Upgrading the Salto Grande scheme

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In South America, where a large proportion of the world's hydropower resources are located, rehabilitation is playing a major part in solving energy needs and positively affecting people's quality of life. The authors reflect on the market for future upgrades on the continent.

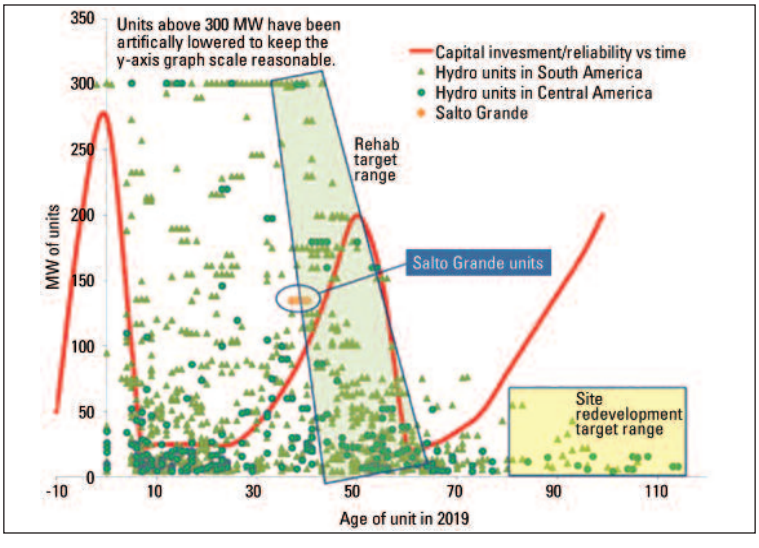
Hydro plants and dams have played a significant role in development and land use in South America, providing electricity for growth and incorporating areas for flood protection and irrigation. The nearly 40-year old Salto Grande hydroelectric complex, located on the border between Argentina and Uruguay, is currently being modernized to meet the power needs of the region.

From public buildings to hydropower stations, the existing infrastructure which is crucial for the region's current living standards and industry, as well as economic growth, is ageing. Government utilities in South America, including both Uruguay and Argentina, are being urged to develop plans to upgrade and maintain the operation of these facilities, as regional growth still depends on the reliable operation of the powerplants. While these plans maximize the potential at existing sites, upgrading hydropower assets also involves a number of unique challenges. For example, the proposed upgrades must be carried out while the plant remains in operation, with minimal impact to the regional grid.

The ageing hydro fleet in South America

The Figure (based on Stantec's internal data and Platts Global Power Database) demonstrates the age of the hydro fleet in South and Central America, and features three key components. The red line represents the capital investment required in a hydropower plant over time to maintain reliable operation. As a result, the line takes the shape of a traditional 'bathtub reliability curve', which describes a form of hazard function and comprises three parts: the first is a decreasing failure rate, known as early failures; the second is a constant failure rate, known as random failures; and, the third is an increasing failure rate, known as wear-out failures. The green area is what is generally referred to as the rehabilitation target range, and corresponds to the expected life of the machinery. The centre of the green area indicates where the first peak would be for that size of plant. Smaller machines are tending to last almost 20 years longer on average than larger machines. The yellow represents the plant redevelopment ranges in this area, where civil works are now requiring major reinvestment so that equipment can operate reliably and new powerhouses can be built. South America is addressing both the green rehabilitation range and the yellow redevelopment range.

The age of hydropower units in Central and South America in 2019.



The Salto Grande hydroelectric complex

As infrastructure in South America continues to age, the hydropower upgrade market in South America has been gaining momentum. Among the key facilities in this respect is the Salto Grande hydro plant, which straddles the border between Argentina and Uruguay. More than 75 per cent of Uruguay's energy has come from hydropower during the past decade. In Argentina, 11 242 MW of hydro accounts for 33 per cent of the total installed capacity of the country. As a result, the upgrade of existing hydropower infrastructure is key for the grid system in both countries.

The plant, on the Uruguay river, is the region's first bi-national hydro project to be developed jointly by the two countries. It delivers an average annual production of 8500 GWh, and provides secondary system frequency regulation, an energy regulation tool employed by power grid operators, for more than 50 per cent of the operation time. The project began operating in 1979, and since then has been supplying power to the equivalent of more than one million homes each year.

After 40 years of safe and reliable operation of the plant, the owner and operator Comision Tecnica Mixta (CTM), decided that the Salto Grande complex was in need of an upgrade. A renewal study to extend the operating life of the equipment and infrastructure was critical. In the Figure, the Salto Grande units would be considered orange data, and therefore, just entering the rehabilitation zone.

The Salto Grande complex has an installed capacity of 1890 MW, with two powerhouses, located on each side of the river. Each powerhouse is equipped with seven units and a central spillway equipped with 19 radial gates. The complex controls the lower sections of the river, supplies water for domestic use and downstream navigation, and controls floods to mitigate the effects on neighbouring cities.

The owner operates and maintains the interconnection ring between the two countries of 500 kV, 350 km of lines and four substations with 1300 MVA of transformer capacity at 150 kV and 132 kV, as well as 600 MVA of stationary inductors. The bi-national board shares and manages all aspects of the plant, including hydrology, operation, maintenance, costs, and personnel, and the complex delivers half of the output to each country.

The upgrade of a large facility such as Salto Grande requires careful planning and understanding. Recognizing the specific needs of the plant, along with replacing time-sensitive equipment, could potentially impact the plant operation reliability critical to the continuing energy production for the two countries.

Planning for the complex

Recognizing the importance of planning and preparation work is vital for any upgrade; CTM, with support from IDB (the Inter-American Developing Bank), launched a comprehensive study for the entire facility in 2014, seeking an upgrade plan based on the priorities and needs of the project. After an international bidding process, the winning consortium comprised Stantec and a local Argentinian company, which had participated in the original design and construction of the project. Stantec carried out the planning-level studies for the rehabilitation and upgrade of the project, including several areas of study and disciplines.

A diagnostic phase resulted in a comprehensive assessment of the plant facilities and equipment, including an investigation of alternative designs to increase the installed capacity and output. The comprehensive assessment phase began with a complex discussion focused on global industry standards for assessing hydropower equipment. Stantec brought its global experience to this discussion, proposing a hybrid platform. The core building blocks included CEATI's HydroAMP protocols, a plan that evaluates and documents the condition of hydro equipment and facilities, for the hydropower-specific equipment combined with international standards for individual elements. The application and results from the HydroAMP protocols were surprising in many instances, because the equipment was found to be in relatively very good condition for its age.

Hydrological studies were the catalyst to running energy models for the various scenarios considered. The installation of bulb units at the bottom of the dam outlet and the upgrade of the existing units were the major scenarios considered, to compare different energy outputs and cost/benefit ratios.

The results of this analysis, combined with the equipment assessment, provided critical information and characterization of the plant's major needs, creating new scenarios for evaluation based on the equipment intervention. From dam automation and instrumentation to turbine, governors, generators, gates, control system, sub-station and plant auxiliaries, the study involved months of plant and equipment assessment, as well as discussion and analysis of potential alternatives for upgrade.

The modernization plan

Thus, the modernization plan evolved into two major elements: the upgrade of the auxiliary equipment, including the main transformers; and, the modernization of the principal generating equipment, including the turbines and the generator.

When they were built, these particular turbines and generators were some of the largest machines of their type in the world. The Salto Grande units are vertical Kaplan machines rated at 135 MW, 150 MVA, 13.8 kV and 50 Hz at 75 rpm. The units have runner diameters of 8.5 m. The combined rotating mass of the turbine and generator is 1043 t. The units include a thrust bearing, supported on a head cover, and the turbine and generator guide bearings.

Although the generators were in very good condition, some slight ageing was noticeable in some of the critical areas of the windings. However, there were no significant recordings of arc discharge in the winding heads. Nevertheless, it was recommended to initiate a plan for generator renewal in the short term, as the windings were reaching the statistical life expectancy. For a multiple unit plant such Salto Grande, the last generator could reach up to 50 years of operation, considering a replacement frequency of one unit per year.

The assessment also determined that the turbines were in excellent condition after nearly 40 years of operation, as a result of the meticulous maintenance and operational practices by the plant owner and the reliable and conservative design of the Russian manufacturer. The five-bladed turbines had no sign of cavitation and the rest of the hydraulic passage was in impeccable condition. It was agreed, however, that planning needed to address the replacement of various turbine wear parts, namely Kaplan turbine hub bushings and seals and guidevane bushings and seals.

Additional studies, including model testing and engineering work, were recommended for the turbines, to determine the best course of action. The energy model showed possible energy gains in the middle range of turbine operation. Because of the sheer size of the equipment and the many logistical challenges, it became clear that the project would take a significant amount of time to execute. This was complicated further by the plant's high energy utilization and multi-unit outage, which needed to be minimized.

The equipment is extremely large and will take many years to manufacture. The working space available at the powerplant, while it appears to be adequate, barely allows for full dismantling of a single unit at a time. To avoid costly forced outages, the team took a proactive approach to the refurbishment schedule and planning.

The general outcome of the study was a strategic plan. The programme takes into account the schedule for tasks to be completed and the costs for its implementation, and provides a general budget for the plant owner, which drives resource utilization and capital expenditure.

The benefits of planning studies in South America

Electromechnical equipment at many dams across South America is reaching the end of its original design life. Units require a greater number of starts and stops, as well as power variations and more frequent regional energy exchanges to complement the high penetration of unconventional renewable energies, such as wind, solar, and biomass, in the region. More importantly, these dams still play a vital role in the lives of millions of South Americans. The modernization of Salto Grande, when completed, will continue to provide much needed renewable energy to the community and will increase reliability and safety operation of the plant. The people of Argentina and Uruguay are reaping the benefits of addressing ageing hydropower infrastructure; powering homes from a reliable source of energy, and replacing heavy imports, such as oil and gas. ◊

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