Challenges for the modernization of the Baygorria plant, Uruguay

C. Calderaro, Stantec, Argentina

Signs of wear on the generating units at the 105 MW Baygorria hydro plant on the Rio Negro in Uruguay have become more pronounced over the years and it has become clear that an upgrade is required. Several challenges and constraints to the modernization process have been identified, which are described here, along with the measures taken. The upgrade will begin early next year.

Construction at the Baygorria hydropower project in Uruguay began in 1956 and the plant officially opened in 1961. Since then, it has provided clean renewable energy for the grid system with an impressive record of reliability. The Uruguayan Power Company (UTE), owner of the powerplant and the national electrical utility of Uruguay, started performing engineering studies for the plant in 2015. In 2020, the company released a call for tenders to carry out refurbishing works on the plant under a turnkey arrangement, including the development of detailed engineering, site preparation, equipment supply, dismantling and assembling, tests and trials, and control systems replacement. UTE is currently preparing for the execution of this work and the plant upgrade.

1. Project details

The 105 MW capacity plant is one of the three on the Rio Negro and operates as a run-of-river installation. The plant is still equipped with three original Swedish Kaplan turbines manufactured by Nohab and Siemens. The Rio Negro is the largest river that flows across Uruguay from north to south, and becomes a tributary of the Uruguay river, which is shared between Uruguay and Argentina.

The dam was designed with a spillway flow of 9500 m/s, a river module of 572 m/s, reservoir at el. 54, and a reservoir surface area of 100 km^2. The nominal net head of the original units was 14.7 m, corresponding to a runner centreline set at el. 36.8, delivering 35 MW, with a nominal flow of 276 m^3/s, and generators selected for 36 MVA at 0.95 power factor. The powerhouse design includes a highway that passes along the roof and consists of a very narrow building with a roof hatch of 8.5 × 6.15 m, which is used to lower the major power generation equipment.

The 105 MW Baygorria hydro plant in Uruguay.

2. Decision to upgrade

The units at Baygorria run with fair efficiency and have only experienced minor disruptions to operation, so no major intervention has been necessary since their commissioning. Nevertheless, there are clear signs of wear and tear and an increasing need to upgrade the main power generation equipment and auxiliaries.

During the modernization planning, several factors were weighted to decide on upgrade alternatives for the equipment. Some of those factors required a straightforward decision, as there were components such as the generator rotors that had undergone several crack repairs and were most likely reaching their fatigue limit. In the same way, the stator winding that was never replaced was showing signs of aging and the need for replacement. Turbine components were showing signs of wear, but their condition was fair, and unless major efficiency gains were obtained, their replacement would not be economically feasible. This was the case for the guidevanes, the replacement of which, when considering age and condition, did not justify the minor efficiency gains that could have been achieved.

3. Challenges

The most obvious and major restrictions affecting a possible upgrade to Baygorria were the narrow powerhouse, as well as the dimensions of the hatch. In addition to those, the capacity of the external gantry crane also posed a limitation, when considering the replacement or upgrading of the existing units.

When deciding on a reliable output, the greatest challenge for a unit upgrade is cavitation, meaning the formation of voids within. As the tailwater levels and runner submergence are predetermined and can hardly be modified, the question was how much incremental flow could be allowed to pass through the turbine safely, and still operate with no cavitation, or with a safe margin against sigma break.

This was the challenge for the Baygorria turbines: deciding the new unit output, obtained by incremental water flow and geometry modifications to the hydraulic neatline of the turbine, mainly the runner. As mentioned above, the runner hub diameter will be reduced, allowing more flow through the unit, while maintaining the runner blade diameter. That means the higher flow will yield more unit output. However, as the flow speed increases, so will the cavitation risk. Hence, a good balance between output gain and cavitation needs to be achieved. The starting point for this analysis was a hub/blade diameter ratio $\upsilon = 0.44$, with a turbine diameter of 6689 mm, and a discharge ring diameter of 6700 mm, based on the existing designs of the Swedish manufacturer. The new units will have a

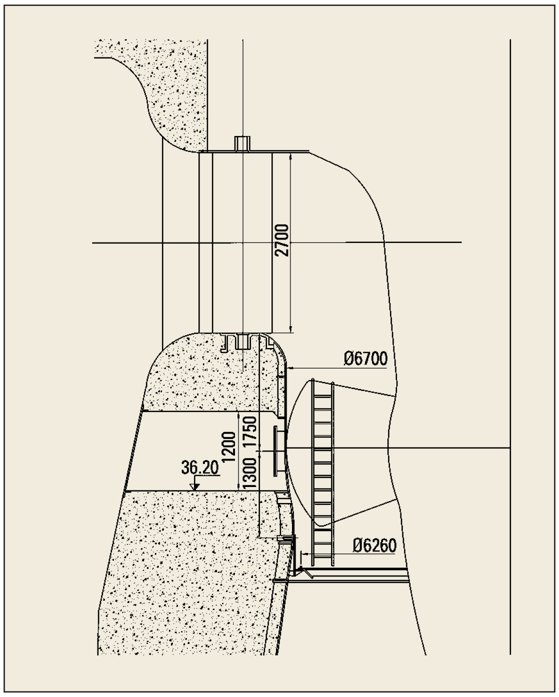

Fig. 1. The tailrace gate pit inspection and repair.

nominal flow of nearly 287.5 m^3/s, with a slightly smaller hub that will help the flow increase through the unit.

The units at Baygorria have an additional limitation: no turbine runner inspection gallery had been constructed at the draft tube cone, and as such, the runner inspection required the full dewatering of the unit and entry through the tailrace gate pit for inspection and repair work (Fig. 1). This limitation required more outage timefor carrying out runner inspections and repairs, which justified a more conservative approach when deciding on flow increases.

4. Design and upgrade

The information collected from the SCADA system over nearly 20 years provided the operational data points of the units to assess the optimum design point, and created the equation for the tailwater elevation versus flow:

$$y = 1.8004E\text{-}14 \times 4 - 3.3600E\text{-}10 \times 3 + 1.2580E\text{-}06 \times 2 + 5.1378E\text{-}04x \times 3.6752E{+}01$$ *y* elevation (m), × unit flow(m^3/s).

This equation was used to establish the sigma plant values based on the number of units (Fig. 2).

The new units will retain a nominal head of 14.7 m with an operating range of 9.5 to 16.5 m. The head values will also be used to weight the efficiencies of the unit and the minimum power required for those operating data points. The nominal turbine output was set to be 38.5 MW for the head of 14.7 m. That is an increase of exactly 10 per cent in turbine output compared with the existing unit. The generator capacity will increase to 40 MVA.

The dismantling of the existing equipment will be constrained by the lifting capacity of the external gantry crane and the reduced hatch in the powerhouse roof. The generator stator will need to be cut into pieces to be lifted and removed from the powerhouse floor. The turbine runner will also need to be fully dismantled within the powerhouse before it can be lifted by the crane, an operation that might require an overturning of the runner within the powerhouse (or on the powerhouse floor).

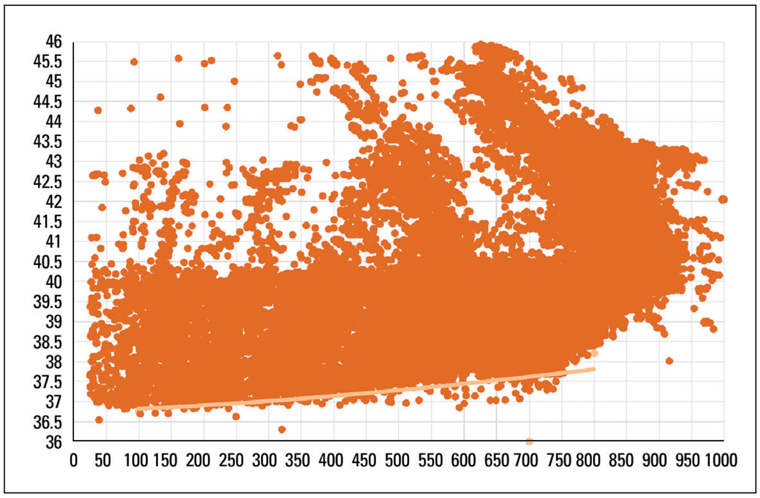

Fig. 2. The tailwater elevation versus flow equation.

These operations will require careful engineering planning of the sequences of installation and a high degree of attention will need to be paid during the execution, as there will be equipment still in operation in the powerhouse, while heavy components are being moved during unit upgrade and replacement, with the premise that power generation will take priority over the modernization works.

During the engineering phase, a detailed 3D dismantling sequence was developed to identify space needs, load-carrying capacity of the powerhouse floor, as well as the need for lifting equipment and assembly devices.

Similar importance has been assigned to other activities for the modernization, such as the addition of a generator breaker for each unit, to improve safety and operational flexibility, as well as the replacement of the control system, new governors, and exciters. The HVAC system of the powerhouse will also need to be upgraded to improve the cooling for the new units and reduce the high temperatures anticipated in the busbar gallery. In the same way, the fire fighting and fire detection systems for the powerhouse will also be upgraded.

These major works at the Baygorria hydro plant are expected to start in early 2023. The total project duration is scheduled to be almost five years and will result in a fully renovated plant. The increased capacity from 105 to 120 MW will help to expand Uruguay's clean power generating capacity. ◊

Carlos Calderaro, currently Technical Practice Lead and Mechanical Engineer at Stantec, has 34 years of hydropower engineering experience. With a focus on hydraulic turbine mechanical design and other major mechanical equipment, he works on large-scale projects, not only during the design phase, but during equipment manufacturing, erection installation, and commissioning.

Stantec, Cerrito 740 Piso 5°, C1010AAP, Caba, Argentina.

C. Calderaro