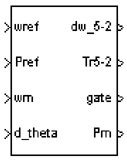
# Steam Turbine and Governor

Model the dynamics of speed governing system, steam turbine, and multimass shaft

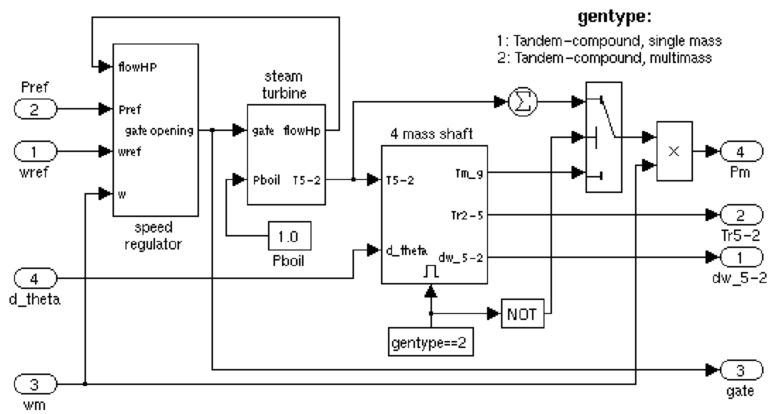
## Library

Machines

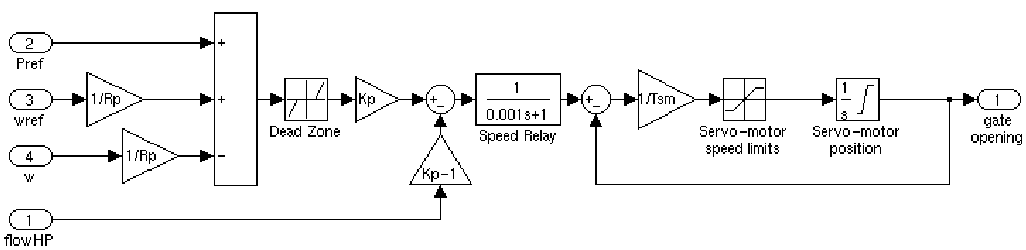
## Description



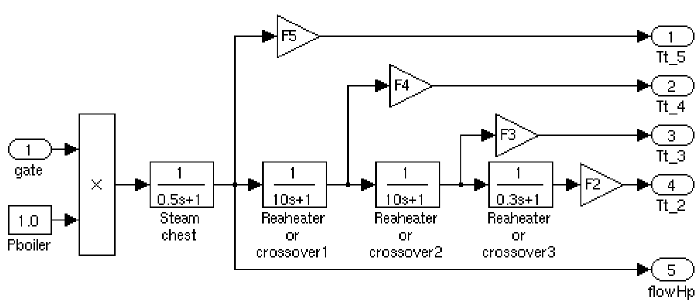

The Steam Turbine and Governor block implements a complete tandem-compound steam prime mover, including a speed governing system, a four-stage steam turbine, and a shaft with up to four masses.




The speed governing system consists of a proportional regulator, a speed relay, and a servomotor controlling the gate opening. It is similar to one of the models proposed in [1].

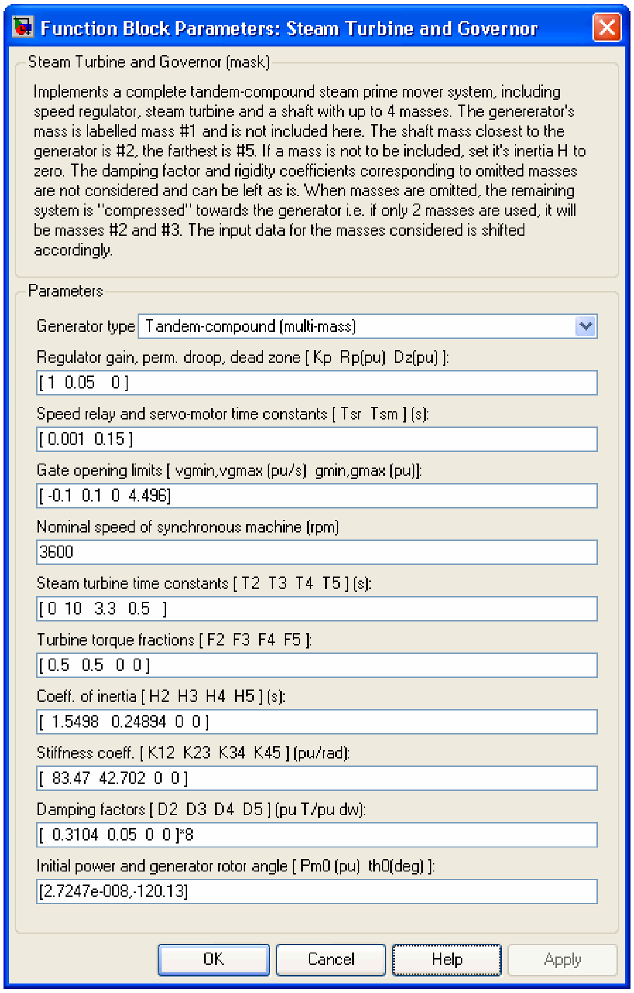



The steam turbine has four stages, each modeled by a first-order transfer function. The first stage represents the steam chest while the three other stages represent either reheaters or crossover piping. The boiler is not modeled and boiler pressure is constant at 1.0 pu. Fractions F2 to F5 are used to distribute the turbine power to the various shaft stages:




The shaft models a four-mass system, which is coupled to the mass in the Synchronous Machine model for a total of five masses. The machine's mass is labeled mass #1. The mass in the Steam Turbine and Governor block, which is closest to the machine's mass, is mass #2, while the mass farthest from the machine is mass #5. The shaft is characterized by mass inertias H, damping factors D, and rigidity coefficients K. If you choose to simulate a single-mass shaft, the entire four-mass shaft subsystem in the Steam Turbine and Governor block is disabled and all the torque from the turbine is added together and applied to the machine's mass:

## Dialog Box and Parameters




**Generator type**

Specifies rotor type: single mass or multimass tandem-compound. If you choose a single-mass system, the multimass shaft subsystem in the Steam Turbine and Governor block is disabled and the turbine's output torques are summed together and applied to the single mass in the Synchronous Machine block.

**Regulator gain, permanent droop, dead zone**

The gain Kp, permanent droop Rp (pu), and dead-zone width Dz (pu). Set gain to 3 if you want to use the steam flow feedback loop. Otherwise, set gain to 1.

**Speed relay and servo-motor time constants**

The speed relay and gate servomotor time constants Tsr (s) and Tsm (s).

**Gate opening limits**

The minimum and maximum gate opening speed vgmin and vgmax (both in pu/s), and minimum and maximum gate opening gmin and gmax (both in pu).

**Nominal speed of synchronous machine**

The synchronous speed of the generator driven by the steam turbine (rpm).

**Steam turbine time constants**

The turbine time constants T2 to T5 (s). Numbered consistently with turbine torque fractions and mass numbers; i.e., T5 is the time constant of the first turbine stage, which models the steam chest.

**Turbine torque fractions**

The turbine torque fractions F2 to F5. Must total 1, otherwise an error message appears. Fraction numbers correspond to mass numbers; i.e., F2 is the fraction of torque to be applied to mass #2 of the multimass shaft.

**Coefficient of inertia; Stiffness coefficient; Damping factors**

Only visible if generator type is `multimass`. Coefficients of inertia H2 to H5 (s), stiffness coefficients K12 to K45 (pu/rad), and damping factors D2 to D5 (pu torque / pu speed deviation) are associated with the masses of the multimass shaft. K12 corresponds to the rigidity coefficient between masses #1 and #2, and so on.

> **Note** If you do not want to simulate all four masses in the multimass shaft, simply set the inertia of unwanted masses to 0. The rigidity coefficient and damping factor corresponding to omitted masses are not considered. When masses are not simulated, the remaining system is "compressed" toward the generator; i.e., if only two masses are used (excluding the generator), they are masses #2 and #3. The input data for the masses considered are shifted accordingly. In any case, inertias must be consistent with torque fractions. You cannot set an inertia to 0 and set the corresponding torque fraction to a nonzero value. However, you can set a torque fraction to 0 and set the corresponding mass inertia to a nonzero value.

**Initial power and generator rotor angle**

If the shaft is multimass, enter the initial mechanical power Pm0 (pu) and initial generator angle Θe0 (degrees). If the shaft is single mass, enter only initial mechanical power.

Initial mechanical power is automatically updated by the load flow utility of the Powergui block. Initial angle is also computed by the load flow utility and is written in the associated Synchronous Machine block dialog box.

## Inputs and Outputs

`wref`
: The speed reference, in pu. It is normally connected to a Constant block with the value set to 1.0 pu.

`Pref`
: The electrical power reference, in pu. It is set to a constant value corresponding to the initial active power drawn from the Synchronous Machine block connected to the Steam Turbine and Governor block.

`wm`
: The generator's speed, in pu. This is one of the signals in the last output of the Synchronous Machine model (internal variables).

`d_theta`
: The generator's power angle deviation. It is also one of the signals in the last output of the Synchronous Machine model (internal variables).

`dw_5-2`
: Output a vector containing the speed deviations, in pu, of masses 5, 4, 3, and 2.

`Tr5-2`
: Output a vector containing the torques, in pu, transmitted by masses 5, 4, 3, and 2.

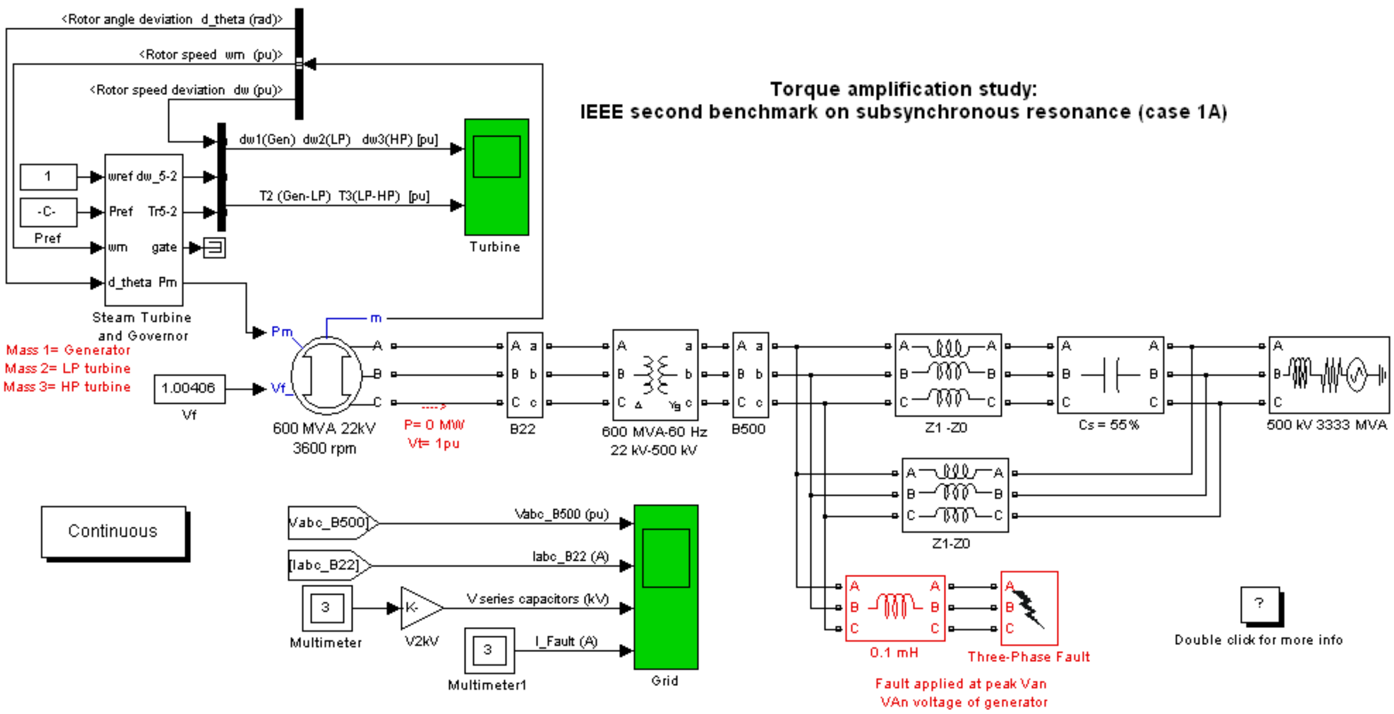
`gate`
: Gate opening in pu.

`Pm`
: The mechanical power, in pu, that you connect to the first input of a Synchronous Machine block.

## Example

The `power_thermal` demo illustrates the use of the Steam Turbine and Governor block. This system is an IEEE benchmark used to study subsynchronous resonance and particularly torque amplification after a fault on a series-compensated power system [2]. It consists in a single generator connected to an infinite bus via two transmission lines, one of which is series compensated. The subsynchronous mode introduced by the compensation capacitor after a fault has been applied and cleared excites the oscillatory torsional modes of the multimass shaft and the torque amplification phenomenon can be observed. Open the Simulink diagram by typing `power_thermal`.

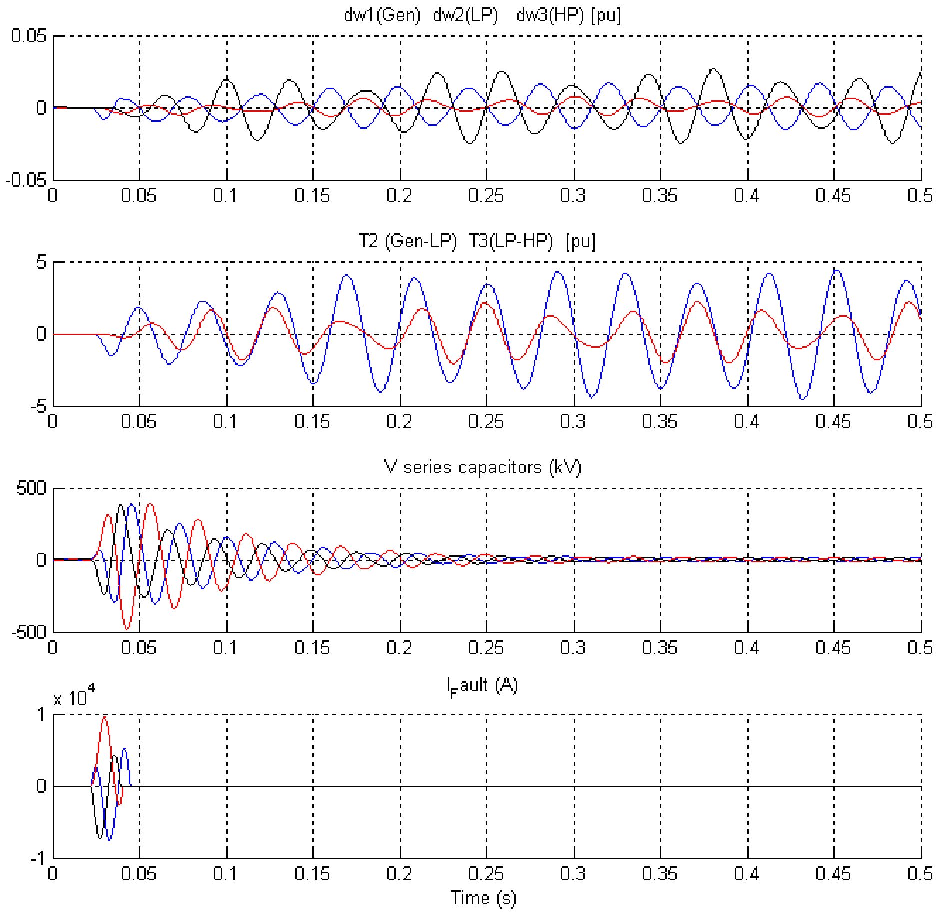
This system is slightly different from the one presented in [2]. Since we are using the Synchronous Machine mass as the first mass, we cannot model the exciter's mass as is done in [2]. Therefore, our system has only three masses, representing the generator's rotor (mass #1) and the turbine's low and high pressure stages (masses #2 and #3, respectively).




In order to start the simulation in steady state, you must first initialize the synchronous machine and steam turbine by using the **Load Flow and Machine Initialization** utility of the Powergui. Set the generator as a `PV generator` with zero active power to simulate an initially unloaded generator.

This test is performed without regulators. The machine's excitation voltage is also set to a constant value (1.00406 pu), which is computed by the load flow.

Run the simulation. Once the simulation is completed, observe the mass speed deviations, torques, series capacitor voltages and fault currents.




The peak values of all these signals correspond within 3% to those given in Table 5, case 1A, of [2]. The torque amplification is clearly observed on all masses of the shaft system. The high-pressure turbine (mass #3) transmits a peak torque exceeding 2 pu to the low-pressure turbine (mass #2), while the low-pressure turbine transmits a peak torque exceeding 4 pu to the generator's rotor (mass #1).

## References

[1] IEEE committee report, "Dynamic models for steam and hydro turbines in power system studies," *IEEE Transactions on Power Apparatus and Systems*, Vol.PAS-92, No.6, 1973, pp.1904-1915.

[2] IEEE Subsynchronous resonance working group, "Second benchmark model for computer simulation of subsynchronous resonance," *IEEE Transactions on Power Apparatus and Systems*, Vol.PAS-104, No.5, 1985, pp.1057-1066.

## See Also

Excitation System, Hydraulic Turbine and Governor, Powergui, Synchronous Machine

**Was this topic helpful?** Yes No