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REGULATION OF FLOWS DISCHARGED BY PETREŞTI HYDROPOWER PLANT

Adina PARASCHIVESCU[1], Florica POPA[2], Cornelia CODREANU[3], Bogdan POPA[4]

Lucrarea prezintă un studiu privind redresarea debitelor provenite de la centrala hidroelectrică Petreşti, prin intermediul unui lac situat în aval de centrală, lacul Sebeş. Acesta alimentează o microhidrocentrală, MHC Sebeş, amplasată la piciorul barajului. În prima fază a fost realizat barajul până la o cotă intermediară, apoi până la cota finală permiţând realizarea nivelului normal de retenţie în acumulare. Data realizării microhidrocentralei este incertă, prin urmare redresarea debitelor este asigurată prin golirile de fund ale barajului MHC Sebeş.

The paper presents a study concerning the regulation of the flows coming from Petreşti SHP, by means of a reservoir located downstream of the power plant. Sebeş reservoir supplies a micro-hydropower plant, Sebeş SHP, located at the dam toe. The dam was performed up to an intermediary elevation during the first stage and then up to the final elevation, allowing the achievement of the normal water level in the reservoir. The date for the micro-hydropower plant performance is uncertain, therefore the flows regulation is provided through the bottom outlets of Sebeş dam.

Keywords: flows regulation**,** hydropower plant operation

1. Introduction

Sebeş river is a tributary of Mureş river and is developed on a head of 971 m, between the normal retention level (NRL) of Oaşa reservoir, elevation 1255 mASL) and Petreşti locality, elevation 284 mASL.

Development scheme of Sebeş River consists in two large storages: Oaşa included within the development scheme of Gâlceag SHP, and Tău respectively, from the development scheme of Şugag SHP, both storages being able to achieve a monthly-seasonal regulation of the flows. Obrejii de Căpâlna and Petreşti storages, located downstream of Tău reservoir have lower storage coefficients, being able to provide a daily-weekly regulation of flows; they are included within the development scheme of Săsciori SHP and Petreşti SHP, respectively.

[1] Eng., Institute of Hydroelectric Studies and Design SA, Bucharest, Romania
[2] Eng., Institute of Hydroelectric Studies and Design SA, Bucharest, Romania
[3]Eng., Institute of Hydroelectric Studies and Design SA, Bucharest, Romania
[4] Reader, Faculty of Power Engineering, University ”Politehnica” of Bucharest, Romania

Petreşti storage and Petreşti SHP are located at the downstream limit of the developed stretch, the storage main role being to regulate the flow turbined in the upstream power plants so that to prevent the record of high and fast variations of flow on the downstream stretch. Petreşti storage has also the role to provide the power plant elasticity for a short period up to the starting of Săsciori power plant, upstream.

Petreşti dam achieves a storage with V_t = 1.2 mil.m^3, the normal retention level being at 294 mASL.

Petreşti storage is included within the development scheme of Petreşti SHP (fig. 1), a power plant at the dam toe, equipped with 2 KOT units, each with an installed discharge of 52 m^3/s and an installed capacity of 4,25 MW, the power plant having a power output according to the project of 6 GWh/year. Due to its low capacity, the storage can provide the operation autonomy of Petreşti power plant, without an upstream contribution, for short periods of time.

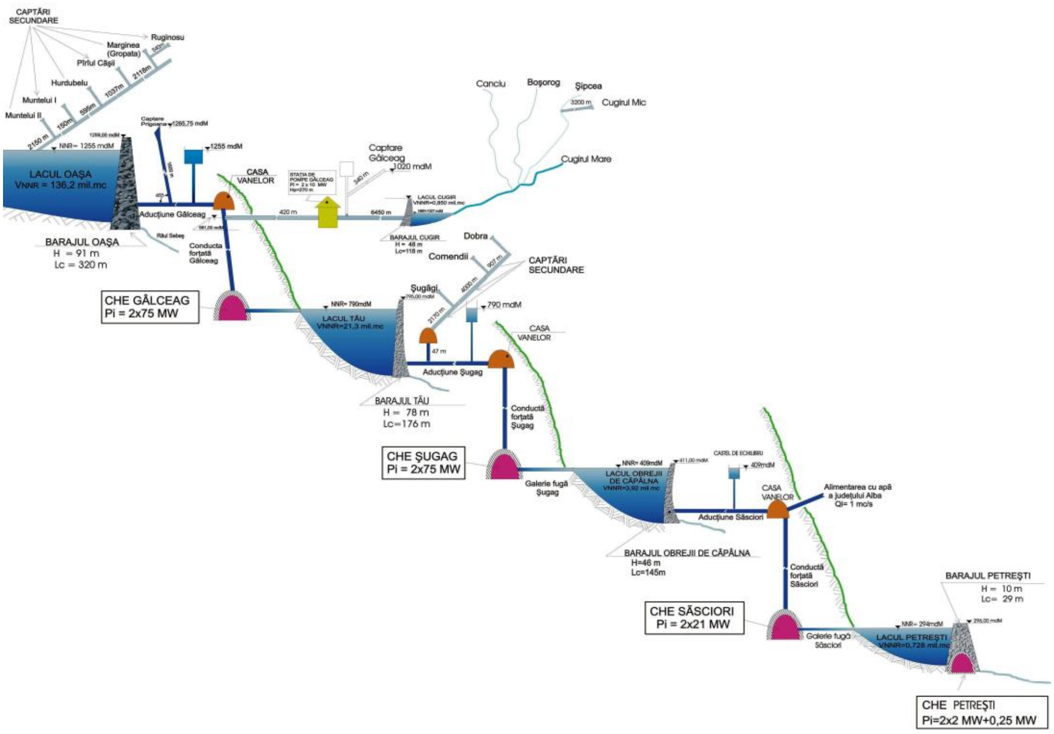

Fig.1. Complex scheme of Sebeş hydroelectric development on Oaşa – Petreşti stretch.

In view of regulating the flows turbined in Petreşti SHP for stopping the erosions of Sebeş riverbed, as well as for the water supply of Sebeş town utilities, in 2004, it was studied the possibility of carrying out a dam for the achievement of a compensation reservoir downstream of Petreşti SHP, provided with a small hydropower plant (SHP) for the turbining of the flows regulated by the reservoir.

Works at the reservoir dam and at Sebeş SHP have started in 2006, going to be carried out in stages, as follows:

- stage I – sill at elevation 268 mASL, the dam achieves a storage which to allow the water supply for Sebeş town utilities;
- stage II – dam completion so that the reservoir to be operated with NRL at elevation 273 mASL;
- stage III – performance of Sebeş SHP, at the dam toe, which to turbine the flows regulated by the compensation reservoir and to provide a constant flow of about 12 m^3/s, downstream of Sebeş SHP.

Downstream of Petreşti dam, under the present conditions, the sanitary flow is provided by a SHP located at the dam toe. From the section of Petreşti dam it has to provide about 1,16 m^3/s for the water supply of some consumers from the zone.

Sebeş reservoir has as main purpose the compensation of the turbined flows, coming from Petreşti SHP, from a maximum turbined value of 26 m^3/s to a value as constant as possible of about 12 m^3/s through a small hydropower plant, Sebeş SHP, located at the dam toe. Unfortunately, the date of the power plant performance is unknown and this is the reason why it has to be provided the regulation of the flows turbined at Petreşti SHP also if the micro-hydropower plant shall not be performed anymore.

2. Data and calculation assumptions and results

Purpose of this calculation is to determine the operation methods of the bottom outlet in view of regulating the water downstream of Sebeş dam, at a flow value as low and constant as possible on the riverbed. It is also required to be provided a sanitary flow and the water supply of Sebeş town utilities.

Depending on the geological and geographical condition of the lands in the area, as well as on the possibility of performing the Sebeş dam from technical point of view, the maximum active capacity of Sebeş compensation reservoir has resulted to be of about 0.993 mil.m^3, at the normal retention level of 273 mASL (figure 2).

Specific elements of Sebeş compensation reservoir are shown in table 1.

Water supply intake of Sebeş town is located at 267.3 mASL, therefore the water level in the reservoir shall not be under this elevation, although the minimum operation elevation of the reservoir active capacity is of 259.5 mASL (the elevation of the future SHP intake). *This condition lowers the active capacity of the reservoir in value of 0.682 mil.m^3*.

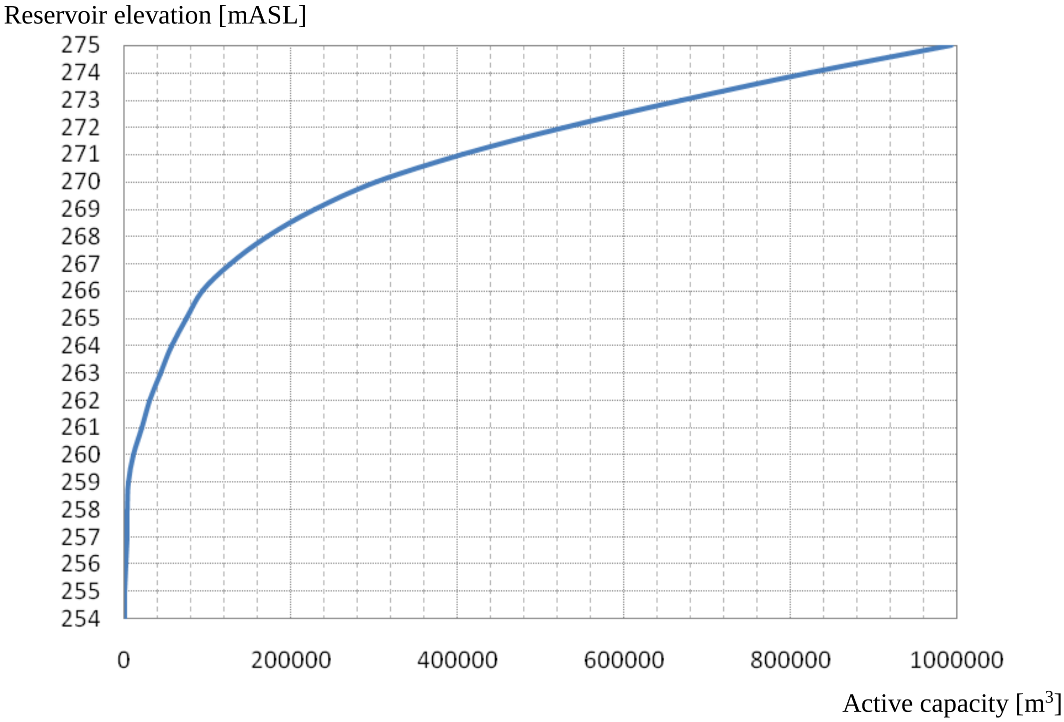

Fig. 2. Variation of the active capacity of Sebeş compensation reservoir between the level of water supply intake and the normal retention level.

Table 1

Specific elevations of Sebeş compensation reservoir, in mASL

River thalweg elevation	254.0
Bottom outlet apron elevation	257.5
NminE (SHP intake elevation)	259.5
Intake elevation of Sebeş town utilities water supply	267.3
Weir sill elevation	270.5
NWL	773.0
Crest elevation	275.0

In order to achieve the reservoir compensation role this was operated daily under various operation regimes of Petreşti hydropower plant, located upstream.

Therefore, it is considered the daily operation of Petreşti SHP in two steps (corresponding to the two load peaks from the national power system) starting from 2 h in the morning and 2 h in the evening, reaching to 24 h per day. The operation diagrams of Petreşti SHP are shown in figure 3.

Operation of Sebeş compensation reservoir was carried out theoretically, at an interval of 1 s, provided that the reservoir is emptied until the end of the day.

Petreşti SHP has operation restrictions at only one unit, due to the fact that Sebeş reservoir can not provide the regulation from 52 m^3/s to 12 m^3/s, mainly from physical-geographical causes, so that its installed discharge is considered to be of about 26 m^3/s.

Conditions to be observed during Sebeş reservoir operation and taken into consideration during the computation are the following:

- to be provided a sanitary flow on Sebeş river valley, of about 1 m^3/s, if Petreşti SHP would operate for less than 2 h or not to operate at all;
- to be provided the water supply discharge for Sebeş town, about 1 m^3/s;
- to be regulated the flows turbined by Petreşti SHP, from a value of 26 m^3/s (operation required with one unit) to a lower value, without pulsating either by the bottom outlet, or by the intake of the future SHP).

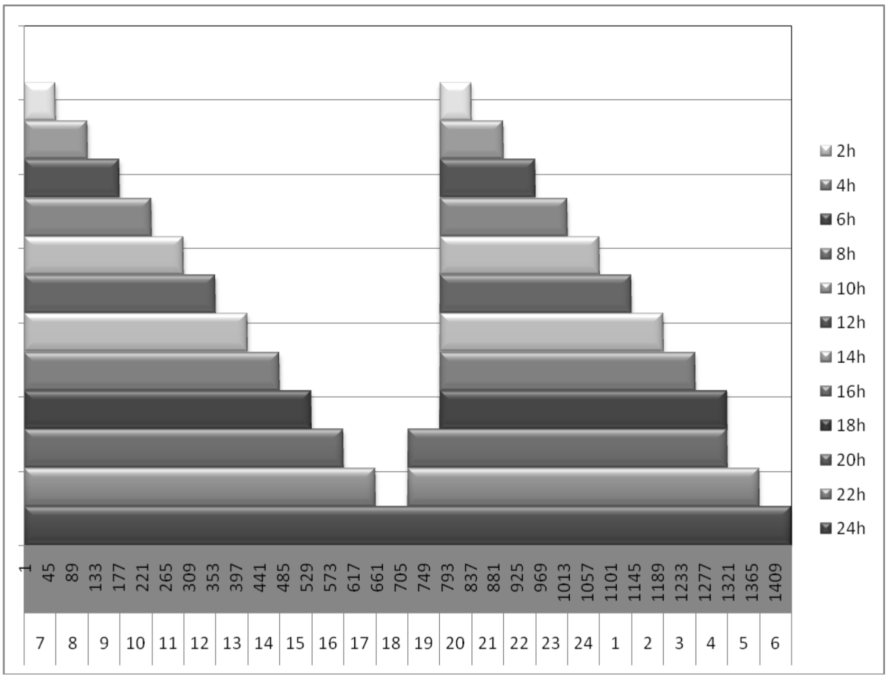

Fig. 3. Hourly intervals of Petreşti SHP operation during the calculation supposed days

There are considered three assumptions for the opening of the bottom outlet: 20 cm, 30 cm and 40 cm. Representation of the bottom outlet flow curve for the considered calculation assumption is shown in figure 4.

Fig. 4. Flow curve of the bottom outlet, in the assumption of the two openings of the gate.

Using the storage capacity curve (figure 2) and the flow curve (figure 4), it was carried out a theoretical daily-hourly operation of the polder, being considered a constant discharge of 25 m^3/s, on different periods of time (2, 4, …, 24 h), under the assumption of the operation twice a day.

3. Computation relations

Computation of the final capacity of the reservoir at the end of a day is carried out based on the balance (1), between the initial flows from the reservoir, the inflows (turbined by SHP Petrești) and the outflows (given by the bottom outlet curve depending on the reservoir level).

The calculation used in the paper is shown below, being specified that the capacities used within the calculation are in fact flows, because the time step used is the second.

Capacities balance from Sebeş compensation reservoir, exemplified for a certain moment, *j*, is:

$$Vf_j = Vi_j + Va_j - Vd_j\ ,\ \ j = \overline{1,86400}\ , \tag{1}$$

where:

j = current moment (in s from the day).

$Vf_j =$ final capacity at *j* moment;

$Vi_j =$ initial volume at *j* moment;

$Va_j =$ inflow volume in the reservoir at *j* moment;

$Vd_j =$ outflow volume (given by the bottom outlet curve), at *j* moment.

The initial volume from the current moment represents the final volume from the previous moment. During the first moment the initial volume is zero (the reservoir is empty):

$$Vi_j = Vf_{j-1},\ Vi_0 = 0\ \ . \tag{2}$$

The inflow volume in the reservoir at *t* moment is considered to be a constant value equal to the installed discharge of one unit from Petreşti SHP, in the calculation being considered the assumption that the power plant is operating at the installed discharge of one unit (about 25 m^3/s).

The outflow volume from Sebeş reservoir is given by the bottom outlet curve and it is found by interpolating two points existing on the curve and adjacent to the calculation point.

By assumption, it was considered that at the end of the day, the active capacity in the reservoir does not lower under the value of 15 000 m^3.

If Petreşti SHP operates at least 14 h per day, in two steps, it was required the condition of closing the bottom outlets, starting from certain elevations/volumes in the reservoir, and to be provided only the required flows (sanitary and water supply). This condition is graphically represented in figure 5.

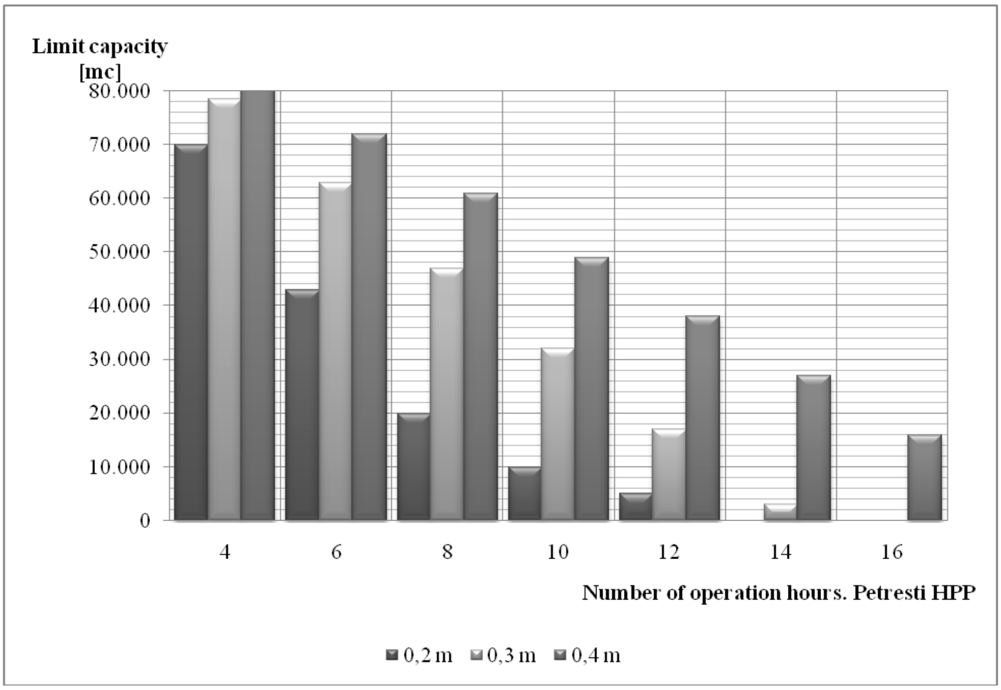

Fig. 5. Limit active capacities in Sebeş reservoir depending on the number of operation hours of Petreşti SHP, established for the closing of the bottom outlets and for providing the required flows.

Analysis results are shown in figure 6 and in tables 2, 3 and 4, being commented/analyzed within the conclusions paragraph.

Table 2

Use of the bottom outlets for the regulation of the flows at an opening of 20 cm

Hour of Petreşti SHP operation	Qoutflow, min, (m^3/s)	Qoutflow, max, (m^3/s)	Regulation providing (% from the time on a day)	Max, capacity to be stored in the reservoir (m^3)	Filling level of the reservoir after 24 h (% from the active capacity)
24	8,77	9,11	30,9	1387640,3	315,9
22		9,11	30,9	1236851,3	281,6
20		9,11	30,9	1086062,4	247,2
18		9,11	41,2	899410,5	204,7
16		9,11	58,5	752003,7	171,2
14		9,11	71,0	607798,6	138,4
12		9,11	94,9	466294,8	106,2
10		8,86	100,0	327051,3	74,5
8		8,65	100,0	243511,0	55,4
6		8,48	100,0	182626,2	41,6
4		8,29	100,0	123838,4	28,2

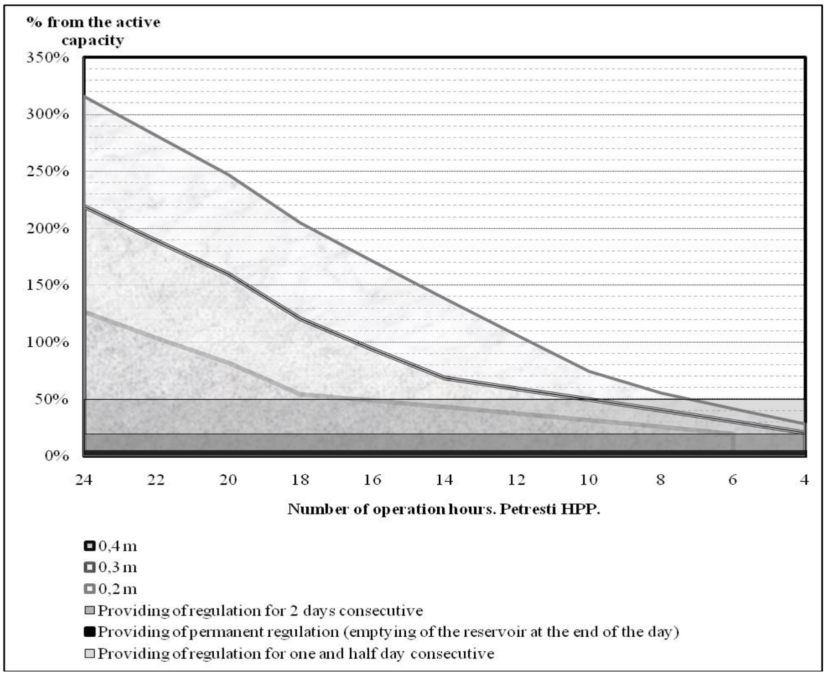

Fig. 6. Filling level of Sebeş compensation reservoir under the assumptions of the technical calculation carried out (% from the active capacity).

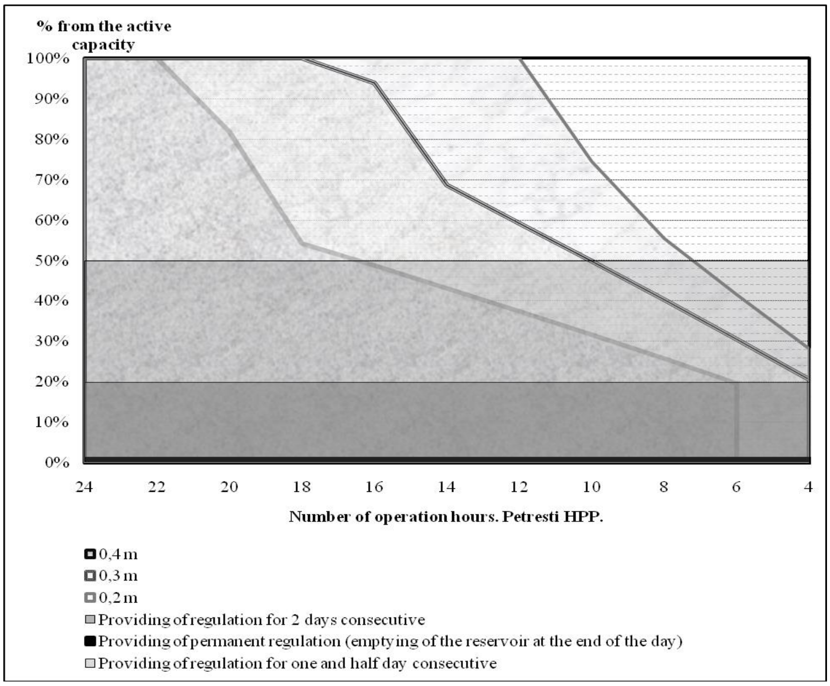

Fig. 7. Operation chart of the Sebeş dam bottom outlet.

Table 3

Use of the bottom outlets for the regulation of the flows at an opening of 30 cm

Hour of Petreşti SHP operation	Qoutflow,min, (m3/s)	Qoutflow,max, (m3/s)	Regulation providing (% from the time on a day)	Max, capacity to be stored in the reservoir (m3)	Filling level of the reservoir after 24 h (% from the active capacity)
24	13.20	14.23	43.75	962398.05	219.09
22		14.23	50.28	830363.37	189.03
20		14.23	63.40	701898.22	159.78
18		14.23	83.33	529768.14	120.60
16		14.14	100.00	412341.95	93.87
14		13.76	100.00	301467.79	68.63
12		13.59	100.00	259996.89	59.19
10		13.42	100.00	218952.54	49.84
8		13.25	100.00	177188.49	40.34
6		13.04	100.00	134174.77	30.54
4		12.82	100.00	90574.56	20.62

Table 4

Use of the bottom outlets for the regulation of the flows at an opening of 40 cm

Hour of Petreşti SHP operation	Qoutflow,min, (m^3/s)	Qoutflow,max, (m^3/s)	Regulation providing (% from the time on a day)	Max, capacity to be stored in the reservoir (m^3)	Filling level of the reservoir after 24 h (% from the active capacity)
24	17.66	19.39	75.97	555675.35	126.50
22		19.39	95.90	454989.79	103.58
20		19.02	100.00	359404.59	81.82
18		18.41	100.00	238152.05	54.21
16		18.28	100.00	214295.71	48.78
14		18.15	100.00	189519.83	43.14
12		17.99	100.00	164539.69	37.46
10		17.82	100.00	139171.78	31.68
8		17.65	100.00	113362.28	25.81
6		17.46	100.00	86191.53	19.62

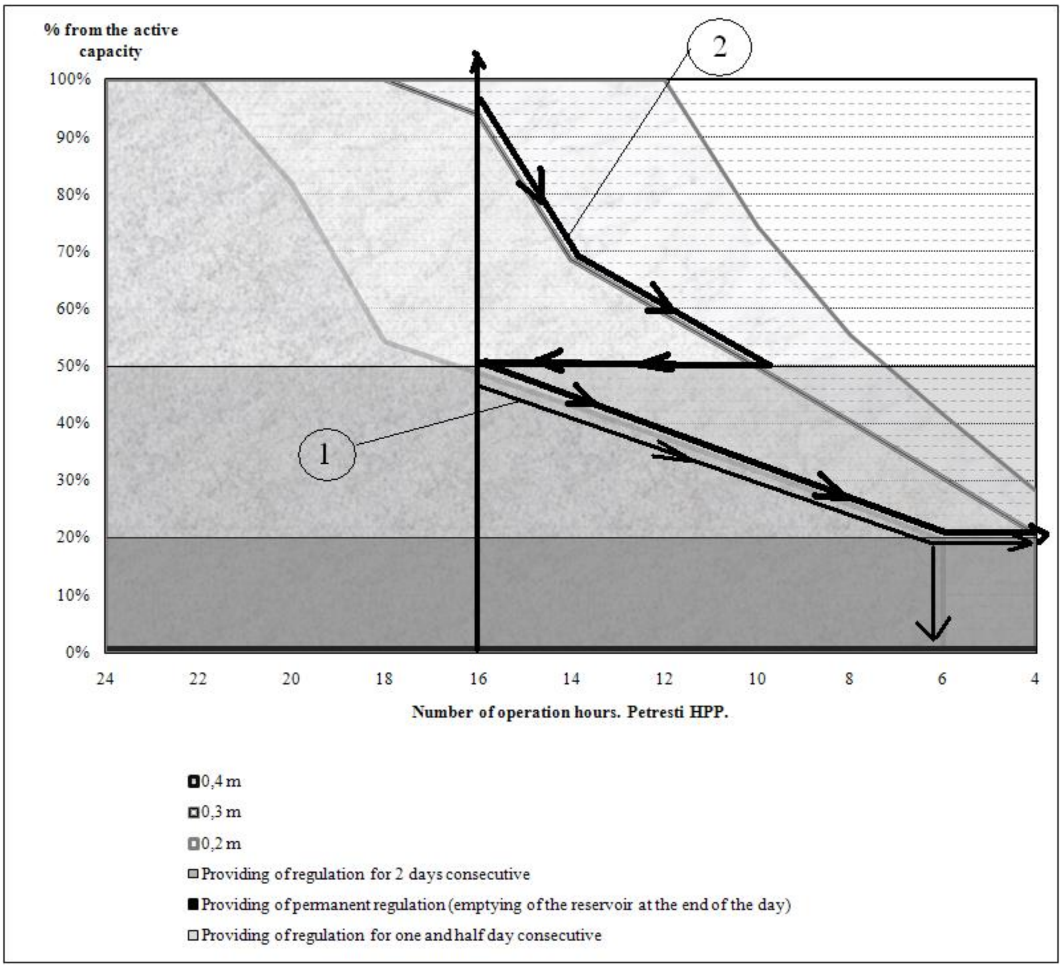

Fig. 8. Example of using the chart from figure 7.

4. Conclusions

Further to the study presented in the paper the following conclusions are drawn:

- for an operation duration of SHP Petreşti higher than 18 h, in two steps of 9 h, Sebeş compensation reservoir can not provide the regulation of the flows and is overflowing;
- for an operation duration of SHP Petreşti lower than 4 h, in two steps of 2 h, Sebeş compensation reservoir provides only the required flows. Therefore, the bottom outlets are not opened, the outflow from the reservoir is constant, 1 m^3/s;
- for an operation duration of SHP Petreşti between 4 and 14 h, in two equal steps, for providing the required flows (sanitary and water supply), from a

certain elevation in the reservoir, for reaching a limit active capacity, respectively, the bottom outlets are closed (figure 5);

- depending on the opening of the bottom outlets, of 20, 30 or 40 cm, it can be achieved a complete daily regulation starting with 10, 16 and 20 h of operation, respectively of Petreşti SHP in two equal steps, but the reservoir remains filled up to the end of the day (it can carry out the regulation for two consecutive days if the operation duration is under 6, 8 10 h, respectively);

- an example for the use of the resulted chart is shown in figure 8. Therefore, there are two regulation options if SHP Petreşti operates 16 h in two steps of 8 h in one step.

a) Short regulation variant (1) – the bottom outlets are opened at 40 cm and are kept opened until the volume reaches to about 20% from the active capacity (figure 7), moment when the bottom outlets are closed up to 30 cm being therefore provided the flows daily regulation.

b) Long regulation variant (2) – the bottom outlets are opened at 30 cm and are kept opened until the volume reaches to about 50% from the active capacity (figure 7). Then the bottom outlets are opened up to 40 cm and are kept opened until the volume reaches to about 50% from the maximum active capacity, the bottom outlet are opened more and are kept this way until the volume reaches to about 20% from the active capacity, moment when the bottom outlets are closed up to 30 cm and are kept opened until the end of the day.

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