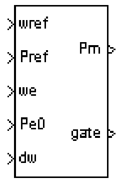
# Hydraulic Turbine and Governor

Model hydraulic turbine and proportional-integral-derivative (PID) governor system

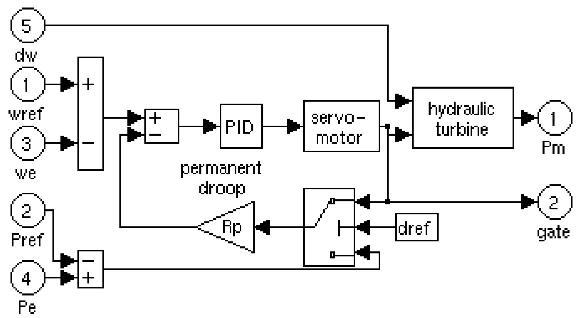
## Library

Machines

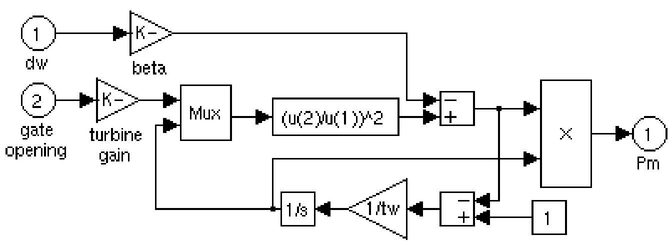
## Description



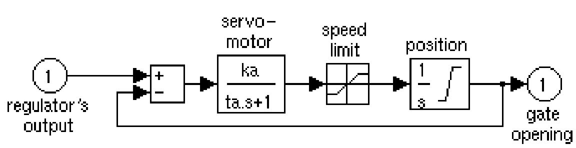

The Hydraulic Turbine and Governor block implements a nonlinear hydraulic turbine model, a PID governor system, and a servomotor [1].



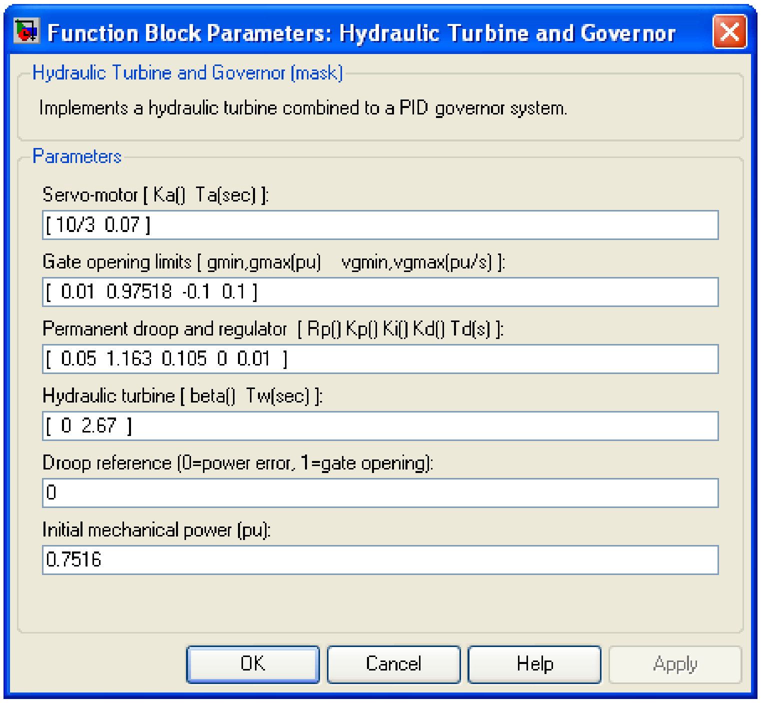

The hydraulic turbine is modeled by the following nonlinear system.




The gate servomotor is modeled by a second-order system.




## Dialog Box and Parameters




**Servo-motor**
: The gain Ka and time constant Ta, in seconds (s), of the first-order system representing the servomotor.

**Gate opening limits**
: The limits gmin and gmax (pu) imposed on the gate opening, and vgmin and vgmax (pu/s) imposed on gate speed.

**Permanent droop and regulator**
: The static gain of the governor is equal to the inverse of the permanent droop Rp in the feedback loop. The PID regulator has a proportional gain Kp, an integral gain Ki, and a derivative gain Kd. The high-frequency gain of the PID is limited by a first-order low-pass filter with time constant Td (s).

**Hydraulic turbine**
: The speed deviation damping coefficient β and water starting time Tw (s).

**Droop reference**
: Specifies the input of the feedback loop: gate position (set to 1) or electrical power deviation (set to 0).

**Initial mechanical power**
: The initial mechanical power Pm0 (pu) at the machine's shaft. This value is automatically updated by the load flow utility of the Powergui block.

## Inputs and Outputs

`wref`
: Reference speed, in pu.

`Pref`
: Reference mechanical power in pu. This input can be left unconnected if you want to use the gate position as input to the feedback loop instead of the power deviation.

`we`
: Machine actual speed, in pu.

`Pe0`
: Machine actual electrical power in pu. This input can be left unconnected if you want to use the gate position as input to the feedback loop instead of the power deviation.

`dw`
: Speed deviation, in pu.

`Pm`
: Mechanical power Pm for the Synchronous Machine block, in pu.

`gate`
: Gate opening, in pu.

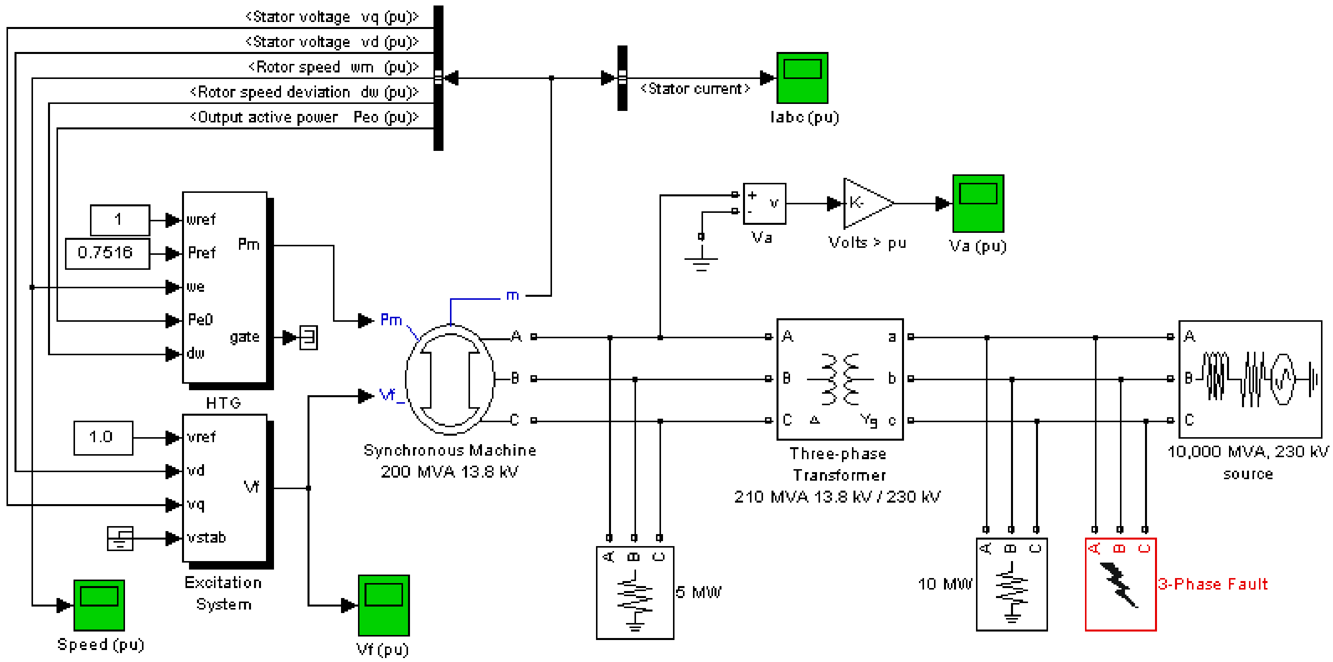
## Example

This `power_turbine` demo illustrates the use of the Synchronous Machine associated with the Hydraulic Turbine and Governor (HTG) and

Excitation System blocks. It also demonstrates the use of the load flow tool of the Powergui block to initialize machine currents and initial mechanical power of the HTG block. A three-phase generator rated 200 MVA, 13.8 kV, 112.5 rpm is connected to a 230 kV network through a Delta-Y 210 MVA transformer. The system starts in steady state with the generator supplying 150 MW of active power. At t = 0.1 s, a three-phase to ground fault occurs on the 230 kV bus of the transformer. The fault is cleared after six cycles (t = 0.2 s).

In order to start the simulation in steady state, you must initialize the Synchronous Machine block for the desired load flow. Open the Powergui and select **Load flow and machine initialization**. The machine **Bus type** should be already initialized as `PV generator`, indicating that the load flow is performed with the machine controlling the active power and its terminal voltage. Specify the desired values by entering the following parameters:

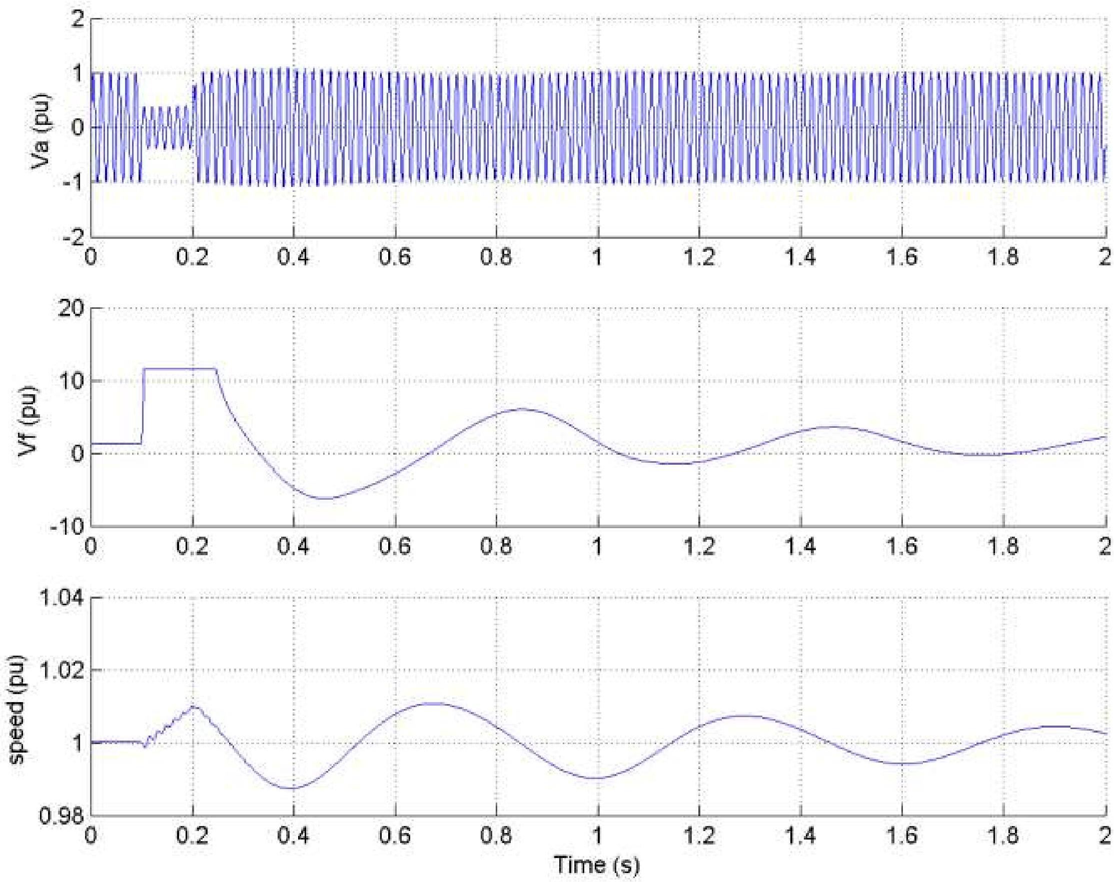
- Terminal voltage U AB (Vrms) = 13800
- Active power (watts) = 150e6




Then click the **Update Load Flow** button. Once the load flow has been solved, the line-to-line machine voltages as well as the phase currents flowing out of the machine. The machine reactive power, mechanical power, and field voltage requested to supply the electrical power should also be displayed:

- Q = 3.4 Mvar
- Pmec = 150.32 MW (0.7516 pu)
- Field voltage Vf = 1.291 pu

The load flow also initializes the HTG and Excitation System blocks. Open the HTG block menu and notice that the initial mechanical power is set to 0.5007 pu (100.14 MW). Then open the Excitation System block menu and note that the initial terminal voltage and field voltage are set respectively to 1.0 and 1.291 pu. Open the four scopes and start the simulation. The simulation starts in steady state.




Observe that the terminal voltage Va is 1.0 pu at the beginning of the simulation. It falls to about 0.4 pu during the fault and returns to nominal quickly after the fault is cleared. This quick response in terminal voltage is due to the fact that the Excitation System output Vf can go as high as 11.5 pu, which it does during the fault. The speed of the machine increases to 1.01 pu during the fault, then it oscillates around 1 pu as the governor system regulates it. The speed takes much longer than the terminal voltage to stabilize, mainly because the rate of valve opening/closing in the governor system is limited to 0.1 pu/s.

## References

[1] IEEE Working Group on Prime Mover and Energy Supply Models for System Dynamic Performance Studies, "Hydraulic Turbine and Turbine Control Models for Dynamic Studies," *IEEE Transactions on Power Systems*, Vol.7, No.1, February, 1992, pp. 167-179.

## See Also

Excitation System, Steam Turbine and Governor, Synchronous Machine

**Was this topic helpful?** Yes No