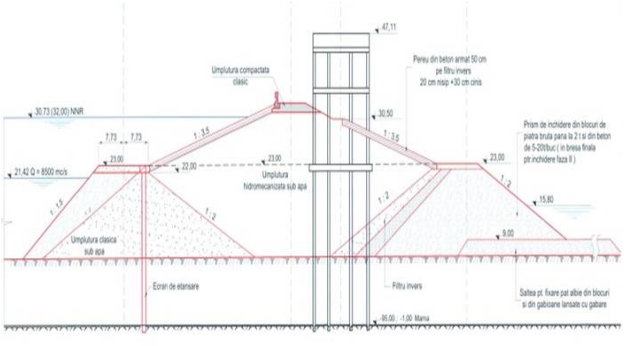

Fig 4. HPD Turnu Magurele – Nicopole, section through the closing embankment dam.

The drawings and data were taken from project documentations [22].

A rough calculation for the hydropower potential of the river sector covered by the Turnu Magurele – Nicopole reservoir, in terms of power (*P*) and energy (*E*), using existing data and the usual formulas [24]:

$$P = 9.81 \cdot Q \cdot H \,[\text{kW}], \tag{1}$$

$$E = T_a \cdot P \,[\text{kWh}], \tag{2}$$

where:

Q = 6500 m^3/s is the mean flow of Danube in this section;

T_a = 8760 h/a is the number of hours for one year;

H is the gross head and can be determined with the formula:

$$H = i \cdot L, \tag{3}$$

where:

i = 4 cm/km is the average slope of Danube riverbed over this sector;

L = 282 km is the length of the sector covered by the reservoir.

By performing those simple calculations, it results:

$$H = 11.28 \text{ m}, \tag{4}$$

$$P = 719 \text{ MW}, \tag{5}$$

$$E = 6.3 \text{ TWh/a}. \tag{6}$$

The ratio between the estimated average electricity production of the future HPP and the hydropower potential in terms of energy is:

$$E_a / E = 0.7 = 70\%, \tag{7}$$

and it can be considered an efficiency of the use of hydropower potential in Turnu Magurele – Nicopole HPD.

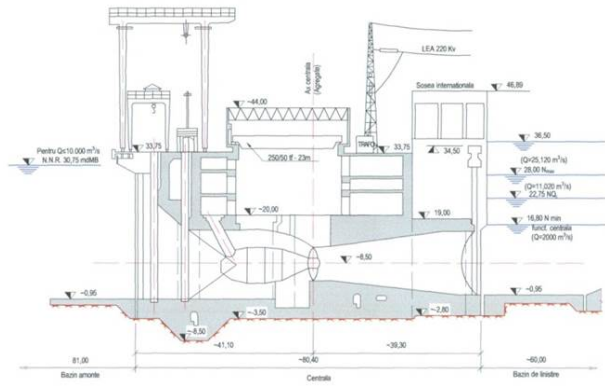

Fig 5. HPD Turnu Magurele – Nicopole, section through a hydropower unit.

3. Pros and cons of the project

The construction of Turnu Magurele – Nicopole HPD will be beneficial as it increases the production of electricity from RES in both countries, Romania and Bulgaria, helping at the fulfilment of new targets established by the EC until 2030. This HPP can also provide system services which are very important for both national power grids as the penetration of other nonpredictable RES as wind and solar, is increasing.

From the point of view of the navigation, with the creation of the reservoir related to this HPD, Danube will become navigable all year long on the related sector while now only around 60% of the time can be considered a waterway.

Moreover, the construction of Turnu Magurele – Nicopole HPD will be beneficial for the operation of low Olt sector HPD, Ipotesti – Izbiceni. This sector consists in five HPPs provided with reversible units and acting as a cascade pump storage plants (PSPs). The general idea of the development of low Olt sector was to be completed with one more HPP, Islaz, which could pump-up water from the Danube River, when the flow of Olt river waters is low. Danube River represents the inferior reservoir, huge with respect to Olt River, as at the junction of the two rivers the mean flow of Danube is 30 times larger than that of Olt river. Then, from Islaz reservoir the water can be pumped-up through the five reservoirs. The alternative of Islaz is Turnu Magurele – Nicopole HPD which will realise downstream Izbiceni, the last HPP on Olt River, a constant level of 30.5 mABSL ensuring the possibility for this plant and implicitly for the other four upstream HPPs to be operated in pumping mode.

This mode of operating low Olt HPD as a PSP will be beneficial for the national power grid.

Besides, as the environmental concerns are very high, one can expect that the Turnu Magurele – Nicopole HPD is provided with a fish passage allowing for sturgeons and other fishes to go upstream during migrations. The design, the construction and the monitoring of this fish passage will be a good example on how to realize such an additional construction for Iron Gates I dam.

Finally, it must be mentioned flood control, irrigations and social aspects related to employment of many thousands of people from various domains related to the construction of this huge objective.

Despite so many pros there are also a non-negligible con related to environmental impacts that this kind of large HPDs have: the longitudinal connectivity of Danube River will be once more affected, impact on water ecosystems, flooded areas etc.

4. Conclusions

Nowadays, there are new opportunities and new potential to consider, particularly in terms of strengthening the European Union's efforts to overcome the economic crisis in a sustainable way. In difficult times when the unemployment phenomenon is widespread, the execution of some hydropower developments can absorb a large volume of workforce over periods of 5 ÷ 10 years.

It is well known that many infrastructure works have been carried out in developed countries in times of economic crisis.

As a conclusion of the data presented above, which were based on syntheses extracted from the studies carried out before 1990, it can be pointed out that the most favorable conditions for technical and economic achievement as well as the partnership between Romania and Bulgaria, is comprised of the Turnu Magurele – Nicopole HPD.

In the event of the adoption of the implementing decision, it is necessary to agree with the Bulgarian (and possibly Serbian) side the following issues of common interest:

- establishing the necessary works for defending the lands and localities, redeveloping the ports and ways of communication, as well as the way of accomplishing and supporting these works, including the related annual expenditures;
- establishing the set-up potential and the share of participation in its realization and capitalization.

It is stated that all existing studies are valid up to the level of 1988. Over a period of more than 25 years, there have been many changes, especially regarding the situation of the land, the use, the mode of ownership, etc., so that the related costs, currently estimated only based on inflation indices, are now higher. On the other hand, at this time there were built dams along the Danube. These dykes will be overburdened in the case of river barrage in the section of the hydrotechnical node, so that the volume of fillings in the reservoir will be reduced.

For a proper technical and economic efficiency analysis, under the current circumstances, it is necessary:

- resumption of support studies in the chosen site: topo elevations, real cost estimation of occupied land, hydrological study, system study, etc.;
- the recalculation of the energy parameters through the updating of the supporting studies and equipping the hydrotechnical node with the current standards;
- the updating of the investment on the works in the retention front (dams, dams, lakes – constructions and equipment), as well as those related to the two banks (dams, designing, pumping stations, defense works of localities, etc.).

It is necessary to update specialized studies on navigation, agriculture, forestry, fish farming, flood protection etc.

Regarding the provision of the debts for the Cernavoda nuclear power plant and the improvement of the navigation on the Danube, downstream of the Turnu Magurele – Nicopole HPD, several hydrotechnical works can be made locally.

In the framework of the European Union Strategy for the Danube Region, pillar 1: "Energy efficiency and renewable energy", it is foreseen: "To develop a plan of global measures for the sustainable development of hydro-energetic potential of the Danube River and its tributaries".

It is necessary to make every effort to obtain funds for the development of a new complex arrangement on the Danube where, through a constructive dialogue between the various competent authorities, a balance between the economic benefits and the environmental protection is ensured.

References

1. Nicolae Pop, "Danube River" (in original in Romanian "Fluviul Dunărea"), Editura Științifică și Enciclopedică, 1985.
2. www.icpdr.org
3. www.undp-drp.org
4. www.hidroelectrica.ro
5. Ivana Matic Bujagic, Svetlana Grujic, Mila Lausevic, Thilo Hofmann, and Vesna Micic, "Emerging contaminants in sediment core from the Iron Gate I Reservoir on the Danube River", Science of the Total Environment, Vol. 662, 2019. pp 77-87.
6. Dubravka Vukovic, Zivorad Vukovic, and Srboljub Stankovic, "The impact of the Danube Iron Gate Dam on heavy metal storage and sediment flux within the reservoir", CATENA, Vol. 113, 2014. pp 18-23.
7. N. Milenkovic, M. Damjanovic, and M. Ristic, "Study of heavy metal pollution in sediments from the iron gate (Danube River), Serbia and Montenegro", Polish Journal of Environmental Studies, Vol. 14, Issue: 6, 2005, pp 781-787.
8. M. L. Matache, A. Tudorache, L. Rozylowicz, and E. Neagu, "Trace elements concentrations in aquatic biota from the Iron Gates wetlands in Romania", Proceedings of the 16th International Conference on Heavy Metals in the Environment, Vol. 1, 2013.
9. D.F. McGinnis, S. Bocaniov, C. Teodoru, G. Friedl, A. Lorke, and A. Wuest, "Silica retention in the Iron Gate I reservoir on the Danube River: The role of side bays as nutrient", River Research and Applications, Vol. 22, Issue: 4, 2006, pp 441-456.
10. Cristian Teodoru, Aristidis Dimopoulos, and Bernhard Wehrli, "Biogenic silica accumulation in the sediments of Iron Gate I reservoir on the Danube River", Aquatic Sciences, Vol. 68, Issue: 4, 2006, pp 469-481.
11. G. Friedl, C. Teodoru, and B. Wehrli, "Is the Iron Gate I reservoir on the Danube River a sink for dissolved silica?", Biogeochemistry, Vol. 68, Issue: 1, 2004, pp 21-32.
12. C. Teodoru and B. Wehrli, "Retention of sediments and nutrients in the Iron Gate I Reservoir on the Danube River", Biogeochemistry, Vol. 76, Issue: 3, 2005, pp 539-565.
13. N. Bacalbasa-Dobrovici, "Fish Population Evolution (1985-1988) in the Last Danube Built Reservoir Iron Gates-II", International Association of Theoretical and Applied Limnology - Proceedings, Vol. 24, 1991, pp 2524-2527.
14. D. Novac, D. Pantelimon, and E. Popescu, "The possibility to increase the rated output as a result of index tests performed in Iron Gates II-Romania", 25th IAHR Symposium on Hydraulic Machinery and Systems, Book Series: IOP Conference Series-Earth and Environmental Science, Vol. 12, 2010.
15. J. Muskatirovic and Z. Predic, "Bottom outlets of the "Iron Gate I" hydro plant as flood discharging structures", Hydraulics of Rivers, Water Works and Machinery, Vol 1, Theme D, Proceedings: 21st century: The New Era for Hydraulic Research and Its Applications, Edited by: G. Li, 2001, pp 448-454.
16. M. Cardu, T. Bara, and C.V. Campian, "Twenty-five years of safe exploitation of the hydropower plant "Iron Gates I" on the Danube River", Energy Conversion and Management, Vol. 39, Issue: 8, 1998, pp 749-755.
17. Bogdan Mihai, Constantin Nistor, Liviu Toma, and Ionut Savulescu, "High resolution landscape change analysis with CORONA KH-4B imagery. A case study from Iron Gates reservoir area", Ecosmart - Environment at Crossroads: Smart Approaches for a Sustainable Development, Edited by: IC Ioja, L. Comanescu, L. Dumitrache, A. Nedelea, M.R. Nita, Book Series: Procedia Environmental Sciences, Vol. 32, 2016, pp 200-210.
18. Cristiana Maria Ciocanea, Carmen Sorescu, Mirela Ianosi, and Vasile Bagrinovschi, "Assessing public perception on protected areas in Iron Gates Natural Park", Ecosmart - Environment at Crossroads: Smart Approaches for a Sustainable Development, Edited by: I.C. Ioja, L. Comanescu, L. Dumitrache, A. Nedelea, and M.R. Nita, Book Series: Procedia Environmental Sciences, Vol. 32, 2016, pp 70-79.
19. Ivan Stevovic, Jovana Jovanovic, and Svetlana Stevovic, "Sustainable management of Danube renewable resources in the region of Iron Gate Djerdap 1, 2 and 3 case study", Management of Environmental Quality, Vol. 28, Issue: 5, 2017, pp 664-680.
20. Dorin Pavel "Available hydraulic forces in Romania" (in original in Romanian "Fortele hidraulice disponibile ale Romaniei"), IRE, Bucharest, 1929.
21. Dorin Pavel, "General plan for the development of hydraulic forces in Romania" (in original in French "Plan general d'amenagement des forces hydrauliques en Romanie"), IRE, Bucharest, 1933.
22. Documentations from Institute for Hydropower Studies and Design (ISPH): "The hydrotechnical complex Turnu Magurele - Nicopole on the Danube. Technical and economic study with constructive solutions. (Synthetic volumes, Hydrotechnical node, Accumulating lake)", 1978; "Technical project of the Turnu Magurele-Nicopol hydrotechnical complex (Volume of synthesis)", 1980; "The Turnu Magurele - Nicopol hydroelectric complex. Internal Prefeasibility Study", 1993.
23. www.economica.net
24. Bogdan Popa and Adina-Violeta Paraschivescu "Introduction to the use of water energy" (in original in Romanian "Introducere in utilizarea energiei apelor"), Politehnica Press Publishing House, Bucharest, 2007.