Primary and Secondary Frequency Control of Synchronous Machines

Lab 1

EEEN40550 - Power System Dynamics & Control

Learning and Program Outcomes

The learning outcomes of this lab activity are twofold:

- To understand the behaviour of synchronous machines as well as primary and secondary frequency regulations for the transient behavior of a power system.
- To define the sensitivity of system variable trajectories with respect to most relevant machine and controller parameters.

The program outcome of the lab is to familiarize with a software tool for time-domain simulation fo electric power systems.

Exercises

Consider the WSCC 9-bus 3-machine system with *d*-*q* axis machine models, AVRs and turbine governors and consider a loss of load at bus 5 occurring at $t = 1$ s. Determine the effect on frequency variations in the following scenarios:

1. Without turbine governors and AGC. Discuss the effect of increasing the inertia constant and/or the damping of the synchronous machines.
2. With turbine governors but without AGC. Discuss the effect of varying the regulator gain of the turbine governors and show some relevant cases, e.g., same droops for all governors and a droop much bigger/smaller than the others.
3. With turbine governors and AGC coordinating all machines. Discuss through simulations the effect of varying the gain K_0 of the AGC.

Data File

Use the file `wscc_reg.dm` that can be found in the collection of data files on the module website. The one-line diagram of the network is shown in Fig. 1.

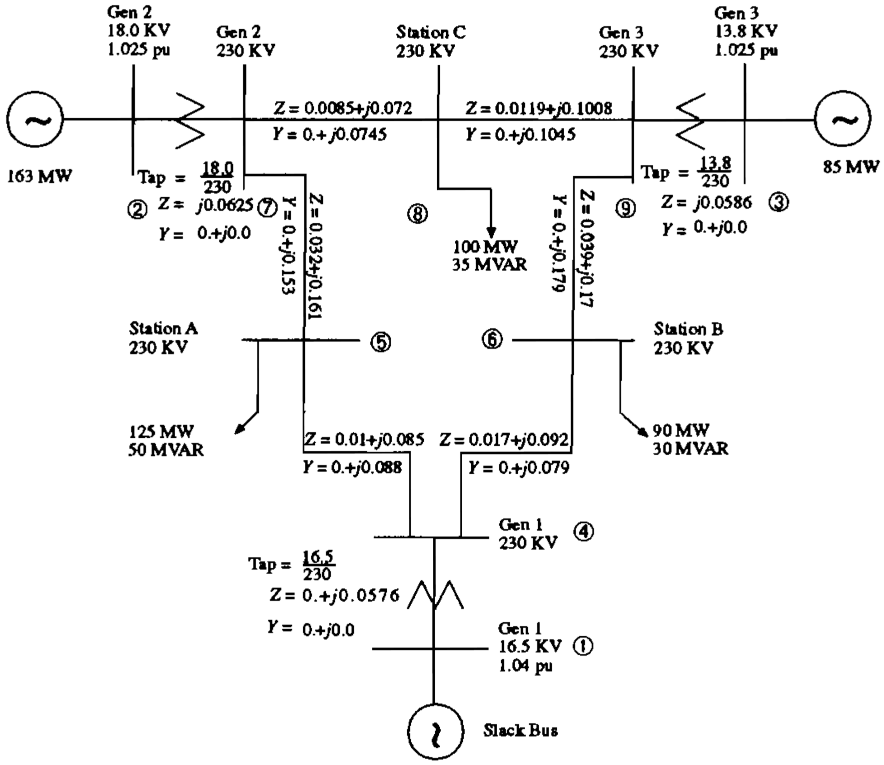

Figure 1 WSCC 9-bus test system.

Hints

- The time domain integration can be solved using the command:

```
>> dome -r TDS wscc_reg.dm
```

  Help on available options can be obtained using the command:

```
>> dome -A TDS
```

- Time domain simulation results can be plotted using the `domeplot` command.
- Assume device default parameters unless otherwise indicated in the exercise. Default parameters are those included in the data file.

- After each exercise, double check the parameters of the control devices.
- If no AGC is considered, 50 to 100 s of simulated time should be sufficient to define the behaviour of the system. To appreciate the effect of secondary frequency regulators, it might be necessary to use a larger simulation time, e.g., 500 s.
- It is important to check that there exists a stable solution for the system "after" the contingency. This can be easily verified by solving the power flow for the system without the load at bus 5 and then solving the small-signal stability analysis.
- The loss of load can be simulated using the device `Switch`. The data format of this device can be obtained by:

```
>> dome -q Switch
```

- Set `Settings.coi = True` for all simulations.
- For all simulations, set `TDS.pq2z = True`.
- It can be convenient to set a fixed time step for the time domain integration: `TDS.fixt = True` and a reasonably small time step, e.g., `TDS.tstep = 0.1`.
- The WSCC 9-bus system models a US network. The system frequency should be set to 60 Hz, e.g., `Settings.freq = 60`.
- The data of the case study `wscc_reg.dm` of this lab activity is based on the following book:

  P. W. Pai and M. A. Sauer, *Power System Dynamics and Stability*, Prentice Hall, 1998.

Dynamic Models and Controller Schemes

The dynamic models used in this laboratory activity are the *d*-*q* axis model of the sychronous machine (4^{th} order). The Dome device that implement this model is `Syn4`. No saturations are considered.

Figures 2, 3 and 4 show the control schemes of the controllers included in the data file `wscc_reg.dm`, namely, the turbine governor, the automatic voltage regulator and the AGC.

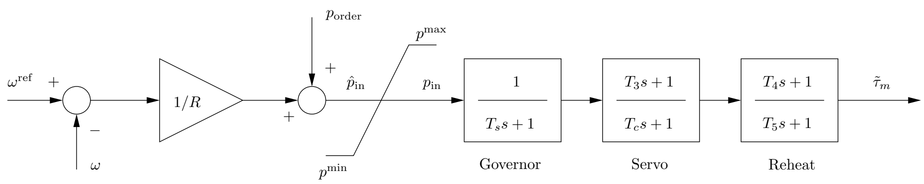

Figure 2 Turbine governor control scheme.

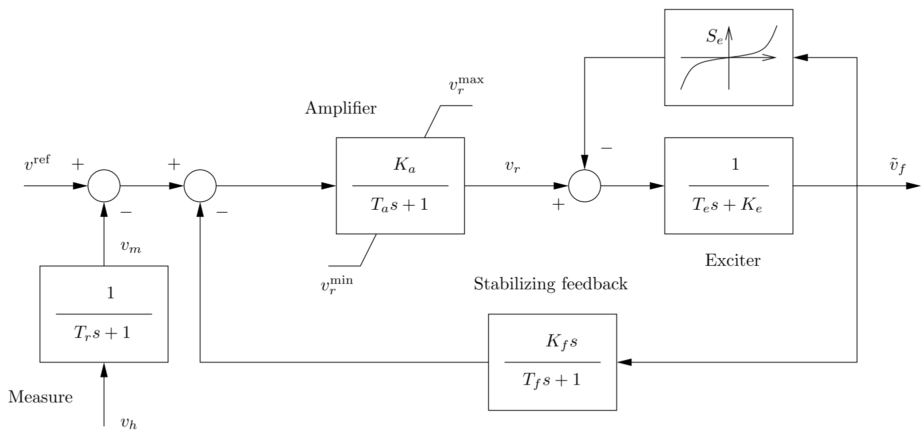

Figure 3 Automatic voltage regulator control scheme.

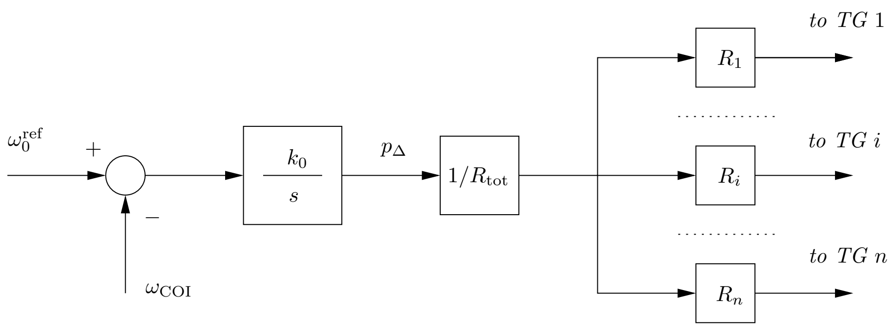

Figure 4 Automatic generation control scheme.