IRON GATES II – ROMANIA, 10 BULB UNITS UPGRADING

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At Iron Gates II Hydro Power System (HPS), the modernization of 10 large bulb units is almost in the middle of the contract execution and first feed-back can be provided. This publication deals with an overview on the past and present activities as well as results and experiences related to the upgrading and modernization of these ten bulb units. Focus is given on the turbine, the generator, on the Automation, Control and Protection systems (ACP) and on the operation of the whole power plant while modernization works are being performed.

The upgrading targets, the corresponding development activities, the results and the acceptance tests in 2 laboratories are presented. The delivery of the new turbine components and the refurbishment of the generator are described. The electrical modernization where complete generator components of the existing units have been overhauled and refurbished had to consider the special aspect of water cooled stator & rotor windings and rotor poles as well.

The completion of the powerhouse related auxiliary systems is another key success factor of this modernization. To modernize the complete auxiliary systems and the complete control and protection system in an uninterrupted operating powerhouse is a complex logistic and demanding task. Special attention is also given to the ACP activities and the description of the new system providing highest availability. Site works included a full test program of dimensional, mechanical and electrical tests prior to dismantling of the units and before commissioning.

Prior to dismantling of the first unit for the modernization an index test has been done to establish the existing performance. With the first modernized unit, again site tests at two heads have been performed. These field tests, together with the comparative, fully homologous model tests for the "old" and the new hydraulic shape of the runner blades have confirmed the smooth operational behavior and the guaranteed performance. The contractual maximum output of 32.5 MW for the turbine represents an output increase of 16%. The site tests revealed 35.46 MW. All these important improvements ensure a significant increase of the annual energy production without any change of the civil construction and without increasing the runner diameter.

Four practically new units have been taken back into commercial operation at present. The fifth Unit is now in progress and is expected to be back in commercial operation during July 2010. The last Unit should be commissioned during 2014.

Keywords: Refurbishment, runner replacement, model test, index test.

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1. Introduction

The Hydroelectric and Navigation System Iron Gates II (Por□ile de Fier II) is located on the river Danube and had originally a total installed power of 540 MW in two plant systems, Romanian and Serbian, of 270 MW each. The Romanian plant system includes 8 bulb hydro-units in the base power plant Iron Gates II and 2 bulb hydro-units in the power plant Gogo□u (see Figure 1).

The Romanian Power Company S.C. Hidroelectrica S.A. in Bucharest, Romania contracted with VA TECH Hydro (ANDRITZ Hydro) for the Iron Gates II Hydro Power Plant and Gogo□u a complete rehabilitation of the electro-mechanical equipment of the 10 Bulb Hydro Units.

The rehabilitation process and upgrading are to be combined not only for the purpose of increase in power output and efficiency, but also from the point of view of the safety operation of all plant system installations, preparation of the hydro unit, as an assembly, for a new cycle of operation of 30 years, to manage the operation of Iron Gates cascade in an optimized way and to prepare the operation of the units with remote control.

Fig.1. General lay-out of HPS Iron Gates II

Technical data of HPS Iron Gates II are:

- Turbine type: horizontal Bulb
- Original suppliers: LMZ (2 units) & UCM Re□ita (8 units)
- Number of units: 8+2
- Years of commissioning: 1984–1986; 1993–1994
- Country: Romania
- Rated head: 7.45 m (original)
- Head range: 2.5 – 12.75 m

- Rated output: 27 MW
- Speed: 62.5 rpm
- Runner diameter: 7500 mm
- Runner number of blades *Z*: 4
- No. of hours of operation: ~ 8000 hours/year.

2. Turbines

The eight units on the main Iron Gates II HPP (see Figure 2) were commissioned between 1984 and 1986. During the operation period of more than 20 years, cracks on the welding zone of two turbine shafts (Unit 4 and Unit 5) and the start process of cracks in the flange area, near the connection with the runner hub, caused severe problems. As a provisional measure, the cracks were grinded, the edges were well hollowed and the holes were then repaired by welding. Later checkups were made yearly, with even greater number of cracks recorded.

The dismantling of the first unit (Unit4) started in March 2004, and works in the workshop and site are ongoing at present on the 5th unit (Unit8).

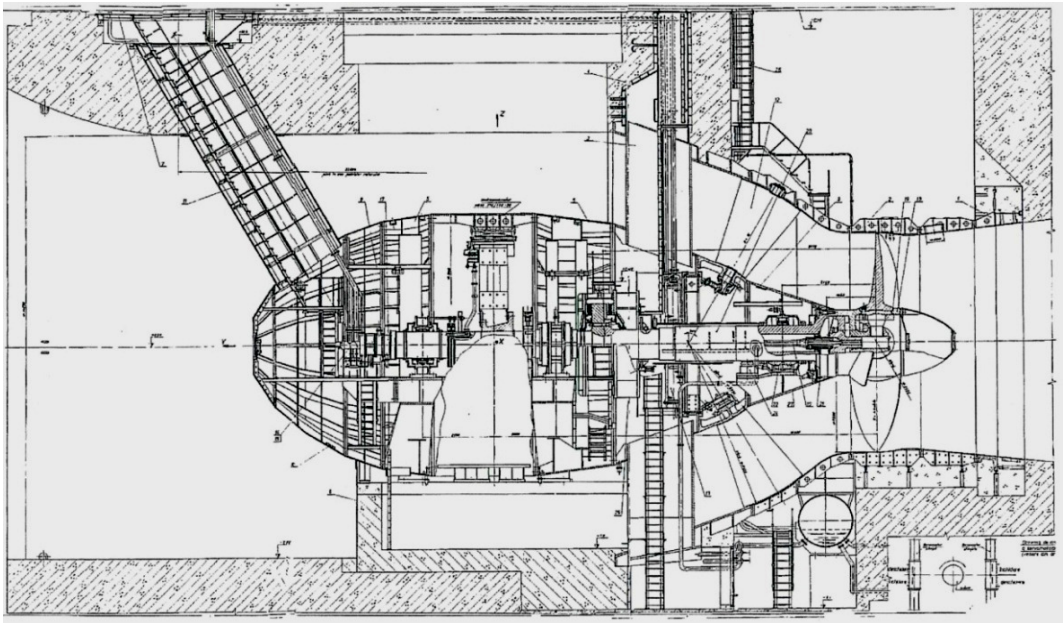

Fig. 2. Layout of the Iron Gates II bulb hydrounit

2.1. Refurbishment works for turbine and auxiliary installation of turbine

The overhaul works are consisting in the replacement of some parts of turbine that cannot be reused for a new life cycle; all other equipments had been rehabilitated and upgraded by applying new solutions enabled by engineering experience. The civil construction is not affected by the foreseen works, the intervention consisting in repairing works or some special treatments applied to the concrete.

Therefore, the technical solutions will be considered as the followings: maintaining the Turbine Runner diameter (7500 mm) with new designed blades; possible replacement for some parts will not affect the existing geometry of hydraulic circuit. The overhaul works and upgrading are done by increasing the rated turbine output from 28 MW to 32.5 MW. The replacement of two turbine shafts (Unit 4&5) is provided, all other 6 are foreseen to be transported to the workshop in view to be 100% checked and rehabilitated.

The rehabilitation in the workshop of all important subassemblies is also provided, such as: hub, hub –inner mechanism, wicket gate apparatus, oil head and oil pipes in shaft etc. The rehabilitation of the embedded parts of turbine (stay vanes, runner chamber, liners, platforms etc) is provided on site, as well as other components that will not require a special machining in the workshop.

The scope of works for the governor and governing system has included the replacement of the speed regulator with a numeric one, integrated in the automation and control system for the hydro unit, the replacement of the electro-pumps, replacement of the control elements and transducers. All other components will be rehabilitated in the workshop or at site, correlated to the situation. A new design (shell type bearings equipped with oil injection system) for the radial bearings is provided. The replacement for all transducers and for the control & measuring apparatus is also provided.

A completely new measuring system for hydraulic parameters related to each Hydro Unit that will enter on the exchange data system with the Serbian part within the cooperation activities for sharing the hydro-energetic potential of Danube on Iron Gates area will be delivered.

2.2. Comparative tests on model and prototype

According to the specification of the contract homologous models for the original and new turbines were built and investigated by laboratory tests. In the first stage, comprised development tests and model acceptance test related to force and torque measurements, have been performed in the VA TECH Hydro laboratory in Linz, Austria. The performance acceptance tests were performed in the neutral laboratory of the Technical University of Lausanne according to the

technical specification agreed by the Serbian and Romanian parties. The old and the new runner were measured and the guaranteed performance improvement was checked and confirmed. The weighted efficiency covering the important operating points could be increased by 2.2%. The output increase was achieved without higher cavitation risks.

The cavitation inspection after 8000 hours of operation at three units until now, confirmed the cavitation behavior on the model test – no signs of cavitation erosion. Index measurements were done before and after rehabilitation in order to verify the improvement potential achieved by the overhaul and replacement. The measured maximum output amounted to 35.46 MW and the new guaranteed for turbine output of 32.5 MW was exceeded significantly by 9% (see Figure 3).

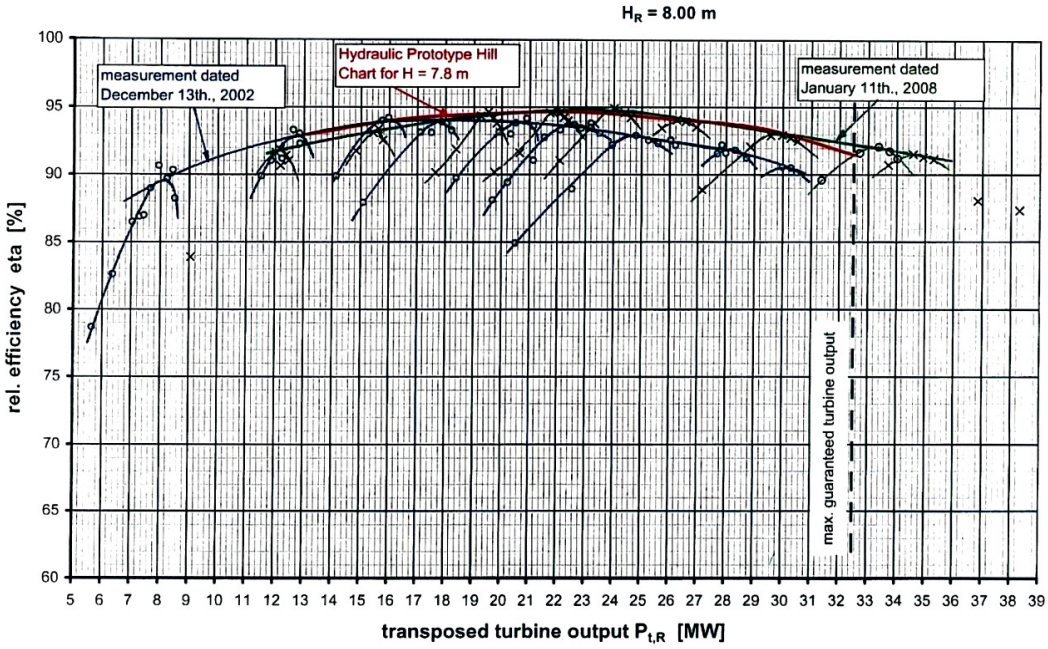

Fig. 3. Efficiency and power output improvement at rated head

For the significant range of gross head H_b the efficiency of the refurbished Unit (HA) is bigger than the original one. An example for three gross heads is showed in Figure 4.

The yearly energy production of the refurbished units is increased.

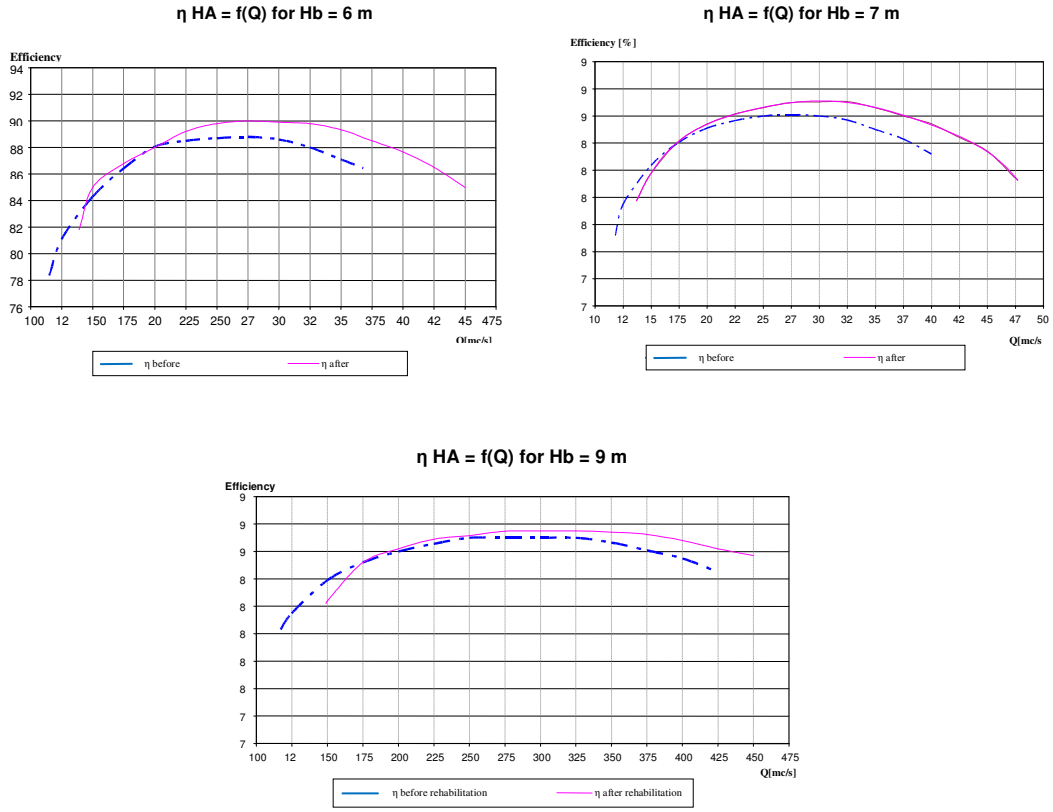

Fig. 4. Efficiency improvement at different gross head

3. Generator

The overhaul works with the upgrading of the Generator and Auxiliary Installation of Generator (see Figure 5) comprise the followings:

- Re-usage of a bigger amount from the existing components of Generators, being possible by taking into account the important resources that the generators maintained in connection with electrical, magnetic and heat requirements;
- Implementation of a new excitation system, including a transformer excitations;
- Replacement of the automation, control and electrical protection equipments on the updated technology level;
- Installation of monitoring and diagnose systems.

The works that are carried on are the following:

- The Generator casing is re-used, modifications are done to the casing only in the case that defects are discovered on the metallic structure after the checking and inspections schedule;
- The Generator core is reused. The core is inspected and checked, for dimensional check, tightness, fixing in the casing, local defects. The core is split up in separated sectors and the planes of separation are compacted.

The stator winding has to be inspected and to follow a set of tests and checking. The diagnose program has as purpose to establish the status of the insulation and its life cycle. The works include the replacement of defect bars during the tests, repainting of varnishing, cleaning of the cooling water system by distilled water, the replacement of Teflon tubes, the checking and repair of the circuits (water circuits and electric circuits).

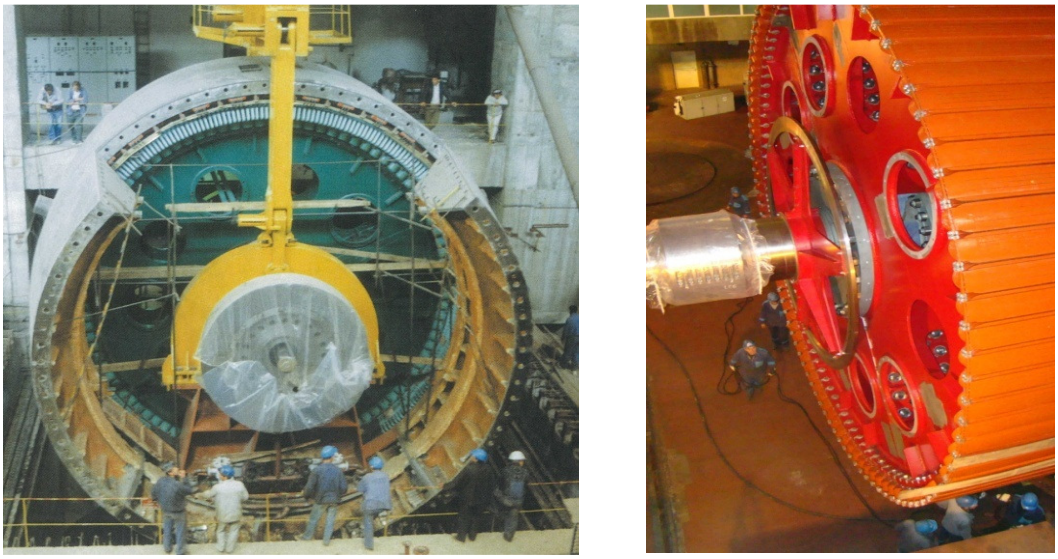

Fig. 5. Generator stator and rotor

As a consequence of damage for the shrinking coupling during the operation, two hubs to the generator rotor (generators no. 3 & no.7) and one generator shaft (generator no.3) are also provided as replacement works. The shrinkage between hub and shaft will be checked at all generators, specifically due to the new power increase.

The rotor poles must be dismantled from the rotor rim, must be inspected, tested and reconditioned. The replacement of main insulating is provided, if this one was heated up. The checking and repairing for all circuits (cooling water circuits and electrical circuits) is also provided.

The replacement of all transducers and all measuring and control devices is also provided. Instead of regulating generator, the installing of a new braking system is provided. The excitation system will be replaced by a new one, being a component for the automation and control system.

4. Refurbishment of parts. Fabrication of new parts

After dismantling the parts (turbine and generator), a NDT examination is performed. The bad condition of many parts (e.g. turbine shaft, guide vane, turbine servomotor piston, thrust bearing pads, generator hub) proved the necessity of the rehabilitation. Only for example, at the 5th unit that is in the process of rehabilitation now, all trunnions of the guide vane showed cracks in the welding area between guide vane and trunnion (see Figure 6).

Fig. 6. Excavation on guide vanes long trunnions

Additional unexpected refurbishment measures must be taken in this case. The guide vane must be transported in the factory, the trunnions were cut off and new trunnions were welded to the guide vane bodies. This bad condition of the above mentioned parts was partly caused by the poor original fabrication and quality test methods applied at that time and partly by wear during the time of operation. The parts are also on the critical path of the execution schedule with time impact. For these reasons, to reduce the time impact and the cost with time impact the decision was taken to order the fabrication of new parts (e.g. one new

turbine shaft, two new turbine servomotor piston, one new generator hub and two new guide vanes).

5. Hydro-mechanical components

The following equipments are included as hydro-mechanical equipments:

- emergency roller gates (ERG), trash racks from upstream intake of hydro unit
- pumps installations for ERG.

The rehabilitation works must be performed for the existing metallic structure (without any structure modifying).

All the elements from automation and control system as well as the ERG pump installation are entirely replaced. The detailed checking for metallic elements must be performed, and following to decide exactly the scope of rehabilitation works, depending on the conclusions found on the expertise reports.

6. Power electrical systems

On the Power Plant, the diagnose programs for the electrical systems must be performed with the purpose to find the technical status and spare life duration and also to check the reliability of equipments in view to support increased power parameters.

For power transformer of 63 MVA the rehabilitation works with an increase of rated output at 67 MVA are provided. The transformers are transported to the workshop in view of performing the refurbishment works.

For bus ducts (one phased) with a small size the diagnose program must be performed in order to establish its reliability to support the new parameters of generator. If it is the case, the bars will be refurbished accordingly.

7. Automation, command and control systems

Old systems must be replaced by new ones that will have numerical equipments with four command levels: local; machine hall; control room; dispatch center. The Control System is based on VA TECH Hydro's 250 SCALA product line.

The Automation System provides data acquisition, signal processing, and communication to field equipment, communication to Control System as well as related processing and control functions.

The diagnosis and monitoring of the hydro units and their auxiliary equipments is made by the Monitoring and Diagnosis System.

The communication between Control System, Automation System, Protection System, Monitoring and Diagnosis System is based on an Ethernet network in redundant configuration.

8. Conclusions

The rehabilitation program applied to the hydro power plants Iron Gates II HPS offers a chance to make design change and use improved materials, thus refurbishing and modernizing the machinery, which translates into a trouble free, safe and reliable operation over a long period (another 30 years).

Four new units have been taken back into commercial operation at present. The fifth unit is expected to be back in commercial operation by the end of July 2010.

With the new runner, the output of the upgraded turbine increases by 16% (from 28 MW to 32.5 MW). The index test performed on site revealed 35.46 MW. This is all more remarkable without any change of the civil construction.

Also, the weighted efficiency has been increased by more than 2% and no cavitation on runner blades and discharge ring has been recorded.

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