DEVELOPMENT OF THE HYDRO-ENERGY POTENTIAL OF THE PRUT RIVER BETWEEN ROMANIA AND THE REPUBLIC OF MOLDOVA ON A SIG BASIS

Assoc. prof. PhD. PETRU PLEŞCA
Technical University of Moldova, Chişinau, R. Moldova
Senior lecturer PhD. GABRIEL SĂNDULACHE
"Gheorghe Asachi" Technical University of Iaşi, Romania

ABSTRACT: *It is proposed to use the hydraulic load as the drop at the hydro turbine upstream of the Costesti-Stinca hydrotechnical node with a value of 18m for 3 low-drop hydropower plants for one of 6m operating on multiannual average flow in the Prut river Q=74.5m3/s which produces a power of N=10.5MW. And downstream of the existing dam, the drop between the water level of 62m and the water level at the overflow in the Danube river with a level of 2m can be used, that is, a drop of 60m is possible. But succeeding in predicting that the drop is only 3m in this part, to place 20 mini-hydro plants, which will work on the flows discharged by the hydro aggregates at the Costesti-Stica HPP, where they are installed with flows of 65 m3/s each. In this part, it can produce a power over 60MW, and in total over 72MW. That means that the existing power of 2*16MW will exceed the value of 100 MW.*

Keywords: *the hydro turbine and potential hydroenergy; geodesic and hydrometric dates;*

1. Introduction

Until now, it has been located on the Prut river, at a distance of 585 km from its confluence with the Danube. The lake was created by a dam with a height of 47 m and a length of 7400 m, retaining a volume of water of 735 million m^3 at N.N.R., having a surface of 59 km^2 and a maximum depth of 41.5 m, with bottom emptying. It was built with the aim of regulating the flow of the Prut river, but also for the water supply of the populated centers, of the industrial enterprises in this area, for the production of electricity and mitigating floods. The water and energy produced by the Romanian and Moldovan parts are split in half. The problem of valorizing the hydropower potential in this area was studied, proposed and published by Prof. Dorin Pavel back in the 1930s in "Plan general damenagement des forces hydrauliques Roumanie" in which he also gave options for Bessarabia and Moldova such as Prut, Baca and Răutu shown in fig. 1 and 2 and parameter data such as flows, power drop tab.1.

2. Material and Metod

To determine the hydropower potential, data and observations of the hydrometric stations of the services in the Republic of Moldova and Romania are used, data in table 2.

In order to determine the flow rates, daily, monthly, annual flow data were taken at hydrometric stations, according to which the flow rates required for hydraulic and energy calculation were determined (table 3).

3. Results and discussions

Based on the study of the water levels on the Prut river from the entrance to the north of the Republic of Moldova in the town of Criva with an elevation of Hn=109m and to the south at the overflow in the Danube river in the town of Giurgiulesti with a minimum elevation of Hs=2m we have a drop of Hc=107m . On the one hand, it is already exploited from a hydropower point of view at the hydrotechnical node Stinca-Costesti with a drop of Hsc=27.2m from which a power of 16MW is produced at flows of Q=65m3/s, i.e. equal from Romania and the Republic of Moldova The rest of the falls are not capitalized, but in the Framework Scheme of AGUAProject and IPSH it was studied to locate a hydrotechnical node in the north at Radauti Prut and Lipcani with a reservoir at normal level V=800mln m3 of water with an electric hydroelectric plant, but with the opinion unfortunately only the old bridge was restored in this place.

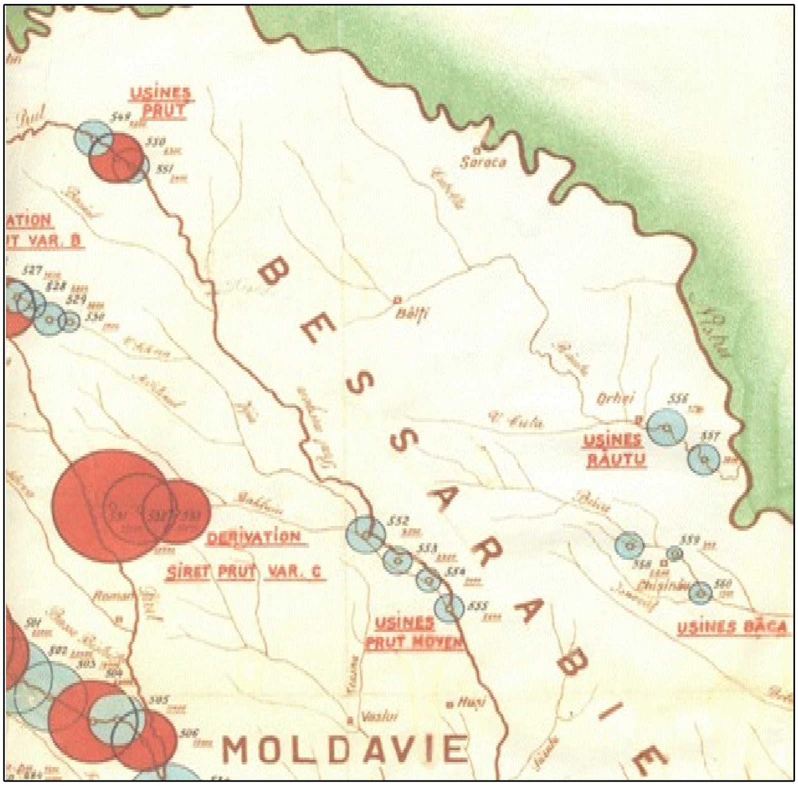

Fig.1. Location schemes of the Prut river hydropower plants
developed by Prof. D. Pavel

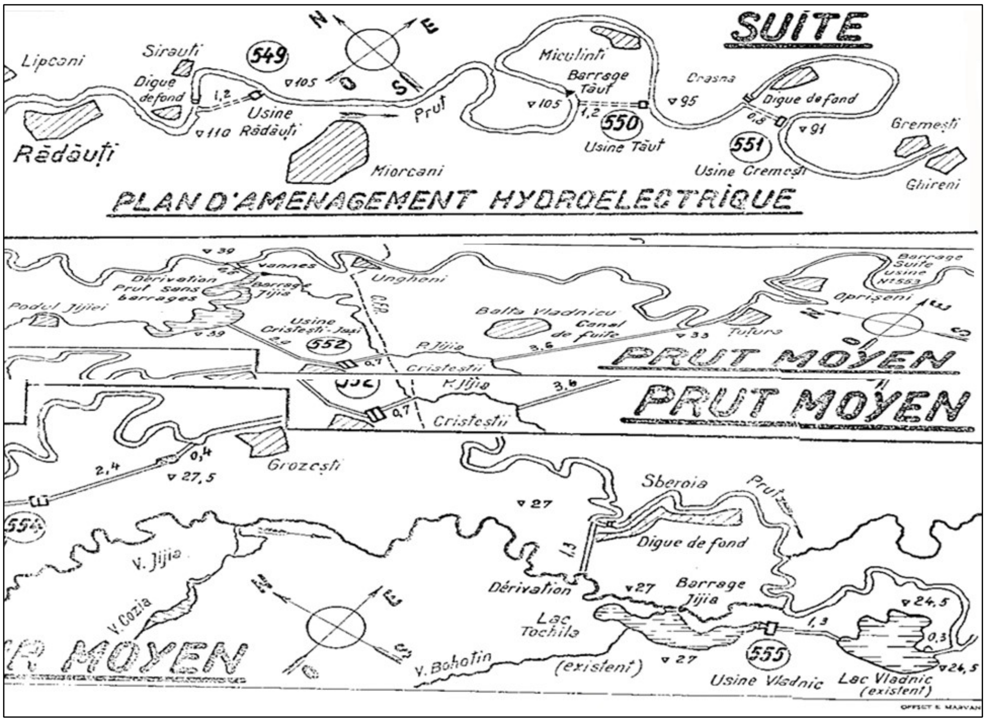

Fig. 2. Location of hydropower plants on the Prut river after variant schemes Prof. D. Pavel

Table 1. Locations of hydropower plants on the Prut river provided by Prof. Dorin Pavel

BASSIN	USINE No.	USINE Dénominat.	kW installé Pi	Hb Chute brute	Débit Qi	Qi / √H	Production En mil kWh/an.	Investissements mill. Lei	Lei/kWh
Haut-Prut	551	Cremeşti . . .	3400	4	110	55,0	14	165	2,01
	549	Rădăuţi	4200	5	110	49,2	16	210	2,24
Prut Moyen	552	Iaşi	4500	6	110	44,9	24	580	4,10
Prut Moyen	554	Măcăreşti . .	2000	2,5	110	69,7	11	430	6,64
Prut	562	Galaţi	5100	5- 4,3	140	64,9	32	210	1,12
Prut Moyen	553	Prisăcani . .	2200	3	110	63,5	12	570	8,06
Prut Moyen	555	Vladnic	2600	2,5	130	82,3	14	280	3,40

Table 2. Multiannual levels at the hydrological stations located in the Republic of Moldova

№	River/station/parameters	H_{med}, cm	H_{max}		H_{min}	
			cm	date	cm	date
	r. Dunabe					
1	s. Giurgiuleşti/ H, t	298	640	07-08.07.2010	-37	08.12.2005
	r. Prut					
2	s. Şirăuţi/ H, Q, ρ,R, t,h, L	111	1164	28.07.2008	22	15-18.09.2012
3	s. Lopatnic/ H, t	674	1672	30.07.2008	181	27.11.1987
4	s. Corpaci/ H, t	1329	2367	31.07.2008	212	30.12.1979
5	s. Dumeni/ H, t	1387	2510	31.07.2008	254	30.01.1982
6	or. Costeşti/ Q, H	1340	2425	31.07.2008	254	30.01.1982
7	s. Brăneşti/ H, t, L	268	832	31.07.2008	170	12-22.1994(2)
8	or.Ungheni/ H,Q, ρ,R, t, L	97	699	09.07.2010	-86	, 27.12.1984
9	s. Leuşeni/ H, t, L	151	697	13.08-1991	-49	02-03.12.2012
10	or. Leova/ H, ρ, t, L	107	620	05-06.05.1996	-114	16,17.12.2015
11	s. Brînza/ H, t, h, L	203	527	20.07.2010	0	13-14.02.1984

Taking into account that it is necessary to retain a large part of the spring floods and precipitation, it is proposed to place upstream of BA Costesti-Stinca starting from Curba de remuu at the normal retention level of Hrn=90.8m, namely in the localities of Lopatnic (Md) and Mitoc (Ro) with the current water level of 91.6m. On this sector, it is proposed to place 3 hydrotechnical nodes of low drop Hc=6m, as the variations in these values are within the natural limits during the flow regimes and there is no danger of flooding. That is, to propose hydrotechnical dams with ecological hydropower plants, which will retain the volumes of flood water, to increase the depths, to accumulate water for water supply and irrigation, such as to take water from higher levels that reduce the geometric pumping height, to improve navigation conditions and fish farming and the main thing is to produce renewable, green, ecological electricity and to form transport access, such as the possibility of applying locks and fish ladders, the operation of cranes when necessary, which will use locally produced energy.

Another identical hydrotechnical and hydropower node can be located further up the river in the Pererita locality also with a fall of Hc=6m, that is, if the normal retention level at

Table 3. Average monthly flows m^3 /s on the Prut river at PH (hydrometric station) Şireuţi Month Monthly average Monthly rate Monthly average

Luna	Media lunară 2021	Norma lunară	Media lunară 2010*
ianuarie	36.5	37,4	47,6
februarie	45.4	39,7	41,8
martie	109	76,9	111
aprilie	134	117	98,9
mai	111	117	192
iunie	130	118	450
iulie	105	113	539
august	40.2	78,4	154
septembrie	30.5	63,8	103
octombrie	21.7	50,2	67,8
noiembrie	22.3	46,4	54,7
decembrie	27.4	37,7	84

Table 4. Average monthly flows m^3 /s on the Prut river at PH (hydrometric station) Ungheni Month Monthly average Monthly rate Monthly average

Luna	Media lunară 2021	Norma lunară	Media lunară 2010*
ianuarie	48.3	57,7	33,9
februarie	45.9	61,7	51
martie	126	66	81,6
aprilie	103	106	80,5
mai	97.2	110	92,6
iunie	111	117	192
iulie	117	110	594
august	54.0	102	197
septembrie	37.4	73,5	137
octombrie	38.7	60,3	77,6
noiembrie	40.1	52,8	40,5
decembrie	39.3	50,6	57,3

Lopatnic is established at the water level Ha=91.6+6=97.6m and at the locality of Pererita the level will already be raised to the water level Ha=97.6+6= 103.6m.

The last node can be located between Lipcani and the town of Drepcauti, here the water level will be raised to the level of Ha=103.6+6=109.6m, which does not affect the Ukrainian side. But the Romanian side can continue to use a sector, but already in collaboration with the Ukrainian side. In each of these 3 nodes, a multi-year average flow can be produced according to flow data at the PH Sireuti hydrometric station on the Prut River with Qm=74.5m3/s from the N power relationship.

$$N=\gamma\eta QmHc=9,8\cdot 0,8\cdot 74,5\cdot 6=3500kW \quad (1)$$

γ-specific gravity of water, 9.8kN/m^3; η=yield of the aggregate and at 3 nodes it will be produced in total upstream of CHE Costesti-Stinca Nam=3·3500=10500kW

Table 5. The volume of annual water discharge in the Dniester and Prut rivers through the Republic of Moldova

Anul	Scurgerea Nistru, km³	Scurgerea Prut, km³	Scurgerea (Prut+Nistru), km³	Precipitații, km³
1977	10.20	3.47	13.67	16.3
1978	12.30	3.75	16.05	20.9
1979	12.40	3.82	16.22	20.6
1980	19.00	4.43	23.40	24.8
1981	14.00	4.48	18.50	21.7
1982	10.70	3.37	14.10	14.0
1983	7.73	2.16	9.89	13.8
1984	7.47	2.68	10.15	21.3
1985	8.71	2.67	11.40	19.6
1986	6.69	1.61	8.30	13.0
1987	6.18	1.18	7.36	16.7
1988	9.74	3.01	12.75	21.0
1989	9.62	2.19	11.80	18.2
1990	5.43	1.08	6.51	13.0
1991	8.77	2.93	11.70	21.4
1992	7.78	2.22	10.00	13.9
1993	8.33	2.37	10.70	18.4
1994	6.12	1.69	7.81	13.1
1995	7.07	2.05	9.12	18.8
1996	10.70	3.48	14.20	22.7
1997	11.00	2.83	13.83	21.1
1998	14.20	3.85	18.10	21.5
1999	14.00	3.88	17.90	18.3
2000	9.74	2.09	11.80	15.3
2001	11.00	2.92	13.90	20.1
2002	10.40	3.47	13.90	19.6
2003	8.23	2.27	10.50	15.3
2004	7.81	2.10	9.91	19.7
2005	9.84	3.09	12.90	20.7
2006	10.90	4.07	15.00	17.2
2007	7.45	2.09	9.54	16.7
2008	12.50	3.92	16.40	18.9
2009	9.87	1.92	11.80	14.4
2010	14.10	4.29	18.40	24.0
2011	8.39	1.82	10.21	13.6
2012	6.26	1.48	7.74	17.7
2013	9.11	2.07	11.18	19.4
2014	7.19	2.21	9.40	20.5
2015	6.20	1.72	7.92	14.4
2016	5.67	1.19	6.86	20.9
2017	6.37	1.70	8.07	20.0
2018	7.47	2.52	9.99	18.0
2019	7.70	2.56	10.26	16.5
2020	7.53	2.55	10.10	15.2
2021	7.25	2.26	9.51	21.2
Norma, km³	9.31	2.65	11.96	18.3

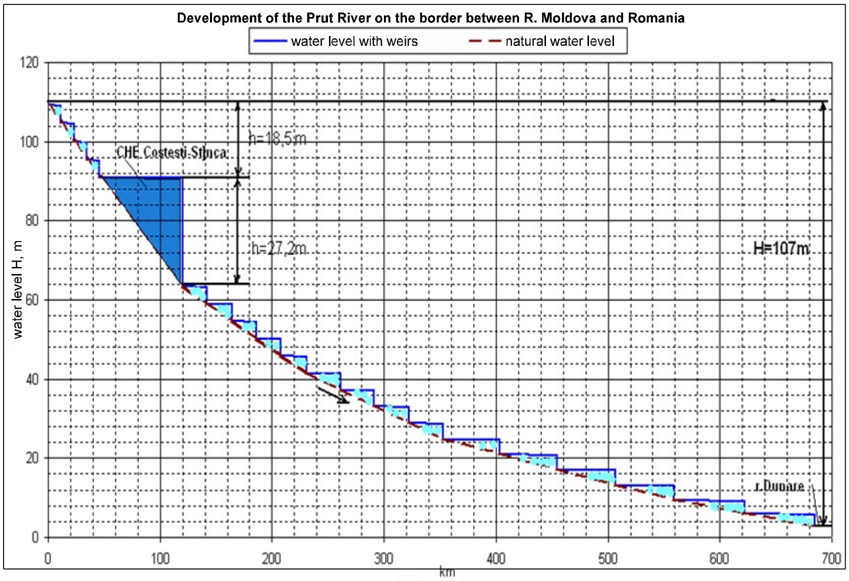

Fig. 3. The location of hydropower plants upstream and downstream of the existing Costesti-Stinca HPP on the Prut River within the borders of the Republic of Moldova and Romania

For the downstream part resulting from smaller slopes and lower protection dams, it is possible to recommend falls around Hc=3m. And the possible fall downstream to be used to determine that the difference in levels downstream after the dam is equal to Hav=62m and the water level at the outlet of the Prut river to the Danube river with a minimum level of Hie=2m, that is, the possible fall downstream is Hc= 60m. Then we have the possibility to install up to 20 nodes with hydroelectric plants with a drop of Hc=3m and with minimum flow rates of one hydro turbine at Costesti-Stinca CHE Qt=65 m3 /s or when both are working then there will be a flow rate of up to 2Qt=130 m3/s. And the power in the first case will be:

$$N=\gamma\eta QmHc=9,8*0,8*65*3=1530kW \quad (2)$$

and grown up

$$N=\gamma\eta QmHc=9,8*0,8*130*3=3060kW \quad (3)$$

If we place all 20 MCHE downstream with a distance interval between 20-40km, we can capitalize from downstream in case the flow passes through a single hydroturbine N=20·1530=30.6MW and for the flow to both hydroturbines to increase twice, i.e. N=61.6MW. And the total is the possibility to produce upstream and downstream of the existing node over a power of over:

N=Nam+Nav=10500+61600=72100kW

4. Conclusions

Regarding the possibility of increasing the electricity production capacity to ÎS "Nodul Hidroenergetic Costeşti-Stinca" on the Prut river, resulting from the research carried out during the last years by following the data of hydrometric and hydrological observations at the points on the Prut river up to and after the Costeşti-Stînca dam, taking into account the data of the regimes working conditions of CHE hydro units in both parts, such as flows, falls, powers and energy produced in time variation, the operation of emptying galleries, their modification, the transformation of floods, the state of turbines, equipment and other devices for operating the hydro plant, the hydrotechnical node and the results of the studies of the follow-up of the behavior of the objectives over time from the NH and the conclusions of the researches of the specialized institutes. it can be emphasized:

1. It is necessary to change the NH Exploitation Regulation, which will give priority to the Energy Exploitation Chart, because currently it is subordinated to the other uses that limit energy production (the modification is made by the parties if it is of common interest, or new conditions of exploitation of NH), especially since water volumes are not used for irrigation.
2. Electricity production at the NH can b increased by optimizing the filling and emptying regimes of the water volumes in the reservoir, if this is done on a technical-scientific basis using the technical possibilities of the existing hydropower equipment at maximum efficiency.
3. Based on previous technical-scientific research, it was determined that the current hydro turbine can, with some modifications, create a power of up to 20 MW, that is, in this condition, the hydrogenerator must be rebuilt with a power of up to 19 MW at the same speed of 187.5 rpm min, increases up to 3 MW. This means that the Romanian part can also increase the production capacity to 20MW.
4. Another option to increase the production of electricity gives the possibility to use the bottom galleries located next to the energy galleries. Initially, these galleries were sized based on the needs to evacuate flows during construction (at small falls), and after the NH was put into operation at upstream levels above the NN, they initially carried high flows and reduced operational safety. In order to limit the negative aspects of evacuation in this situation, it was decided to narrow the section through the construction of a wedge frame, which led to the reduction of the flow discharged through this gallery almost twice. The second bottom gallery of the Moldovan side remained unchanged.
5. In order to ensure the flows with a longer duration within the limits of the servitude, ecological flows downstream on the river Prut (according to the project 15m3/s), taking into account that the minimum flow along the entire length of the river must be ensured a minimum flow of 5m3/s (and the current ecological one set at 8m3/s), which can only be provided by the Romanian side through the

reserve outlet, it is necessary and it is technically possible to use the water evacuation through turbines with the help of bulb-type submersible hydro units, for example, installed at the foot of the dam at the exit from these galleries, using the fall already formed at the dam for the controlled evacuation of flows within the limits of 15-30 m3/s, which are not covered by the existing hydro turbines. In this case, the installed power can be increased up to 3-5 MW at small drops.

6. It is necessary to study the possibility of using the bottom galleries for the turbination of the discharged water during floods at high flow rates, which reduces empty discharge to a minimum, since only in the years 1988-96 this volume exceeded 2 billion m3, which is considered to be be used for energy purposes.
7. If the hydropower potential upstream and downstream is to be exploited, it is possible to increase the power produced over 100MW and also to place the MCHEA storage hydropower plant.

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