Automatic Voltage Regulation of Synchronous Machines

Lab 2

EEEN40550 - Power System Dynamics & Control

Learning and Program Outcomes

The purpose of this lab activity is to get familiar with the automatic voltage regulation of synchronous machines. The learning outcomes of this lab activity are twofold:

- To understand the dynamic interaction of automatic voltage regulation fo synchronous machines and the transmission system.
- To understand the effect of PSS controllers on synchronous machine transient behaviour.

The program outcome of the lab is to familiarize with a software tool for eigenvalue analysis as well as time domain simulation of electric power systems.

Exercises

Consider the dynamic model of the IEEE 14-bus system with AVRs and a PSS controller. Consider the outage of line connecting buses 2 and 4, occurring at $t = 1$ s. Determine the effect on bus voltages and machine rotor speeds in the following scenarios:

1. Without AVRs and PSS. Discuss the effect of varying d- and/or q-axis machine time constants.
2. With AVRs on all machines and without PSS controllers. Discuss the effect of varying the AVR gains.
3. With AVRs on all machines and a PSS controller connected at machine 1. Discuss the effect of varying the gain of the PSS.
4. Determine the effect of load models. Considering the case with AVRs on all machines and no PSS, define the behaviour of the system when loads are modelled as constant impedances.

For all scenarios, solve the time domain simulation as well as an eigenvalue analysis of pre- and post-disturbance operating points.

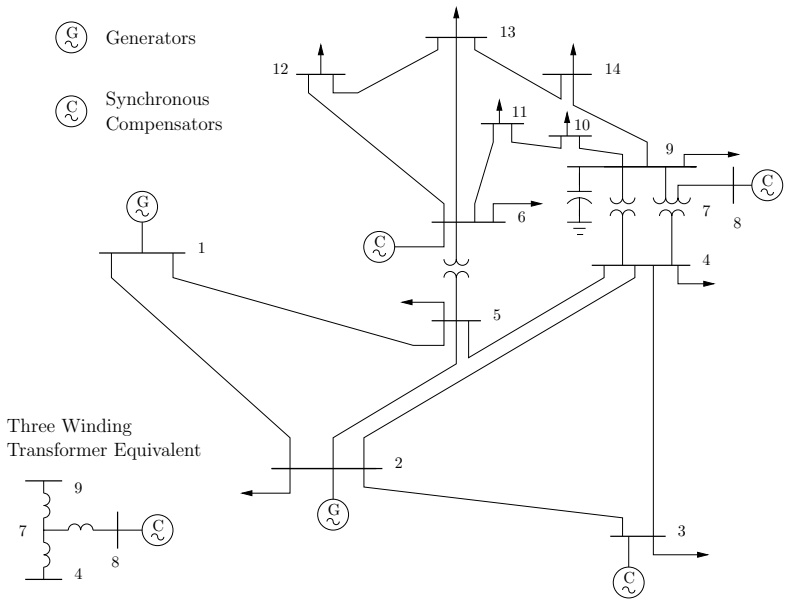

Figure 1 IEEE 14-bus test system.

Data File

Use the file `ieee14_pss.dm` that can be found in the collection of data files on the module website. Note the `ALTER` commands at the end of the data that impose a load increase of 20% with respect to the base case. The one-line diagram of the network is shown in Fig. 1.

Hints

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

  ```
  >> dome -r TDS ieee14_reg.dm
  ```

  Help on available options can be obtained using the command:

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

- The eigenvalue analysis (or small-signal stability analysis)can be solved using the command:

  ```
  >> dome -r EIG ieee14_pss.dm
  ```

Help on available options can be obtained using the command:

```
>> dome -A SSSA
```

- Time domain simulation results can be plotted using the `domeplot` command.
- Eigenvalue analysis results can be plotted by enforcing the option `SSSA.plot = True`. This will generate a plot of the root locus of the current operating point.
- 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.
- 20 to 30 s of simulated time should be sufficient to define the behaviour of the system.
- The eigenvalue analysis of post-disturbance conditions can be obtained by solving the power flow of the system with line connecting buses 2 and 4 offline. With this aim, set `u = 0` in the data file for the line that connects bus 2 to bus 4, or simply comment out the transmission line data.
- Set `Settings.coi = True` for all simulations.
- For all scenarios except for scenario 4, set `TDS.pq2z = False` and `SSSA.pq2z = False`. This will ensure that loads are modelled as constant PQ. For scenario 4, set `TDS.pq2z = True` and `SSSA.pq2z = True`. This will ensure that loads are modelled as constant impedances.
- 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 IEEE 14-bus system models a US network. The system frequency should be set to 60 Hz, e.g., `Settings.freq = 60`.

Dynamic Models and Controller Schemes

The dynamic synchronous machine models used in this laboratory activity are 5^{th} and 6^{th} order models. The Dome devices that implement these models are `Syn5d` and `Syn6a`, respectively. No saturations are considered.

Figures 2 and 3 show the control schemes of the controllers included in the data file `ieee14_pss.dm`, namely, the automatic voltage regulator and the PSS.

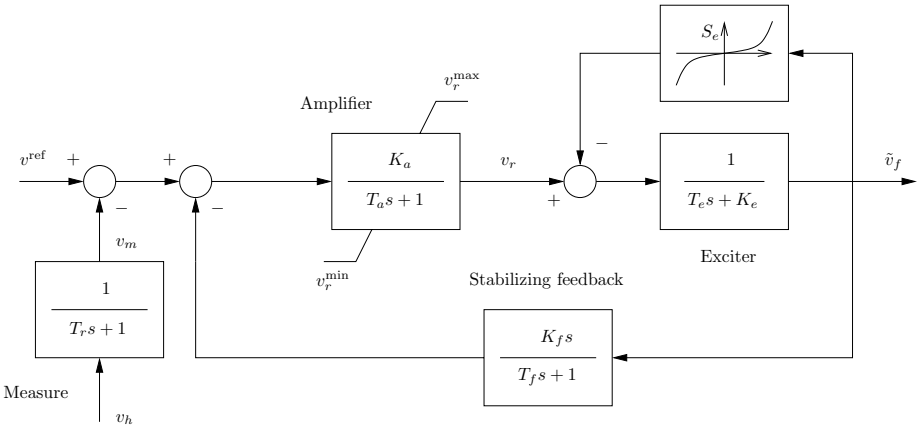

Figure 2 Automatic voltage regulator control scheme.

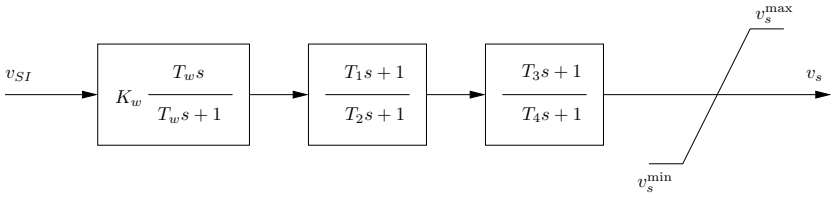

Figure 3 Power system stabilizer Type II control diagram.