REFURBISHMENT AND UPGRADING THE LOWER OLT HPP-S - AN IMPORTANT CONTRIBUTION TO INCREASING HIDROELECTRICA'S CAPACITY OF PROVIDING ANCILLARY SERVICES

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Originally designed for multiple use (energy generation, irrigation and navigation), the operation of lower Olt HPP-s faced many difficulties arisen from the inappropriate quality and efficiency of the mechanical equipment which failed to function under reversible, turbine and pumping mode.

All those equipments, after an ample refurbishment and upgrading process, will successfully function at 265 MW under reversible mode, thus increasing Hidroelectrica's capacity to provide ancillary services.

Keywords: equipment tear and wear, refurbishment, increase of technical parameters.

1. Introduction

On Slatina-Danube sector of Olt River, five hydropower plants, namely Ipotesti, Draganesti, Frunzaru, Rusanesti, Izbiceni were built; the last stage, namely Islaz, that is going to pump water from the Danube, is not realized yet.

Each of the five hydropower plants on the Ipotesti - Izbiceni sector, which were commissioned between 1986 – 1999, is equipped with four reversible bulb units, designed to operate with P=13,25 MW / unit, resulting a total installed power of 265 MW in turbine mode.

The Danube-Slatina sector has been designed to satisfy the following requirements:

- Providing the water levels for the irrigation of the farmed neighbouring land surfaces;
- Generation of more than 500 GWh/year of electric energy by using the available hydroelectric potential of Olt River;

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- Protection against the flooding of the neighbouring areas of Olt River;
- Providing the facilities for the shipping of products obtained in the agricultural area from the upstream of Slatina city, as well as necessary materials from import in the Slatina industrial area;
- Providing the safe road connections between the two banks of the Olt River;
- Obtaining of important water surfaces for the pisciculture development.

The units have been executed in Romania, as a result of a domestic design. The fact that they were not based on sufficient studies and experiments, led to many deficiencies during the operation. The number and great importance of these deficiencies led to extremely high maintenance costs, to significant power restrictions and large unavailability periods.

After concluding the technical and economical analyses and obtaining the endorsements, approvals and decisions according to the laws in force, the contract for refurbishing the equipments of the five HPP's was signed with a Consortium led by Voith Siemens Hydro Power Generation in April 2004.

The works have started by performing model tests for the hydraulic machine in the EPF Lausanne Laboratory in May 2005; at present, the refurbishment works are in progress at 4 units. The completion of works for all twenty units is scheduled for September 2010.

2. Need of works

The necessity of the refurbishment works appeared as a result of the following:

- Major technical accidents: break of the turbine shafts occurred at Frunzaru HPP(HU2) and Draganesti HPP (HU1, leading to the flooding of the power plant), and generators burnings;
- Failure to operate in pumping mode;
- The multitude of technical failures: heating of the generator winding, bearing binding, oil loses, water loses at seals, excessive vibrations, output restrictions, fatigue cracks at turbine shafts;
- High maintenance and operation costs;
- Long periods of out of operation.

Related to the **power unavailability**, we must highlight that, compared to the total installed capacity of 265 MW, on December 31, 2006 only 184 MW were available, which means that approximately one third of the installed capacity was not available, as shown in **Table 1**.

More than 500 major incidents occurred during operation, with a total unavailability time reaching 35.381 hours and 836 million kWh lost because of overflow.

The following table contains the hourly powers – the minimum, average and maximum powers reported at the end of year 2006 for each unit and HPP.

Table 1. Hourly powers recorded at the end of year 2006

HPP	Power [MW]	Unit 1	Unit 2	Unit 3	Unit 4	Total
Ipotesti	minimum	5	6	5	5	21
	average	5	8.75	6.375	9.12	29.25
	maximum	5	11.5	7.75	13.25	**37.5**
Draganesti	minimum	6	0	6	6	18
	average	7.5	0	9.62	9.62	26.75
	maximum	9	0	13.25	13.25	**35.5**
Frunzaru	minimum	3.38	6	6	6	21.38
	average	7.5	8	6.5	8	30
	maximum	10	10	7	10	**37**
Rusanesti	minimum	4	5	6	6	21
	average	5.5	7.5	8	8	29
	maximum	7	10	10	10	**37**
Izbiceni	minimum	4	4	4	6	18
	average	6	7	7	8	28
	maximum	8	10	10	10	**37**

Related to the **high maintenance costs**, we believe that it is enough to specify that since 1986 to 2006, the costs related to unforeseen works reached USD 85 millions, plus the costs related to an annual oil consumption of approximately 30 tons. Besides the high cost of the maintenance works, it is important to mention also the cost increase tendency, which is presented in **Fig. 1** below.

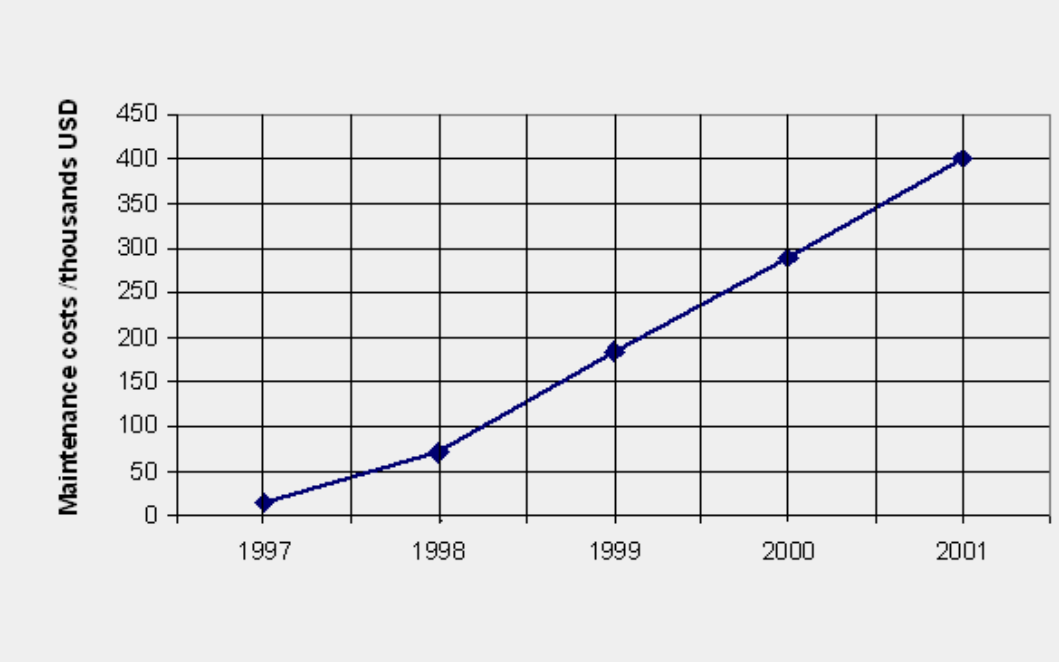

Fig. 1. Average annual costs tendency at Slatina-Danube

Besides the obvious necessity for some ample refurbishment works, the analyses have also shown their opportunity, mainly consisting of the following:

- The existence at international level of new technologies with a higher reliability than the initially applied solution;
- The state-of-the-art in the electronic field allow execution of installations with automatic remote control systems;
- The feasibility study shows the efficiency of an important volume of refurbishment works.

3. Existing equipment technical status

The technical status of the units in the five HPP-s located on the Lower Olt can be characterised as extremely unsatisfactory.

Out of the many recorded flaws we shall only mention the following:

- break of the turbine shaft occurred at HU1 Draganesti in January 1999, which led to the flooding of the power plant, with the associated prejudices (related to cleaning the power plant, replacing the flooded engines, drying the generators, degradation of approx. 21 tons of oil, loses due to discharging the water that could not be energetically used any more

etc.). The unit had not been available for 2 years and 3 months, and the repair cost was of approximately ROL 3 billion.
A similar event occurred at HU2 Frunzaru.
Such events can endanger the safety of the operating personnel.
It is worth mentioning that after carrying out the NDT tests the results showed that the shafts of all turbines had fatigue cracks in the transition area to the coupling flange of the rotor hub.

- The units have never succeeded to operate in pumping mode. The tests performed on a unit have shown that even for low testing values (4-5 MW), the unit has an unsatisfactory behaviour, with a worrying noise level, specific to cavitation.
- There have not been reached the design parameters for the generator, which has a faulty ventilation and cooling system. Due to generators' overheating, the average operating powers were retained close to the minimum guaranteed value. HU2 Draganesti has been completely withdrawn from operation in 2003, as a result of the major deformation of the stator, which led to frictions in the rotor. This generator had operated for a long time at a power restricted to 5MW and its repair was very expensive.
- The measures taken by the employer and the supplier in order to improve the operation of the units did not have notable results because of the major design and initial execution deficiencies.

4. Main applied new technical solutions

The analyses of the major deficiencies occurred during the units operation have shown that the entire machine (pump, turbine and generator) had to be redesigned and replaced. Outer hydraulic contour with embedded parts will stay in their original condition, except for the discharge ring and outer distributor ring.

The hydraulic machine (except for the stay vanes) and the generator will be replaced, and the bulbcasing, hatchcover, operating ring and draft tube liner will be refurbished. All the auxiliary installations of the unit and HPP will be subject of remedy and replacement works.

The main applied new technical solutions are:

4.1. The turbine runner (with the nominal diameter of 4500 mm) has 5 (instead of 4) blades, made of 13% chromium steel and a nominal speed of 130.4 min^{-1} (instead of 125 min^{-1}).

4.2. The hydro unit has only one shaft instead of two. The generator rotor and the turbine-pump runner are directly coupled with the turbine shaft via pre-stressed bolts. The torque is transmitted by friction.

4.3. The existing hydro unit has 3 guide bearings (two for generator and one for turbine) and one axial bearing.
The new hydro unit has only one runner side guide bearing and one combined guide and thrust bearing.

4.4. The design of the guide apparatus is new and improved related also to the pump mode operation.

The wicket gates are actuated by only one servomotor and one closing weight as shown in **Fig.2**.

The closing weight is mounted onto the regulating ring and closes the guide apparatus from any position and under any operating condition on failure of the governor oil pressure.

Simultaneously it prevents opening of the wicket gates in “closed” position by the water pressure:

The complete guide apparatus is mainly maintenance-free and requires no lubricants.

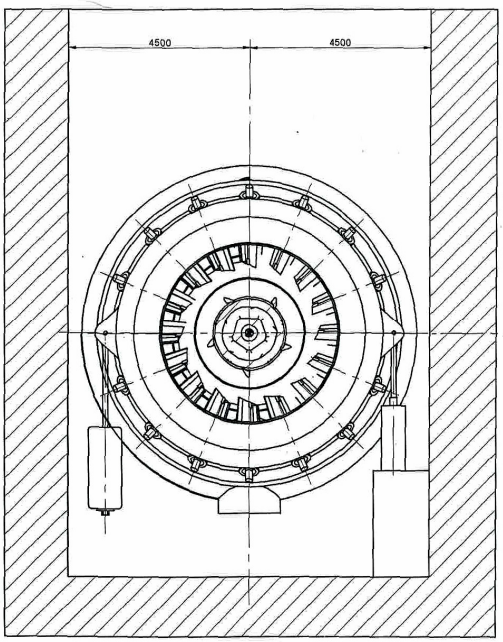

Fig. 2. Servomotor and closing weight

4.5 The generator is designed to eliminate the deficiencies occurred in the operation of the existent units.

In **Fig. 3** a cross section through new bulb unit is presented.

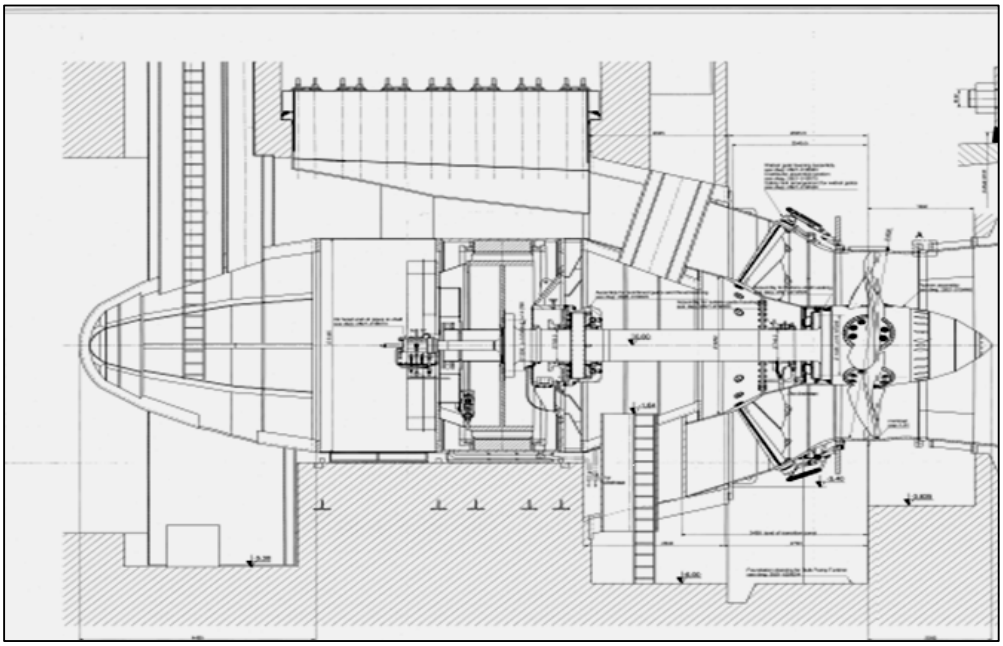

Fig. 3 Cross section through new bulb unit

5. Technical performances after the refurbishment

By this project the main aim was the units to achieve the initially designed parameters, to realize the pumping regime, to eliminate the occurred deficiencies in operation and to ensure a new operating cycle.

According to the feasibility study that was the basis for the contracting of the work, the following performances will be obtained:

- installed power in turbines: 265 MW
- installed power in pumps: 210 MW
- average energy in the natural inflow: 795,9 GWh/year
- generated energy on Ipotesti-Izbiceni sector from the pumped inflow: 148,1 GWh/year
- total generated energy on Ipotesti-Izbiceni sector: 944 GWh/year
- electric energy consumption for pumping on Ipotesti-Izbiceni sector: 259,5 GWh/year

Must be mentioned the fact that the model tests confirmed the required power parameters achievement and a substantial increase of the average weighted

efficiency of the hydraulic machine, with around 2% from the existent turbines and even over the required contractual guarantees, that is:

- turbine regime: guaranteed 91,80% - realized 91,85%
- pumping regime: guaranteed 74,55% - realized 78,41%
- combined regime: guaranteed 87,54% - realized 88,57%

6. The main benefits of Lower Olt River project

- Availability of the entire installed power of 265 MW in the existing HPP.
- Ensuring the operation in pumping mode in order to provide the needed water for irrigations.
- Creating the possibility for the Units' participation on the ancillary services market.
- Increasing by 20% the average multi-annual energy production after year 2010.
- Ensuring a new life cycle of 30 years for the equipments.
- Increasing the safety conditions for operation, operating staff and the environment.
- Reducing the maintenance and operation costs in the next 30 years

Conclusions:

The refurbishment works for the equipments have been necessary and opportune.

The results from the carried out model tests, the quality of the equipment manufactured by present as well as the actual works status, lead to the idea that the refurbishment of the five hydropower plants on Lower Olt will be a successful project that solves one of the major technical problems of the national hydroenergetic system.

In the development strategy of Hidroelectrica it is foreseen the completion of the cascade with the last step, HPP Izlaz, that will allow the pumping from Danube.