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NEW PUMPED STORAGE PLANTS AS RENEWABLE ENERGY SOURCES IN ROMANIA

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Abstract. ***In Romania, there are no pumped storage plants (PSPs) significant from the point of view of the National Power System (NPS). For more than 30 years, one site is expected to achieve 1000 MW PSP, using the existing reservoir Tarnita, on Somes river, as the lower reservoir. Recently, Hidroelectrica launched a study identifying new potential sites for PSPs in the Eastern part of Romania, where there is a huge development for wind farms and where Cernavoda nuclear power plant is located, with 2 units of 700 MW each in operation and other 2 units to be built until 2035. These PSPs will cover the ancillary services and, according to a new Government Ordinance, will enable a better integration of the existing RES into the NPS, and will increase the generation of electricity from RES by their own production of electricity.***

Keywords: pumped storage, renewable energy, Romania

1. INTRODUCTION

Pumped storage Plants (PSPs) represents the only viable alternative to store electricity at the level of a National Power System (NPS) and there are the most suitable plants for supplying ancillary services [1, 2].

Among the possible classifications of PSPs, [3], there is one upon the circulation of water: in close or open circuit. The PSP is in *close circuit* or *obligatory pumping* if the water is used between two reservoirs placed at different levels. If there are at least three reservoirs, the water is pumped up in a pumping station (PS) and it is released through turbines to another reservoir or receiver, usually located at a lower level then the first one, the PSP is in *open circuit* or with *contributive pumping*.

In Romania there are five PSPs in a sort of close circuit, [4], in fact the last five hydropower plants (HPPs) in cascade on the Lower Olt river, equipped with reversible units, but they have never acted as PSPs, even if recently refurbished. These PSPs form the Ipotesti-Izbiceni sector and, for each development, the upper reservoir is created by his own dam and the lower one is the reservoir formed by the downstream dam and so on. The Romanian energy strategy foresees the performance of another plant, in order to complete the lower Olt river development. This last PSP, Islaz, will form Islaz reservoir which will be the lower reservoir for the existing Izbiceni PSP and will have as own reservoir the Danube river. When this last PSP will be achieved on Olt river, the goal of building the last five plants on Olt river, as PSPs, can be considered as accomplished, meaning pumping up water from the Danube river when Olt river is low and using the six reservoirs for storing water.

However, there are three hydropower developments (HPDs) which can be considered PSPs in open circuit: Lotru, Sebes and Dragan-Iad. In [4], following a methodology presented by Punys et al in [5], the authors determines, for those 3 open circuit PSPs in Romania, the electricity generated by the amount of water from the natural inflow in the upper reservoir, which in some countries, as Poland, is considered renewable and benefits of support system. This occurs due to the fact that the electricity generated by the amount of water, previously pumped into the upper reservoir, is considered non-renewable as it is impossible to determine whether the electricity consumed from the NPS for pumping is green or not, meaning produced from fossil fuels.

PSPs could hold an important role within the NPS, considering its capacity to store electric energy. The power demanded by consumers is variable over time, both in the course of one day and during one week. During the consumption periods of the load curve, the PSP works as a producer of electricity in periods of high demands (peaks), and as a consumer in periods of low demands. Therefore, the ratio between the generated power and consumed power is balanced, and the electricity producers within the NPS, who require a longer startup / shut-off time (nuclear power plant, thermal power plant), are not disturbed, since stopping / starting of their units is not required in no-load periods.

Other advantages the NPS could benefit of, by the existence of the pumped storage hydropower plants, are:
- participates to the frequency-power regulation;
- provides the fast tertiary reserve and the short-term emergency reserve;
- supplies reactive power and operation in compensator mode providing the compliance with the energy quality standards;
- restore of the NPS in case of a black-out;
- enhances the operating conditions of the nuclear power units and condensation thermal power units on fossil fuels and cogeneration, through the power transfer from the no-load (night and weekend) to the peak;
- improves the NPS participation to the single electricity market (exchange through interconnection within UCTE).

These are the reasons why the objective of building large PSPs has been, still since 1975, a concern related to the operation of the NPS. Thus, during the next ten years, ISPH drawn up field studies, site studies and scheme studies for carrying out such PSPs in Romania, [6]. The following aspects were considered: the need to cover the load peak; the permanent increase of the energy demand; the possibility of exchanging energy with the European power systems; the commissioning of the nuclear power units from Cernavoda Nuclear Power plant.

In this respect, there have been analyzed several sites, of which 17 site have been selected as being favorable for building a pumped storage plant. Among these, the most analyzed location was the one related to Tarnita-Lapustesti PSP, Figure 1. The capacity expected to be installed in this PSP, 1000 MW, enables the decrease of the negative impact caused at the NPS level by the potential commissioning of the 3rd and 4th unit at Cernavoda Nuclear Power Plant, the fluctuation of the power supplied to the system by the wind and photovoltaic power plants.

Figure 1. Sketch for Tarnita-Lapustesti PSP

The locations of Tarnita-Lapustesti PSP and of other six selected sites for analysis: Ignis-Firiza, Rastolita, Izvorul Muntelui, Dunare Banat, Arges-Poiana Paltinului, Dobrogea Podis, are presented on Figure 2.

Figure 2. Sites selected with BCA to be appropriate for realization of PSPs. Legend: 1. Tarnita-Lapustesti, 2. Ignis-Firiza, 3. Rastolita, 4. Izvorul Muntelui, 5. Dunare Banat, 6. Arges-Poiana Paltinului, 7. Dobrogea Podis

It has to be mentioned than no other PSP site can be compared in terms of advantages and energy-economical issues with Tarnita-Lapustesti PSP.

It should be also emphasized that Romania is among the fewest countries in Europe without even one significant pumped storage development, but it is not the only one analyzing the performing of such a plant, a similar case being the one of Slovakia, [7].

One of the most recent papers having as subject this PSP, Popa et al [8], clearly demonstrates, by means of an optimization model based on a genetic algorithm, the great possibility of integrating the future Tarnita-Lapustesti PSP into the existing Fantanele-Tarnita HPD, in addition to all the benefits for the NPS.

A recent Government Ordinance [9] establishes several measures in order to encourage the development of PSPs with the installed capacity higher than 15 MW. Beside the fact that PSPs, by themselves, and works for building them constitutes objectives of national interest and public utility, which waves many taxes and facilitates their achievement, there is one measure related to electricity balance, namely that the electricity used for pumping the water to the upper reservoir is considered to be technological consumption of the PSP.

The Romanian energy strategy for the period 2011-2035 stipulates that, at Cernavoda nuclear power plant, with two 700 MW units in operation, the other two units, of at least similar capacity each, have be completed and that the installed capacity in wind turbines has to reach the level of 5000 MW, [6].

This is the reason why Hidroelectrica has recently started a program for the identification and analysis of 10 potential sites for PSPs in the eastern part of the country, there where the nuclear power plant and most of the wind farms are located. These PSPs will balance the constant power produced by Cernavoda nuclear power plant and the unpredictable power generated by wind farms providing ancillary services.

2. SCORING METHOD FOR PSPs SITES EVALUATION

The approach used by ISPH to identify potential sites for new PSPs in the Eastern part of Romania, for Hidroelectrica, is a multi-criteria analysis shown in [6] and in a recently presented PhD thesis aiming to present and to analyze the existing and the potential new PSPs in Romania [10], named the *scoring method*.

The criteria taken into account for the selection and tiebreaker of potential sites from different alternatives are [11]:
- geometrical criteria, which refers to:
  - heads: greater than 100 m,
  - ratio between head and length of diversion: greater than 1/8;
- so-called soft criteria:
  - the existence of the lower reservoir,
  - the distance from the water supply source for the first fill-in of the upper reservoir (if there is no lower reservoir),
  - topographical issues,

- the distance to the power distribution network,
- the distance to the road infrastructure,
- geological conditions,
- protected areas;

- value of installed capacity criterion.

For these criteria used in the scoring method, there were set scores for different possible cases in order to evaluate different sites [6, 10] presented in Table 1.

Table 1. Selection criteria of potential sites for PSPs used for the scoring method

No.	Scoring criteria	Scores		
1	Head/Length of diversion	< 0,15	0,15-0,2	> 0,2
	Score	5	10	15
2	Installed capacity [MW]	< 100	100-300	> 300
	Score	5	10	15
3	The existance of the lower reservoir	No	Yes	
	Score	0	20	
4	Distance for water suply source for first filling [km]	> 5	< 5	
	Score	5	10	
5	Slope mountainside for the upper reservoir	> 45	30-45	< 30
	Score	5	10	15
6	Distance power distribution network [km]	> 50	20-50	< 20
	Score	5	10	15
7	Access road [km]	> 50	20-50	< 20
	Score	5	10	15
8	Geological conditions for diversion	strongly altered rocks	altered rocks	healthy rocks
	Score	5	10	15
9	Protected areas	Yes	Partial	No
	Score	0	10	15

In order to validate the scoring method, this was applied to six sites already evaluated from the point of view of the possibility to realize PSPs with classical studies using cost-benefit analysis (CBA), the result being the benefit divided with costs (B/C). Those sites are spread evenly over the country territory: Ignis-Firiza PSP (IF), Rastolita PSP (R), Dobrogea Podis PSP (DP), Dunare Banat PSP (DB), Izvorul Muntelui PSP (IM), Arges-Poiana Paltinului PSP (APP).
The scoring method and the comparison of the results with CBA are shown in table 2. It can be observed that the criterion 4 from Table 1: *Distance for water suply source for first filling* was not used. It is to be mentioned that CBA was applied by taking into consideration the daily cycle and a discount rate of 8%.

Table 2. Score applied for six already analyzed PSPs and comparison with classical CBA

No.	Criteria	IF	R	DP	DB	IM	APP
1	Head/Length	10	10	5	10	15	15
2	Power [MW]	15	15	15	10	15	10
3	Lower reservoir	20	20	5	20	20	20
4	Slope	5	15	15	5	10	5
5	Distance [km]	10	10	15	10	5	15
6	Road [km]	5	10	10	5	10	10
7	Geological	15	5	5	15	5	5
8	Protected areas	15	15	15	15	15	10
	Total	95	100	85	90	95	90
	Total / 100	0.95	1	0.85	0.90	0.95	0.90
	B/C	0.83	0.93	0.71	0.81	0.92	0.77

For both methods, scoring criteria or CBA, the best options are those with greater results (scoring or B/C).

Figure 3 shows, for the six potential PSP sites previously analyzed, the total scores and the results obtained applying cost-benefit method, B/C. The graphical representation was performed from the highest to the smallest value for B/C, taking into account that BCA is the classical method to determine the most appropriate options among many options. Also, the total scores were divided by 100 to enable the comparison of two pairs of values on the same graph.

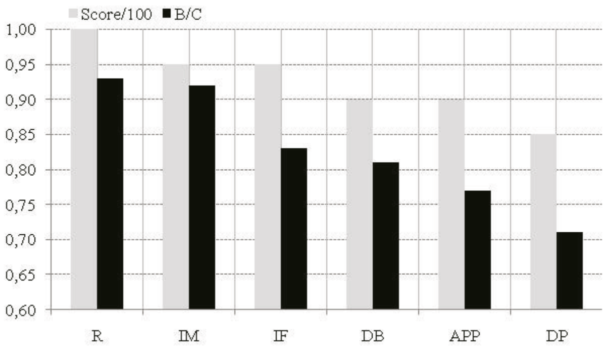

Figure 3. Score divided by 100 compared with B/C for six potential PSPs sites.

It can be easily noticed that both methods put the six sites in same order of importance. The scoring method can be considered validated and it will be used for the assessment of potential sites for PSPs in the Eastern part of Romania.

3. NEW POTENTIAL PSPs IN EASTERN PART OF ROMANIA

The scoring method based on [11] and [6] and validated as presented in the previous section will be applied in order to determine a number of potential sites for future PSPs in the Eastern part of Romania.

The envisaged counties are Constanta and Tulcea from Dobrogea and the Southern part of Moldova region, Galati, Braila, Vrancea and Buzau counties. Due to the fact that in Braila county there were not identified sites able to satisfy the requirements of a PSP, it was considered appropriate to fill up this gap by studying possible sites in Covasna county.

The number and the location of the analysed sites per county is presented below:
- Covasna county: 17 sites corresponding to Ciresu reservoir as lower reservoir,
- Vrancea county: 3 sites corresponding to Zabala river,
- Buzau county: 7 sites corresponding to Siriu reservoir as lower reservoir,
- Constanta county: 13 sites as it follows: Ostrov 1 and 2, Oltina, Valea Negurenilor 1 and 2, Ceairu Bazarghianului 1 and 2, Baltagesti, Tibrinului, Cochirleni, Negresti, Saligny and Medgidia,
- Tulcea county: 8 sites as it follows: Peceneaga, Revarsarea, Turcoaia, Jijila, Seimenii Mici, Tichilesti, Babadag, Hamcearca,
- Galati county: 2 sites as it follows: Poiana and Cosmesti (partially in Vrancea county).

The scoring method was applied for all those 50 sites and 23 sites were chosen in order to cover a more extensive area from Eastern part of the country and as much as possible in each of the six counties mentioned before. These sites are:
- Covasna county: 6 sites from which 1 site with 120 points and 5 sites with 115 points each;
- Vrancea county: 1 site with 115 points;
- Buzau county: 5 sites from which 2 sites with 120 points and 3 sites with 115 points;
- Constanta county: 7 sites as it follows: Saligny and Medgidia with 95 points each, Valea Negurenilor 1 with 90 points, Valea Negurenilor 2 with 85 points, Cochirleni with 90 points, Oltina and Tibrinului with 85 points each;
- Tulcea county: 3 sites as it follows: Tichilesti with 90 points, Seimenii Mici and Turcoaia with 85 points each;
- Galati county: 1 site with 110 points, Poiana.

From those 23 sites, 5 site were selected for a further detailed analysis. The selection criteria were represented by the score and also to have an uniform coverage of the selected region, the Eastern part of Romania.

Table 3 shows for the five sites:
Pi - the installed capacity,
I - the investment,
IPi - the specific investment of the installed capacity,
IRR - internal rate of return and
the score.

Table 3. Score applied for six already analyzed PSPs and comparison with classical CBA

PSP	Pi [MW]	I [mil.€]	IPi [th€/kWi]	IRR [%]	Score
Poiana	178	197,049	1,649	6,4	110
Siriu	148	244,053	2,082	3,5	120
Seimeni	110	210,252	1,107	2,2	85
Ciresu	100	208,171	2,071	2,1	120
Saligny	100	207,054	1,911	1,7	95

4. CONCLUSIONS

Romania has the last five HPPs in cascade forming the Ipotesti-Izbiceni sector of Olt river equipped with reversible units which enable them to operate as PSPs. Nevertheless, the total installed capacity is low and they acted as PSPs only throughout several tests. The last link with the Danube river, Islaz PSP, is missing, so that all the six power plants should operate as a whole, pumping up water from the Danube river when possible, and releasing it through turbines when needed. The existing five power plants can be considered as close circuit PSPs.

Three multipurpose HPDs with PSs can be considered as open circuit PSPs, and namely: Lotru with 3 PSs, Sebes and Dragan-Iad with 1 PS each. The only advantage is that they use in turbines the water pumped up at a larger head than the pumping height.

Taking into account the large penetration of RES and the further development of Cernavoda nuclear power plant, there is definitely a need for PSPs in the Romanian NPS with all their benefits in terms of energy storage and ancillary services.

On the basis of the existing studies for potential sites of PSPs it has been validated a scoring method much simpler that the classical BCA, and which allows a quicker analysis of a large number of sites.

The beginning of the use of scoring method was done for the Eastern part of Romania. Successively, by using this method, 23 sites and then 5 site were selected from the 50 analyzed sites in order to be thoroughly analyzed in terms of PSPs building. For these site there performed feasibility studies and some results are presented in Table 3. Comparing the results obtained with the scoring method with the IRR one can conclude that the first one remains a qualitative method even if a good one.

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