Guri Dam

Modernization of the Guri hydroelectric plant's control, protection and instrumentation system

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In 2005, ABB was awarded a contract to design, supply and install the unit control, protection and instrumentation systems for the Guri Hydroelectric Plant, Venezuela's largest supplier of hydroelectric power. The plant is located in the Nekuima Canyon, 100 km upstream from the confluence of the Caroní and Orinoco rivers. The modernization project, which will extend the plant's life by 30 years, is being carried out by a three-way consortium comprising ABB Venezuela, ABB Canada and ABB Switzerland. First delivery is scheduled for January 2007.

The construction of the Guri Dam was initiated in 1963. The first powerhouse, containing ten generation units, began commercial operation in 1978, with a total installed capacity of 2,065 MW. In 1985, a second powerhouse was built to house an additional ten generation units, each with a capacity of 730 MW. This brought the plant's total capacity to 10,000 MW, making the Guri the second largest hydroelectric plant in the world in terms of power production capability. The plant has three high-voltage switchyards operating at 800 kV, 400 kV, and 230 kV, each arranged in a breaker-and-half configuration. It provides the Venezuelan power market with 12,900 GWh of indispensable firm energy to meet the growing demand of the sector.

The Guri Dam is the second largest hydroelectric plant in the world in terms of power production capability.

The modernization project being carried out at the plant by its owners, C.V.G. Electrificacion del Caroni C.A. (EDELCA), involves activities and works that will provide the echnological and functional upgrading to see this national asset through the next 30 years. Among the improvements is a complete mechanical overhaul of the generation units, which is being carried out by different turbine suppliers and mechanical contractors. The modernization of the control system, protection and instrumentation is being carried out by ABB under a separate contract.

As well as extending the plant's life, the project will improve the plant's availability to levels over 90 percent and should also increase the efficiency of the generating units. The main objective of the modernization project, however, is to maintain the continuous production of clean and reliable electricity.

Control system generalities

The Distributed Control System (DCS,) designed by ABB for the plant, will integrate the first three levels of the existing hierarchical control system. The first level contains the field devices (smart transmitters and remote I/O stations) that communicate with the next control level via a Profibus network. The second level has the Unit Control System (UCS), which will be based on ABB's Industrial^{IT} Controller, the AC800M. This level supports all the automatic control sequences for running the generating units. The redundancy incorporated into the design of the system ensures its reliability. Each UCS will have two redundant human machine interfaces (HMIs) based on the ABB Power Generation Portal (PGP). The controllers, HMIs and accessories will be integrated into existing cabinets at the plant.

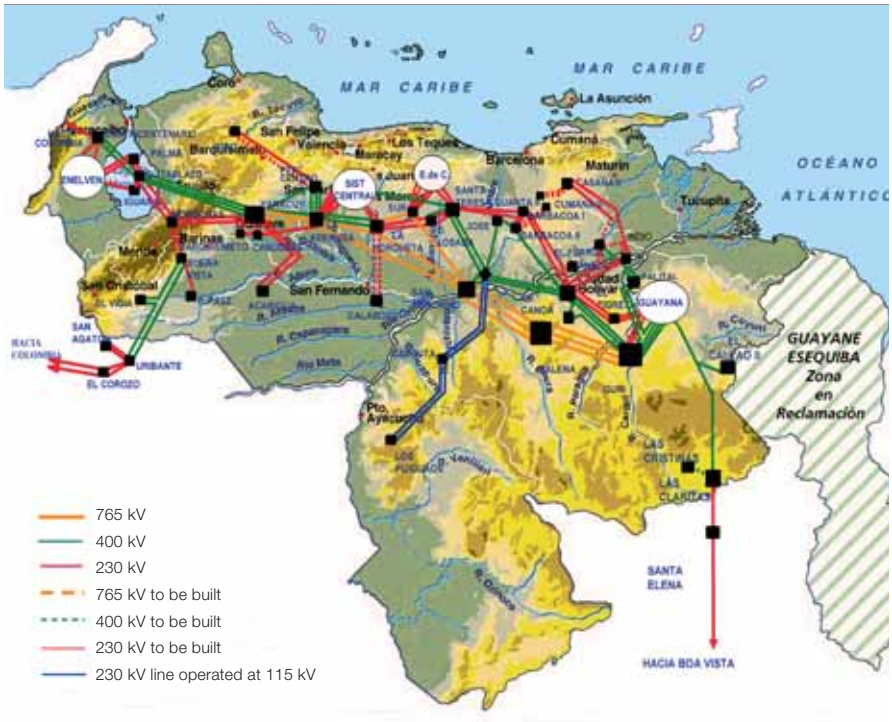
The next level of the control system comprises operator consoles for each unit, which will be located in the existing control rooms of each powerhouse. This level will interface with an existing centralized control system that was installed by SNC Lavalin in the late 1990ies. It will support the entire plant control level and all advanced control applications, including automatic generation, schedule and control, automatic voltage control, river flow control and others.

Distributed Control System (DCS) overview

The distributed control system comprises the ABB Power Generation Portal consoles at the operator level, the ABB Industrial^{IT} AC800M controllers at the process level and the ABB S800 I/O modules, as well as smart transmitters, at the field level. At the operator level, the operators are able to control and monitor the hydroelectric plant using the functions of the control desk, main control panel (MCS) and UCS. The status of the process is presented on color-monitors in the form of the process-, object- and curve displays, alarms and message lists.

At the process level, the control system consists of redundant controllers for each unit, and common system in the two powerhouses. The controllers have the capacity to provide analog and digital processing, loop and logic control, as well as monitoring-, acquisition-, arithmetic-, and communication functions. Each controller has local Ethernet ports that allow peer-

Electrical network fed by the Guri Dam



to-peer communication over a redundant, Ethernet-based Local Area Network (LAN). The controllers can also function independently of the LAN. The operator and controllers communicate with each other using OPC Server/Client. Communication modules are used to enable Profibus connections to remotely located I/O stations and smart transmitters, as well as RS232 serial connections to third party devices. Communication ports built into the controllers are used to communicate with the local I/O clusters.

At the field level, the field input data and process outputs are managed by the ABB S800 I/O modules, which are either grouped in remote I/O stations and located throughout the plant, or in clusters of local I/Os situated within the same enclosure as the controller. In addition to the S800 I/O, smart transmitters are located throughout the plant. The field inputs that are defined as Sequence of Events (SOE) points are managed by special SOE modules within the S800 family. SOE points are recorded at 1 ms resolution and all the SOE points are located within the UCS cabinets.

Plant control philosophy

The station is operated either from the existing Centralized Control System (Master SCADA Station) in Powerhouse #2, the control rooms in Powerhouses #1 and #2, or at the UCSs. Local/remote control transfer between the UCS, the control room and the Master SCADA Station is provided.

As well as extending the plant's life, the project will improve the plant's availability to levels over 90 percent. The main objective of the modernization project, however, is to maintain the continuous production of clean and reliable electricity.

Within the DCS, the plant is controlled at the unit level. An operator at the Unit 1 UCS, for example, has access to Unit 1 graphics, I/O and control functions. All units operate in the same fashion. The DCS does not perform plant-wide control. This is performed by the existing Master SCADA Station, which exists at a control level above the DCS. The existing Master SCADA Station communicates via an interface with the DCS.

The I/O modules and smart transmitters are distributed throughout the plant and the I/O devices are located close to the device(s) that are being controlled and monitored.

Control path

Operator control can take place in a number of different areas throughout the plant. It is therefore important to manage the location of control and to prevent a device from being operated from two different points at the same time.

Operator control can be performed at the following locations within Powerhouse #1:

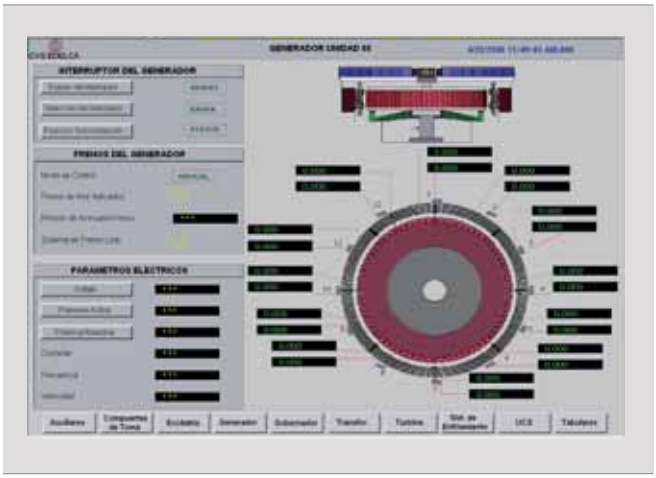
- The control room – bench board and main control panel (MCS)
- Unit 1 – 10 UCSs – on the plant floor. There are 10 UCSs at Powerhouse #1. Individual units can be controlled at each UCS. Control and monitoring functions include unit startup/shutdown and unit monitoring and annunciation.
- 4.16KV auxiliary services – on the plant floor
- PH1 sump pump and drain system – locally on the plant floor
- 440V auxiliary services (local control only)
- Plant control services (local control only)
- Spillway – channels 1,2,3
- Dam sump pump and drain system

Operator control can be performed at of the following locations within Powerhouse #2:

- The control room – bench board and the MIMIC panel (MIMIC)
- Unit 11 – 20 UCSs on the plant floor. There are 10 UCSs at Powerhouse #2. Individual units can be controlled at each UCS. Control and monitoring functions include unit startup/shutdown and unit monitoring and annunciation

Overview display of turbine

Overview display of generator



- PH2 sump pump and drain system on the plant floor
- 4.16KV auxiliary services

The AC800M controller.

General DCS structure

Human Machine Interface

The ABB Process Generation Portal system will be used for the operator stations. The console system is based on industry standards and the XP Windows Operating System.
It has an open architecture that allows for a wide range of communication protocols with the ability to interface to third-party software and databases.

The operator station provides the operator with a graphical interface to the plant. In addition, the operator can make use of the alarm management, sequence of events reports, data-logging functions and user authorization mechanisms.

The AC800M controller

The AC800M uses ABB's newest controller technology. The controllers are built as rail-mounted modules with two built-in Ethernet ports. They comprise central processing units, communication modules, power supply modules and various accessories. The controllers will be setup in a redundant configuration.

Field I/O - S800 I/O modules and smart transmitters

The S800 I/O modules and Fieldbus Communication Interface (FCI) modules are combined to form I/O station or I/O clusters. An I/O that is connected to the controller via Profibus-DP[1)] is considered an I/O station. An I/O that is connected to the controller via ModuleBus is considered an I/O cluster.

Smart Tramsitters and instruments will be installed across the plant. Since these devices will communicate via Profibus-PA[2)], Profibus-DP/PA converters will be needed to allow communication with the controllers.

Protocols and media

There are a number of communication protocols and media used by the controller. These include the following:

- Control network (LAN) communication
- Modulebus communication
- Profibus DP communication
- Profibus PA communication

Control Network Communication

A controller communicates with other controllers and HMIs across the Ethernet LAN and WAN (wide area network). The control network operates at 100 Mb/s.

The control network is structured as a ring with parallel independent lines. Thus, if there is a break in line A, then communication will continue along line B and, if both lines A and B are broken, then the ring structure will change to a bus structure.

I/O Network Communication

The I/O network connects all of the plant's I/O devices to the controller. There are three types of communication protocols used for the I/O network. These are:

ModuleBus: used to communicate directly with the local I/O clusters via plastic fiber optic cable. ModuleBus supports the SOE functionality.

Profibus DP: used to communicate directly with the remote I/O stations and indirectly with the smart transmitters.

Profibus PA: which is used to power the intelligent electronic devices (IEDs) as well as transfer information from the IED.

Protection systems

ABB Switzerland's Power Systems group is providing a redundant generator and transformer protection systems for the modernized plant. Fourteen numerical REG216 systems will protect three 230-MW units, plus four 360-MW units in Power House #1, while 14 numerical type REC316*4 IEDs will protect the corresponding seven short transmission lines at 400 kV from the interconnection switchgear and the step-up transform-

ers at Power House #1. The protection system of the medium voltage auxiliary services of the complete power plant will also be replaced with the most up-to-date relays.

ABB Switzerland is also contracted to modernize the 20 automatic synchronizers and 20 synchro-check devices at the 230/400/800 kV switchgear of the power plant, as well as install a completely new disturbance recording system for the 20 generator units and SMS530 station monitoring system for all of the protections supplied.

Instrumentation system and miscellaneous

ABB Venezuela is acting as the consortium leader and is responsible for the internal coordination and the contract management. Its contribution to the project is the design of the instrumentation system, which will comprise smart transmitters located throughout the plant. Communications between the field devices and the control system will be supported by a Profibus network.

ABB Venezuela is responsible for the preparative engineering works required for the installation of the various new systems at the plant and will be responsible for their installation and integration at site.

Other systems within the remit of ABB Venezuela are:

- The vibration and air gap monitoring systems for the generating units
- A closed circuit television system for process monitoring and security surveillance
- Communication systems: Tele-protection equipment and fiber optic networks

The Guri power plant modernization scheme demonstrates how the successful coordination of people and products can meet the needs of a large-scale project.

A team effort

ABB is a world leader in state-of-the-art control system technology. This technology is being deployed in modern hydro power plants to address users' needs for highly automated, secure and reliable control and to provide access to plant-wide information.

The Guri power plant modernization scheme demonstrates how the successful coordination of people and products can meet the needs of a large-scale project. ABB has experienced, dedicated staff, located around the world. The expertise acquired during ABB projects in a variety of applications ensure that clients will be provided with the personnel best suited to their requirements. ABB offers a comprehensive line of fully compatible products that meet the needs of process control projects from the smallest to the largest applications, like the Guri project. The ABB project team has been able to meet the requirements of this unique project and adapt its products and services to respond to specific customer requirements.

The challenges of the Guri modernization project demand a solid team effort. ABB Venezuela, ABB Canada and ABB Switzerland understand the challenges and are working together, combining expertise and sharing experience. A group of engineers and technicians from EDELCA are also involved in the design of the control system as part of an "on-the-job" training program in ABB's facilities in Canada. This training will facilitate the integration of the new systems into the plant and will guarantee the transfer of technology from ABB to EDELCA.

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Footnotes

1) Profibus-DP: Process Field Bus – Decentral Peripherals

2) Profibus-PA: Process Field Bus – Process Automation