Hydro power
Intelligent solutions for hydro governors
With ABB's integrated solutions encompassing automation, excitation and turbine control, you can rest assure that your power plant gains flexibility while maintaining high levels of availability.
ABB has dedicated years of focused development to design the proven ABB Governor System. Based on ABB’s powerful Distributed Control System (DCS) families and the state-of-the-art microprocessor-based family of controllers, we have created the hydro governor solution for now and the future.

Governing system overview
The ABB Electro-Hydraulic Hydro Turbine Governor cubicle contains the frequency, load and voltage transducers that connect to the potential transformers and current transformers measuring the voltage and current of the generator. The advanced control algorithms for the hydro governor application are executed in the controller and an output is generated to position the wicket gate. Using an external servo amplifier that drives an electro-hydraulic proportional control valve, the wicket gate is precisely positioned for ultimate control.

The ABB Hydro Turbine Governor was built for improved local/remote control for maximum operational flexibility. Local governor control is selected at the governor cubicle, allowing local control by the operator using the Process Panel HMI mounted on the governor cubicle front door. When remote control is selected, the Process Panel remains available for monitoring, while the essential control signals are managed from the unit controller. Overall performance improvement is achieved through enhanced operational features including Bidirectional Linearization 3D-Cam, Electronic Wicket Gate Max Limiter, and built-in Maintenance/Test Mode.

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ABB offers hydro governor control solutions for a wide range of hydroelectric power generation facilities. With years of experience in this field, ABB can offer you governor control solutions specifically engineered to fit the needs of your hydroelectric power plant.
**Speed control overview**

There are two automatic controllers in the ABB governor: a speed controller and a frequency/load controller. Both of these are independently configured, and are intended for controlling the turbine generator at their respective time, during the start-up and normal load control conditions. During the start-up sequence, the speed controller is used while the breaker is open. Under normal conditions, and in the event of a load rejection, the wicket gate will operate under speed control mode. A simplified diagram of the governor speed controls is shown.

The ABB governor is normally started once it is put in automatic mode and all operating permissives are satisfied. During the starting ramp, the wicket gate is opened at predefined ramp rates set in the controller. Initially, the speed measurement is done using speed pick-ups mounted adjacent to a toothed wheel on the main shaft. After reaching approximately 90% speed, the PID controller will take over, and maintain the unit at synchronous speed. At this point, the speed reference is available to the synchronizer through decreased/increased pulses or a speed matching (beat frequency) circuit, until the generator circuit breaker is closed.

**Figure 1. Simplified Francis Turbine Speed-no-Load Controls**

**Figure 2. Simplified Francis Turbine Power-Mode Controls**

**Frequency/load control overview**

Once the ABB unit is synchronized to the grid, the frequency/load controller takes over control of the wicket gate position. During the entire normal load control operation, the governor will only use the frequency/load PID controller. The governor is also provided with Local/Remote, Manual/Auto, Load Ref, Droop Setter, Deadband Setter and Max Gate Limiter at the local process panel for operator action. A simplified diagram of the governor frequency/load controller is shown below.
When synchronized to the grid (GCB closed), the controller uses the combined frequency and load (power in MW) measurements to control the position of the wicket gate. The frequency reference will be locked to a 50/60 Hz fixed value, whereas the load reference is adjustable to a desired value locally by the operator or remotely from AGC Software. The wicket gate position feedback is measured using an MLDT transducer and controlled using an internal proportional type positional servo controller. The distribution valve position feedback is measured using an LVDT transducer and controlled using an external proportional type positional servo-amplifier (where applicable). An optional bidirectional 3D-Cam can also be enabled for performance enhancements.

**Governor modes of operation**

**Governor speed control features:**
- Automatic speed control, using speed pickups or frequency measurements
- Two gate position automatic startup sequence
- Optional adaptive tuning
- Automatic speed control after load rejection
- Independent speed control PID settings
- Synchronizer raise/lower inputs, or optional speed matching control
- Gate limiter

**Online control features:**
- Automatic frequency/load control, c/w regulation gain (droop) curve
- Three adjustable droop levels, with automatic/manual switching
- Grid detection with adaptive tuning
- Bi-directional 3D-Cam for improved feedforward load response
- Independent frequency/load control PID settings
- Manual gate control
- Gate limiter
- Optional frequency deadband
- Multi-level droop control
- Frequency deadband
- Gate limiter (online)
- Power limiter (option)
- 3D-cam (Kaplan runner blades control)
- 3D-cam (power, flow control modes above)
- Runbacks (option)
- Rough zone monitoring (option)
- Speed step test (online)

**Governor maintenance mode features:**
- Manual gate control
- Gate limiter
- Servo loop test mode
- Local actuator gate raise/lower
- Instrumentation supervision
- Local/remote alarm/fault monitoring

**Speed control functional description**

When the unit is ready, the turbine governor receives a start command from either the Unit Controller (external) or from the Local Process Panel HMI. When the start command is given, the gate will move to the predefined Start Position #1 setting. The gate ramps to this value and is maintained at that position until the speed reaches about 90% of rated. When this occurs, the sequence control moves the wicket gate to Start Position #2. The gate is now ramped to an opening, which is slightly lower than the Speed-No-Load (SNL) value. Once the gate is at SNL, the speed controller automatically takes over. The unit remains at SNL under speed control until synchronization (generator circuit breaker closed).

The automatic synchronizer interfaces with the turbine governor to raise/lower the speed setpoint. Once the unit is on-line, the frequency reference setpoint is locked at the 50/60 Hz value and the automatic control is transferred to the frequency/load controller.

**Frequency/load control functional description**

The grid frequency is a measure of the interconnected generators speed. If the total load demand in the system increases, the frequency (speed) will decrease. Likewise, a decrease in the load demand causes the system frequency to increase.
Units tied to the grid are designed to automatically perform primary control action to re-establish the balance between demand and generation. The frequency deviation is influenced by both the total inertia in the system and the speed of response of the primary controlled devices. The governor uses regulation gain (proportional control) to move the gate depending on the following rule:

The primary load control of a unit is described as the change in power $\Delta P$ (MW) with respect to changes in frequency $\Delta f$ (Hz), where $f_0$ is the nominal operating frequency (50 or 60 Hz), $P_o$ is the nominal (rated) power output, and $\epsilon_p$ is the unit regulation (droop). The value for $\epsilon_p$ is normally given in percent and is adjustable by the operator. A typical droop setting in North America is 5%, as per NERC Policy-1. The frequency and unit load relationship given by this equation is plotted over the operating range of the unit, as shown in following figure.

$$\Delta P = (P_o - P), \text{ change in Unit Load (P) with respect to Rated Power (P_o) of the Turbine/Generator.}$$

$$\Delta f = (f_0 - f), \text{ change in Frequency (f) with respect to Rated Frequency (f_0) of the grid.}$$

Optional frequency response and stability analysis
- Frequency response to injected sine wave
- Nyquist and bode plots
- Governor and servo modeling
- Turbine and penstock linear/non-linear modeling
- Generator and grid subjected to stiff grid
- Water hammer analysis and wave reflection time
- Evaluation of water start time ($T_w$), and unit acceleration time ($T_a$) constants
- Fine adjustments of PID and 3D-Cam values

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High speed servo loop
A cascade type servo control loop is used to accurately control the gate position. This is done using a combination of an internal gate servo controller together with a high speed external servo controller for the distributing valve. Key features include:
• LVDT for distribution valve position sensing and control
• External (modular) high speed servo control for distributing valve
• Integral controller based servo loop for gate position control
• Fast, high accuracy and high repeatability gate positions control

Open configuration and predefined function blocks
The ABB Electro-Hydraulic Turbine Governor (EHG) uses the latest microprocessor-based technology. The governor is programmed using Function Block programming, selected from a set of factory built libraries for functions. In addition to function blocks, this controller also supports all IEC-61131-3 programming languages: Structured Text, Instruction List, Sequential Function Charts, and Ladder Diagram, all of which can be used to add additional custom built user functions.

The diagram above shows a typical logic page of the turbine governor application. In this example, the function block drawing for the Distribution Valve Servo Amplifier is shown, the external connection to this logic page are depicted by parameter m and n in the diagram and are also listed on the program pane. Internal connections remaining on the logic page are depicted by the line p. Block j is an On/Off function available from the governor library, Block k is a Scaler function, and Block l is a ServoPD function. These are just some of the many functions available in the governor function block library.

Summary of benefits
ABB’s hydro turbine governor solution is based on our long tradition of governor products and is fully implemented in ABB’s DCS. A new hydropower governor library has been developed, taking full advantage of the powerful microprocessor-based controller and its flexibility for custom functions. The governor can run as a conventional standalone turbine governor or as a combined unit controller and a turbine governor in a redundant or single controller. The special capabilities of ABB’s DCS represent the future of power generation providing economical savings through an optimal and efficient day-to-day operation of complete hydroelectric power plants.

All basic control functions are covered in ABB’s solution for hydro turbines including: fast system response time, high bandwidth, full compliance with IEEE and IEC standards for hydroelectric turbine governing, extensive system documentation and operating/maintenance training.

Supported turbines
• Francis
• Kaplan & Bulb
• Reversible pump/turbine