POWER EXTENSION LIBRARY

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Abstract

Matlab/SimPowerSystems, product of The Mathworks, is graphical user environment for modelling, anlyzing and simulation of power systems. Simulink library of this product *powerlib* contains basic models of turbines, exciters and control systems. Control systems used in these models aren't usually used in Slovak power system and central Europe power systems. This cause that it was necessary to build supporting library for this product.

1 Library contents

Supporting library *power_extension_library,* shown in fig. 1, should be used for modeling these systems:

- Exciter systems (ST1, ST1a)
- Turbines and governors (Hydro turbine, Steam Turbine & governor, Power controller)
- Measurement block (f measurement)
- Frequency load shedding model (FLS model)

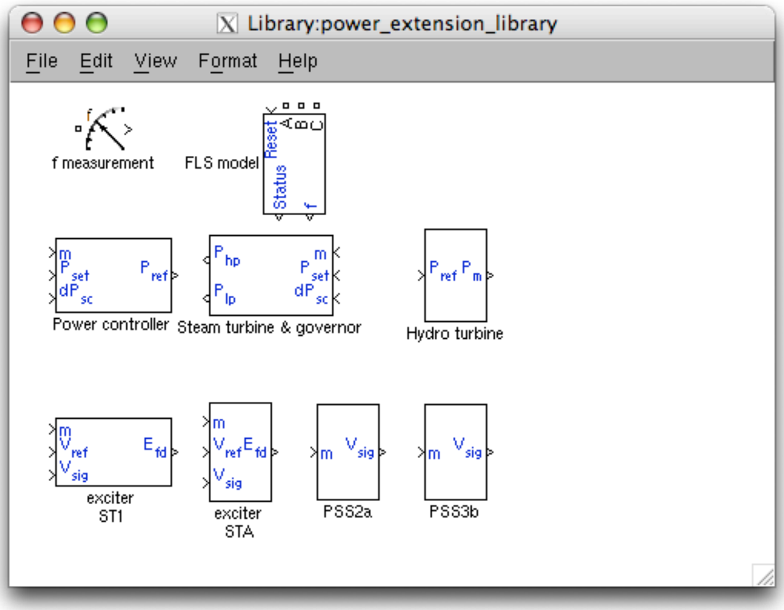

Figure 1: Supporting library power_extension library

2 Initialization process

It is important to mention that models of turbines, exciters and controllers can initiliaze states themselves. Initialize algorithm of these blocks find connection between synchronous machine and these blocks and obtain initial states of this machine. Then the model could compute its own initial states from the aquired initial states of synchronous machine. This process shortens simulation time and accelarates speed of simulation.

3 Description of models in library

3.1 Frequency measurement block

Figure 3.1: Frequency measurement block

The block, shown in fig. 3.1, implements frequency measurement. It measures frequency in p.u. in discrete times with sample period T_s. The frequency is calculated from measured voltage angle by eq. 1.

$$f = \frac{ang(V(k)) - ang(V(k-1))}{2\pi T_s f_n} \tag{1}$$

, where: f - measured frequency
$ang(V(k))$ - actual voltage angle
$ang(V(k-1))$ - voltage angle of previous measurement
f_n - nominal frequency

3.2 Frequency load shedding model

The block, shown in fig. 3.2, implements model of load shedding relay. This model sheds the load when frequency is lower then the assigned value. The load is disconnected until a value at reset input is being changed from 0 to 1. From an output port status you can see an actual status of a switch.

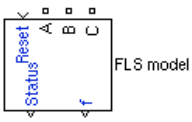

Figure 3.2: Frequency load shedding model

3.3 Active power controller

The active power controller, shown in fig. 3.3, consists of PI controller of power k_p, k_i, frequency corrector k_{kf} and switchable speed P controller k_w. PI power controller error is a result from power reference input signal P_{set}, which passes through limiting ramp block dP_{cmax} then is summed with the initial power reference signal and frequency corrector signal and then reduced by active power from synchronous machine, which is filtered by lowpass filter with time constant T_f. The controller is switched from active power control to speed control, when the frequency becomes lower than 0.996 p.u. or higher than 1.004 p.u. or by user input time T.

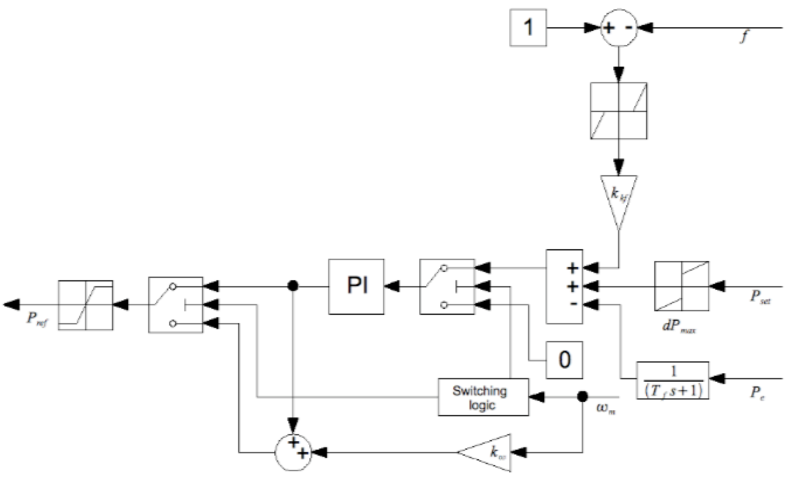

Figure 3.3: Active power controller

3.4 Steam turbine and governor model

The block, shown in fig. 3.4, implements steam turbine with 4 chambers, governor and power controller. Turbine's chambers are represented by time constants T_4, T_5, T_6, T_7 and gains k_4, k_5, k_6, k_7. Sum of the gains must be equal to 1. The time constant T_7 and gain k_7 must be greater than zero for correct functionality of the block. The governor is represented by time constant T_3, limits u_o, u_c and valve nonlinear characteristic. User can adjust valve characteristic by G_v and P_{gv} parameters. The power controller, connected through input port P_{ref}, is modeled same as the active power controller mentioned in previous chapter.

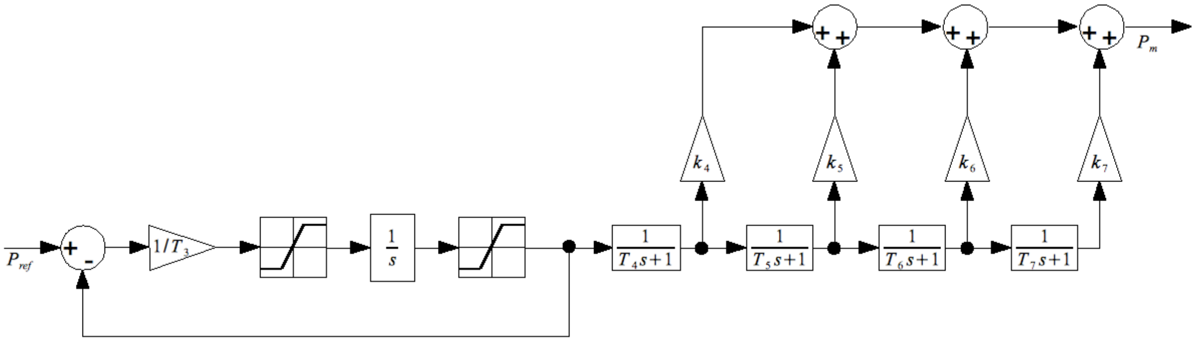

Figure 3.4: Steam turbine and governor model

3.5 Hydraulic turbine model

The block, shown in fig. 3.5, implements model of hydraulic turbine. Model consists of governor (K_g, T_g) and linearized turbine model (T_w). Input port P_{ref} should be connected to the active power controller or any user designed controller model.

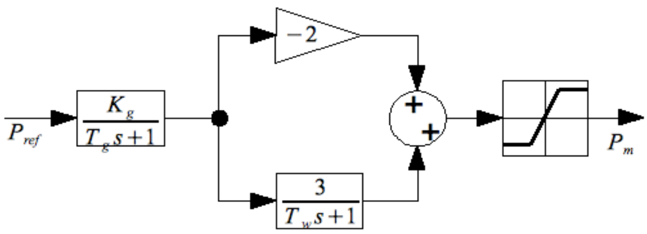

Figure 3.5: Hydraulic turbine model

3.6 Exciting system ST1

The block, shown in fig. 3.6, implements simplified model of ST1 exciting system for synchronous machine. Block consists of PI voltage controller and model of exciter. The exciter is modeled like a transfer function with time constant T_e and gain K_e. Controller error is calculated from reference voltage value V_{ref}, signal from power system stabilizer V_{sig} and actual voltage of synchronous machine V_t.

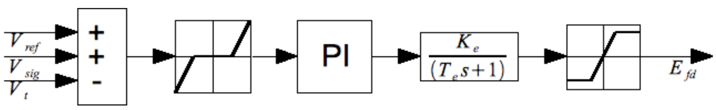

Figure 3.6: Exciting system ST1

3.7 Exciting system ST1a

The block, shown in fig. 3.7, implements simplified model of ST1a exciting system for synchronous machine. Block consists of Lead-Lag voltage controller with derivation feedback. Controller error is calculated from reference voltage value V_{ref}, signal from power system stabilizer V_{sig} and actual voltage of synchronous machine V_t.

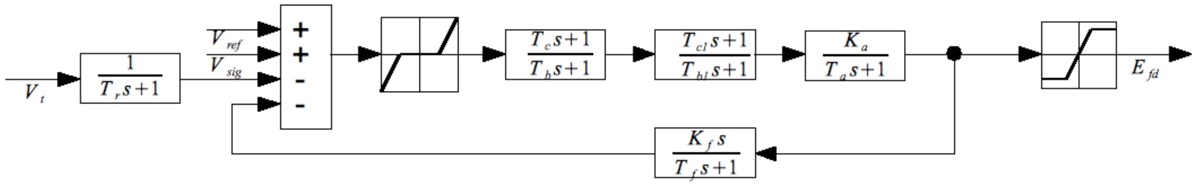

Figure 3.7: Exciting system ST1a

3.8 Power system stabilizer PSS2a

The block, shown in fig. 3.8, implements model of power system stabilizer PSS2a. The stabilizer has 2 bands; from electric power P_e and from machine speed ω_m. Both signals are filtered through washout filters and then pass through lead-lag segments.

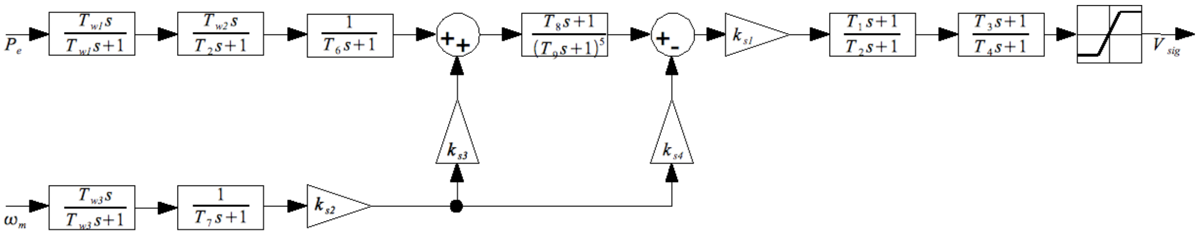

Figure 3.8: Power system stabilizer PSS2a

3.9 Power system stabilizer PSS3b

The block, shown in fig. 3.9, implements simplified model of power system stabilizer PSS3b. The stabilizer has 3 bands; from electric power P_e, from machine speed ω_m and from field current I_{fd}. Each signal is filtered through washout filters and then is multiplied with band gain. Output signal of stabilizer V_{sig} is calculated by sum of the bands saturated through limiting saturation.

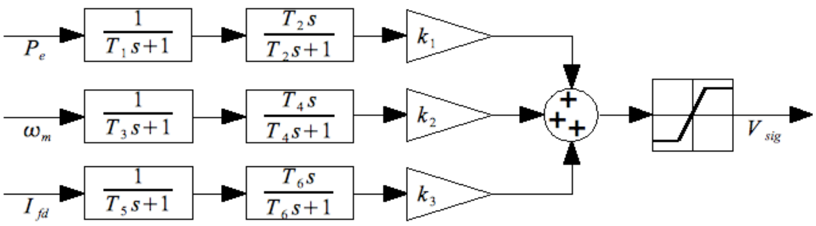

Figure 3.9: Power system stabilizer PSS3b

4 Experiment setup and simulation results

We've modeled simple power system, shown in fig. 4, to demonstrate how some blocks of the library works. Modeled power system consists of one thermal power plant model, 2 loads, 400 kV line, 3-phase switch, 2 load shedding models and net model. Thermal power plant (TPP) is modeled by 259 MW synchronous machine, steam turbine and governor model, exciter ST1 and PSS3b. Net is modeled by 10000 MW synchronous machine and active power controller. Net is connected through 3-phase switch to 400 kV line. Reference value of active power of TPP is changed 10 MW in 100 s. After the desired setpoint of active power of TPP is reached the 3-phase switch opens in 400 s. The active power controller switches from active power control to speed control when the frequency has fallen under 49.8 Hz. The frequency load shedding relay FLS 1 reacts and shed load cause the frequency has fallen under 49 Hz. Then the system is stabilized. Simulation results are shown in fig. 5 and fig. 6.

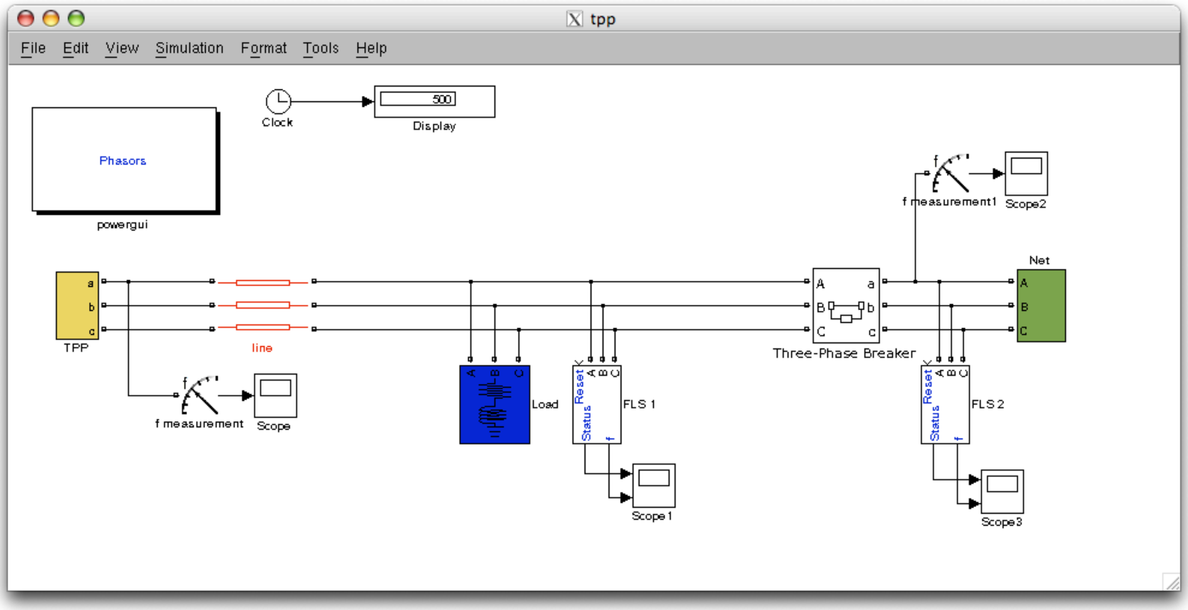

Figure 4: Power system modeled for experiment

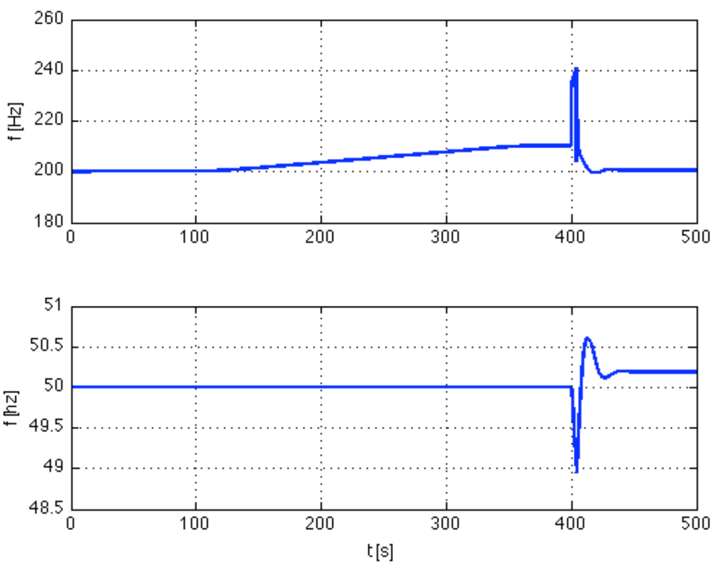

Figure 5: Active power and frequency of TPP

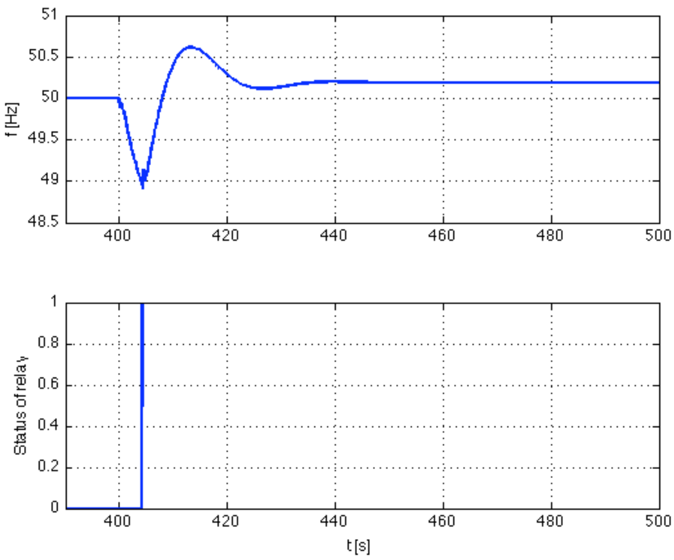

Figure 6: frequency and status of frequency load shedding FLS1

5 Results and conclusions

Matlab/SimPowerSystems library *powerlib* contains many useful blocks for modeling transients in power systems, but this library does not contain blocks for modeling controllers and other devices used in European power systems. Models of turbines in *powerlib* are very detailed, but they decrease simulation speed of huge power systems. Therefore we've decided to build our own library of blocks. One of the main requirements for simulation of power systems is to run the simulation from steady state, so it was necessary to implement to the blocks an initialization algorithm. We also think that it is necessary to implement more models to simulate other types of turbines and controllers, so the library should update. However we think that the library will be a useful tool for developers of power systems, who are using Matlab/SimpowerSystems product.

Acknowledgement:

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