Rehabilitation and modernization of HPP Djerdap 1, Serbia, Europe

1. General

The Iron Gate I Hydroelectric Power Station is the largest dam on the river Danube and one of the largest hydro power plants in Europe. It is located on the Iron Gate gorge, between Romania and Serbia. Romanian side of HPP is called Porțile de Fier I, and the Serbian side is known as Ђердап I, Đerdap I).

The Djerdap Hydropower and Navigation System consists of an overflow dam, located in the middle of the river, two hydropower plants at the dam toe in the extension of the dam towards the banks, and two double-step navigation locks located between each power plant and corresponding bank, respectively.

2. Navigation lock

The difference in the height of water between upper and lower lake is 20 meters, so the vessel transport would not have been possible without a navigation locks on both Romanian and Serbian sides of the river. The process of vessel trafficking is nothing less important, and Djerdap 1 is therefore called - the hydroelectric and navigation system.

Pict. No1 - Navigation lock for vessels trafficking. With a length of 310 meters and a width of 34 meters, this navigation lock is one of the largest in the world.

3. Hydropower plant

The 441m long overflow gravity dam, with spillway sill elevation at 55.20 m, has got 14 spillway bays – each 25.0 m wide, on 7.0 m wide columns separating the spillway bays. Depending on the quantity of water inflowing by the river, the headwater level varies from el. 69.5 m to el. 63.0 m.

Pict.No 2 - Exactly at the half of the dam is the state border between Serbia and Romania.

Each power plant is at the dam toe, 214.0 m long, and consists of an intake structure, machine hall, draft tube and erection bay. Each machine hall houses 6 vertical units with Kaplan turbines 9.5m in diameter, directly coupled to a synchronous generator.

The Romanian side of the power station produces approximately 5.24 TWh annually, while the Serbian side of the power station produces 5.65 TWh. The discrepancy in power output between the two halves is due to the generating equipment.

While Romania's equipment is newer and thus more efficient (thereby generating more power), it is proving more unreliable; resulting in increased downtime for maintenance/repairs, and consequently lower annual power output overall.

The project of building HPP started in 1964 as a joint-venture between the governments of Romania and Yugoslavia for the construction of a major dam on the Danube River which would serve both countries. At the time of completion in 1972, it was one of the largest hydroelectric power stations in the world with twelve units generating 2,052 MW, divided equally between the two countries at 1,026 MW.

Pict.No 3 – The hydropower units - Machine hall.

4. Modernization of HPP

As the original turbines' 40 years lifespan came to an end, in 1998 the Romanian half of the dam started a program of modernization.

As part of this program, the first of the turbines was stopped in 1999. By 2007 the program was completed and the Romanian half of the dam's operations were back to full capacity.

The nominal capacity of each of the six units was increased from 171 MW to 194.3 MW, thus giving an installed capacity of 1,166 MW and increasing the entire power generation capacity of the dam to 2,192 MW at the time.

On the Serbian part of the dam, modernization started in July 2008; so far Units 1 and 4 to 6. The units are being upgraded from 171MW to 190MW, with the help of Russian company Power Machines from Saint Petersburg, as well as their subcontractors with the participation of eleven domestic companies.

After the reconstruction process, the hydro power plant's capacity will be increased by 10%.

The production itself starts with turbines that are located under the machine hall of the hydroelectric power plant.

Only the weight of one of the six blades of the steel turbine is 16.5 tons, and are fastened with screws with a weight of 90 kilograms.

Pict. No. 4 - Only one blade of a steel turbine is heavy at 16.5 tons

Pict. No. 5 - A steel turbine screw weighing 90 kilograms

Part of the hydropower units that river Danube rotates at a speed of 71 revolutions per minute is about 1,300 tons heavy and this is just the beginning of the entire process, because mechanical energy, translated from turbines from the Danube, needs to be turned into an electric one.

This is done thanks to impressive rotors and stators.

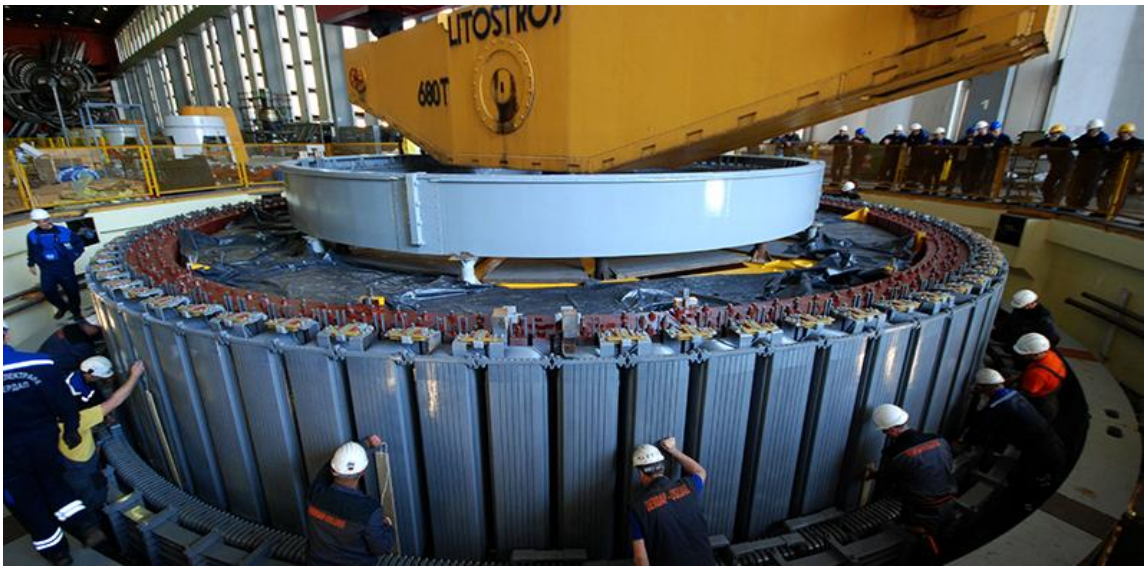
The turbine continues on the rotor with a weight of 630 tons.

Such a rotor, thanks to the power of water, rotates in 330 tons of heavy stator.

Pict. No. 6 – Stator

Although the diameter of the rotor is fifteen meters, the distance between rotor and the stator is only 19 millimeters, and precisely in this process, due to electromagnetic induction, there is appearance of current.

The current is then transmitted to the step-up transformer with appropriate equipment. It changes its voltage from 400 kilovolts to 15.75 kilovolts, and the electricity is further sent from the 400 kV switchyard by transmission lines to big cities in Serbia, while one of transmission line goes to Romania.



Pict. No. 7 – Positioning of rotor into stator frame with mutual distance of 19mm

Reconstruction of Djerdap 1 HPP units is in progress and estimated to continue during the next 3 years. Four 4 new units have been put into operation to till today.

The installed apparent power of each particular unit after completed reconstruction shall be 211.11 MVA.

The entire upgrade process is expected to be completed in 2020, when HPP Djerdap 1's installed capacity will be increased by 114 megawatts.

Scope of modernization includes the following equipment replacement:

- generators,
- excitation system,
- turbines runner blades,
- turbine governors,
- step-up transformers,
- units and step-up transformers cooling water equipment,
- units and step-up transformers control and protection equipment,
- generator voltage equipment (armored busbars, switchgear, measuring transformers),
- auxiliary power supply distribution boards,

- equipment for fire detection inside generators and step up transformers.

New equipment for monitoring of generator parameters are also installed (partial discharge, vibrations, air gap, temperatures of stator core, windings and unit bearings).

Temperatures of windings and oil, gas and humidity in oil are monitored for step-up transformers.

The amount of produced electricity depends on the flow of water which, again, depends on the height of the water in Djerdap Lake that the dam forms.

However, with the regulation of the water level in the lake it must be cautious.

For example, if it was higher than it is allow, it might happen that the Danube floods a part of upstream towns!

Because of this, but also in many other circumstances, there is a Control Center that actually represents the brain of the whole system.

All the data necessary for the functioning of the hydropower plant are sent there and processed by industrial computers (computer center).

In addition to the water level in the lake, there is also the measurement of water flow through the turbine, the temperature, the load management between the generators, the system synchronization, the rise and fall of power, the switching on and off of the generator.

There is also the possibility of secondary regulation, which means that the remote system works hydropower plants can be operated from the Head control center placed in Belgrade.

5. Overhaul of Navigation Lock

Overhaul of Navigation lock is currently in progress.

Scope of works include civil and architectural works on Control tower gondola reconstruction, as well as Engine rooms and external cable trays adaptation works.

Procurement of the new electro-hydraulic installations for gates drives, electrical equipment for control and power supply systems, cranes equipment and all of the Navigation locks auxiliary systems equipment, such as radar system, public address system, traffic light signalization, gates stress monitoring system, etc.

6. References

- **Upgrade of navigation lock of HPP Djerdap 1- Basic design, ENERGOPROJEKT, Belgrade 2017.**
- **Rehabilitation of HPP Djerdap 1 – Detailed design, ENERGOPROJEKT, Beograd 2010.**
- **JP EPS Ogranak HE Djerdap – Web page**

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