

Power Generation

Hydro power

Intelligent solutions for hydro governors

Power and productivity
for a better world™



Hydro power

Intelligent solutions for hydro governors



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. 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.

Hydro power

Intelligent solutions for hydro governors

Features

Cost effective turbine governor cubicle provides:

- Local operator control interface
- Advanced control algorithm using PID control with feed forward
- Complete range of control functions for all types of hydro turbines
- Easy to use engineering tools to add/change functions
- Simplified engineering reducing commissioning time
- Controller redundancy
- Communication direct on control LAN

Functions

- Integrated start/stop sequences
- Control modes
 - Maintenance
 - Offline speed control mode
 - Online gate feedback/frequency control mode
 - Online power feedback/frequency control mode
 - Online flow feedback/frequency control mode
 - Online speed control mode
 - Online level control mode
 - Online manual gate
 - (Independent PID gains for each of the above control modes)
- Gate limiter (offline)
- Instrument monitoring
- Controller and IO card monitoring
- Speed step test (offline)
- Controller watchdog
- Independent overspeed monitoring
- Speed and gate position relays
- High speed (analog) pre-trip and post trip data logger

Supported ABB distributed control systems include:

- Symphony Plus
- Symphony Harmony
- System 800xA
- INFI 90

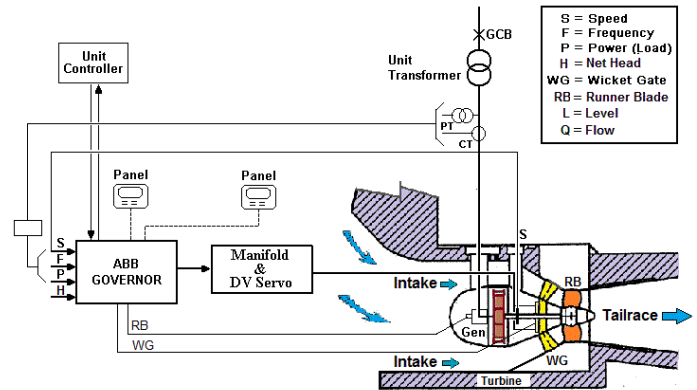


Figure 1. Bulb Turbine and ABB Governor



Figure 2. Front view Turbine Governor Cubicle

Hydro power

Intelligent solutions for hydro governors



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.

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.

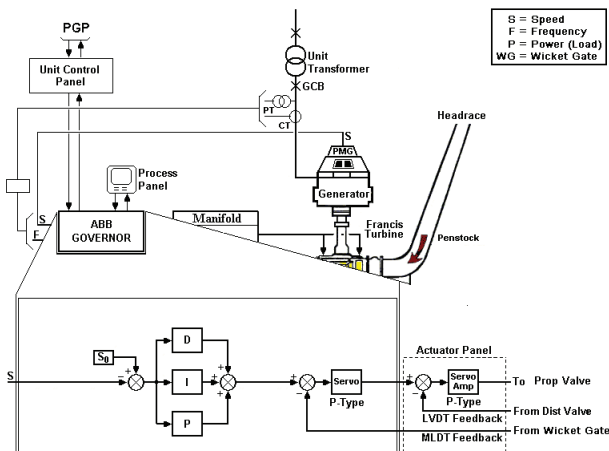


Figure 3. Simplified Francis Turbine Speed-no-Load Controls

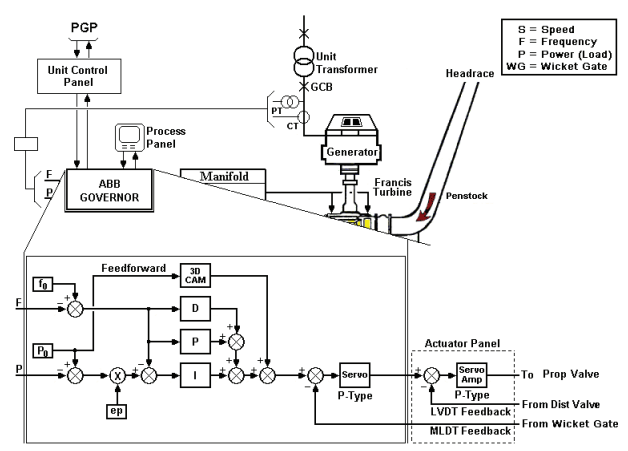


Figure 4. Simplified Francis Turbine Power-Mode Controls

Hydro power

Intelligent solutions for hydro governors

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.

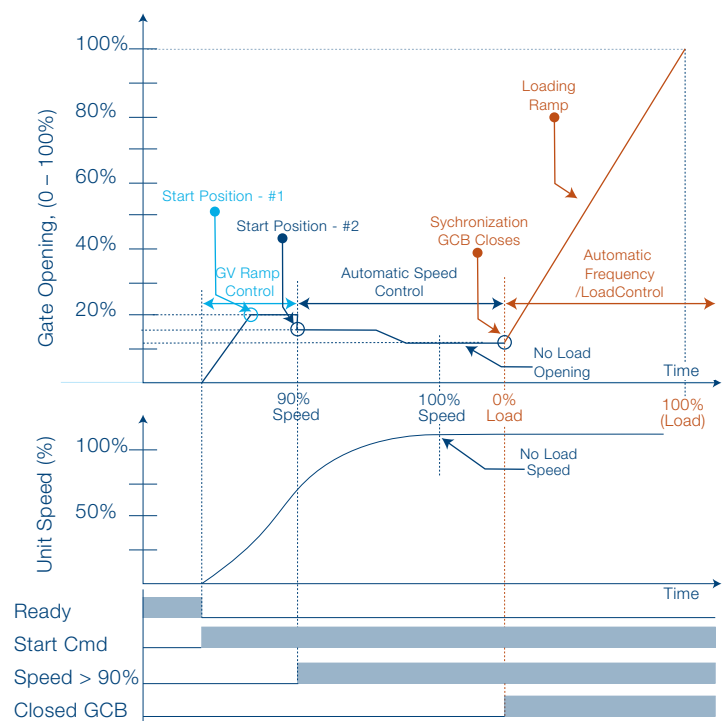


Figure 5. Francis Turbine Startup and Loading Chart

Hydro power

Intelligent solutions for hydro governors

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 ΔP (MW) with respect to changes in frequency Δf (Hz), where f_0 is the nominal operating frequency (50 or 60 Hz), P_0 is the nominal (rated) power output, and e_p is the unit regulation (droop). The value for e_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.

$\Delta P = (P_0 - P)$, change in Unit Load (P) with respect to Rated Power (P_0) of the Turbine/Generator.

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

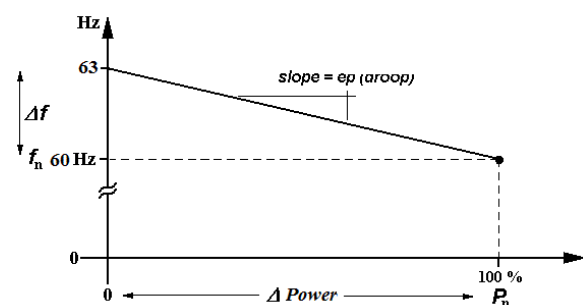


Figure 6. Governor Speed Droop Curve

Compliance with industry standard testing

ASME PTC 29-2005	Speed-governing systems for hydraulic turbine-generator units
IEC 308	International code for testing of speed governing systems for hydraulic turbines
IEC 61-362	Guide to specification of hydraulic turbine control systems
IEC 61131	Programming Industrial Automation Systems
IEEE Std 125-2007	IEEE Recommended practice for preparation of equipment specifications for speed-governing of hydraulic turbines intended to drive electric generators
IEEE Std 1207-2011	IEEE guide for the application of turbine governing systems for hydroelectric generating units

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

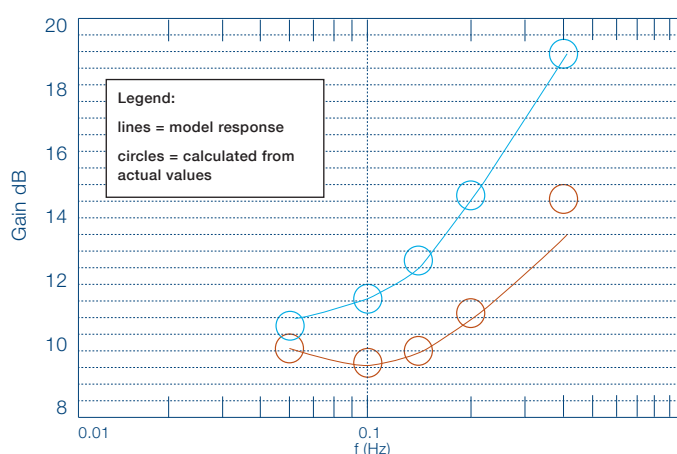


Figure 7. Frequency Response Bode Type (Gain) Diagram

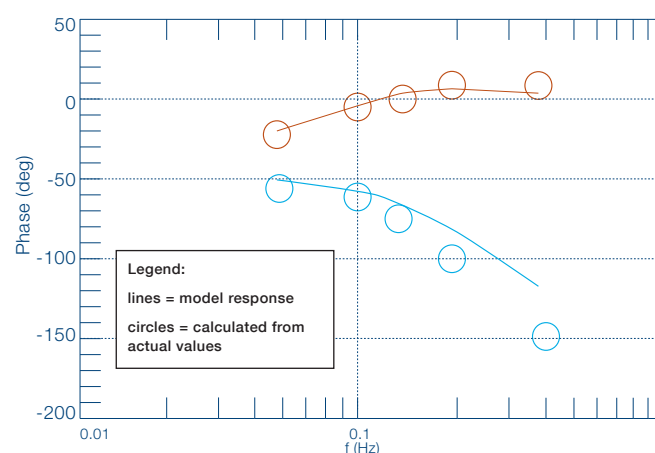


Figure 8. Frequency Response Bode Type (Phase) Diagram

Hydro power

Intelligent solutions for hydro governors

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

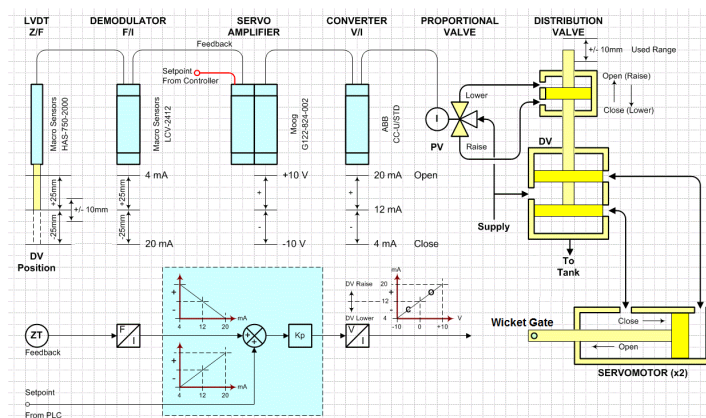


Figure 9. Governor Electro-Hydro (Servo Loop) Interface

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 ④ and ⑤ in the diagram and are also listed on the program pane. Internal connections remaining on the logic page are depicted by the line ⑦. Block ① is an On/Off function available from the governor library, Block ② is a Scaler function, and Block ③ is a ServoPD function. These are just some of the many functions available in the governor function block library.

Governor (Distribution Valve Servo Amplifier)

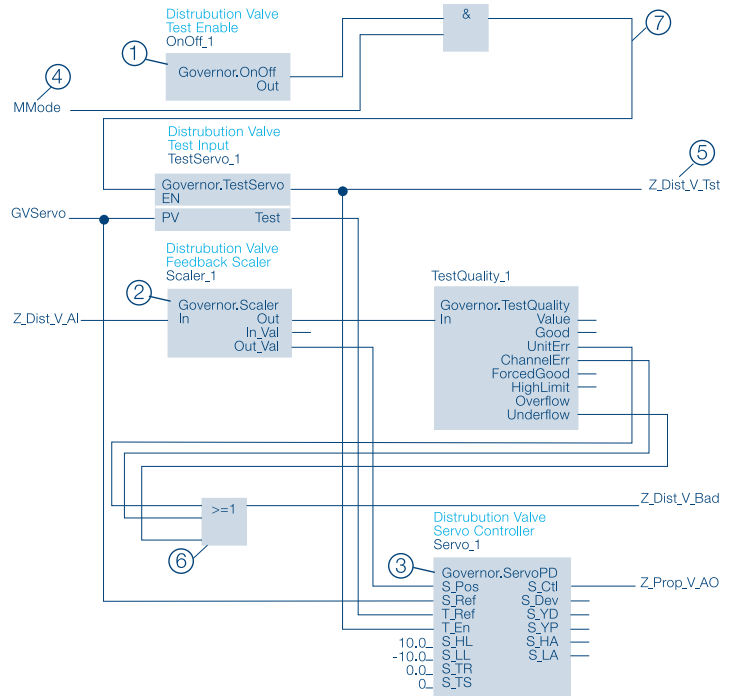


Figure 10. Bot Right Governor Typical Logic Diagram

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 stand-alone 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

Contact us

ABB Inc.

Power Generation

Burlington, ON, Canada L7N 3W5

Phone +1 905.639.8840 x2100

Fax +1 905.639.8639

E-Mail: pspmarketing@us.abb.com

www.abb.com/powergeneration

The information contained in this document is for general information purposes only. While ABB strives to keep the information up to date and correct, it makes no representations or warranties of any kind, express or implied, about the completeness, accuracy, reliability, suitability or availability with respect to the information, products, services, or related graphics contained in the document for any purpose. Any reliance placed on such information is therefore strictly at your own risk. ABB reserves the right to discontinue any product or service at any time.

© Copyright 2016 ABB. All rights reserved.