Project Description – Power System Stability EE504PS

You will be allowed considerable flexibility in selecting a topic. If you have interest in a particular topic please feel free to create a proposal by March 2 for in-class students or by March 16 for off-campus students; project will be due Friday, April 27th for on-campus students and Friday, May 11th for off-campus students. Your final report, which should be approximately 10 typed, double-spaced pages in length plus an Appendix with graphs, computer code, and selected computer printouts not to exceed 15 pages. If you wish to wish to analyze one piece of equipment using Matlab & Simulink, the following format may be used as a guide:

I. Research.
   • Is there a standard model for the device?
   • Can you find any public papers describing the device? (attach)

II. Describe the device.
   • What is the purpose of this device?
   • What are appropriate applications of the device?

III. Explain (or develop) a model.
   • Explain (develop) state-equations for the device.
   • Draw block diagram of the device; use sub-systems to explain what each element of the project represents.
   • List parameters, what they represent and typical values
   • List inputs and output of device

IV. Explain how your model is initialized.

V. Explain how parameters of model might be identified or verified.

VI. Verify that your model works
   • Integrate you model into the model we have been developing in class.
   • Create one or two situations that demonstrate how your device works.

Have fun. This is a great opportunity to develop a model library that can be shared. If you develop a model, please let me know if I may share your model and report.
The indices of interest associated with the closed-loop frequency response are the bandwidth $\omega_B$ and peak value $M_p$.

A high value of $M_p$ (>1.6) is indicative of an oscillatory system exhibiting large overshoot in its transient response. In general, a value of $M_p$ between 1.1 and 1.5 is considered a good design practice.

Bandwidth is an important closed-loop frequency response index. Larger values indicate faster response. It approximately describes filtering or noise-rejection characteristics of the system.

Generally accepted values of performance indices characterizing good feedback control system performance are:

- Gain margin $\geq 6$ dB
- Phase margin $\geq 40^\circ$
- Overshoot $= 5$-15%
- $M_p = 1.1$-1.6
not adequate to cover many of the modern excitation systems. In particular, it is not a good figure of merit for excitation systems supplied from the generator or the power system, due to the reduced capability of such systems during a system fault.

For high initial-response excitation systems, the nominal response merely establishes the required ceiling voltage. The ceiling voltage and voltage response time are more meaningful parameters for such systems.

### 8.4.2 Small-Signal Performance Measures [3, 7]

Small-signal performance measures provide a means of evaluating the response of the closed-loop excitation control systems to incremental changes in system conditions. In addition, small-signal performance characteristics provide a convenient means for determining or verifying excitation system model parameters for system studies.

Small-signal performance may be expressed in terms of performance indices used in feedback control system theory:

- Indices associated with time response; and
- Indices associated with frequency response

The typical time response of a feedback control system to a step change in input is shown in Figure 8.11. The associated indices are rise time, overshoot, and settling time.

![Figure 8.11 Typical time response to step input. © IEEE 1990 [7]](image-url)
Figure 8.14 Excitation system control and protective circuits

and reactive power excursions in the event the ac regulator is removed from service abruptly. Care must be taken to ensure that a trip of the unit operating on manual control does not leave the generator in an overexcited condition.

8.5.2 Excitation System Stabilizing Circuits

Excitation systems comprised of elements with significant time delays have poor inherent dynamic performance. This is particularly true of dc and ac type excitation systems. Unless a very low steady-state regulator gain is used, the excitation control (through feedback of generator stator voltage) is unstable when the generator is on open circuit. Therefore, excitation control system stabilization, comprising either series or feedback compensation, is used to improve the dynamic performance of the control system. The most commonly used form of compensation is a derivative feedback as shown in Figure 8.15. The effect of the compensation is
DIRECT AXIS SYNCHRONOUS MACHINE EQUATION MANIPULATION FOR
THE PURPOSE OF SIMULATION, IGNORING DAMPER WINDINGS

Non-Reciprocal Per Unit System ($\beta \neq 1$) with $L_{mdu} = 1$ and $R_{fd} = 1$

I. Variables

Inputs: $v_{fd}$ and $i_{ds}$

Output: $\psi_{ds}$

Internal: $i_{fd}$ and $e'_q = \frac{L_{md}}{L_{ffd}} \psi_{fd}$

Unknowns: $\psi_{ds}$, $i_{fd}$, and $e'_q$; i.e., output plus internal variables

Note: There are 3 unknowns. Therefore, we need 3 equations.

II. Voltage Equation:

$$v_{fd} = \frac{p}{\omega_B} \psi_{fd} + R_{fd} i_{fd}$$

(1)

III. Flux Linkage Equations:

$$\psi_{fd} = L_{ffd} i_{fd} - \beta L_{md} i_{ds}$$

(2)

$$\psi_{ds} = -L_{d} i_{ds} + L_{md} i_{fd}$$

(3)

IV. Solve for the Input to the Integrator

Select $e'_q$ as the output of the integrator.

Modify Eq. 1 such that it is in terms of $e'_q$ instead of $\psi_{fd}$.

Multiple $\psi_{fd}$ by 1 in the form of $\frac{L_{ffd}}{L_{md}} \frac{L_{md}}{L_{ffd}}$.

$$v_{fd} = \frac{p}{\omega_B} \frac{L_{ffd}}{L_{md}} \frac{L_{md}}{L_{ffd}} \psi_{fd} + R_{fd} i_{fd}$$

(4)

Equation 4 can be rewritten as:

$$v_{fd} = \frac{p}{\omega_B} \frac{L_{ffd}}{L_{md}} e'_q + R_{fd} i_{fd}$$

(5)

where $e'_q = \frac{L_{md}}{L_{ffd}} \psi_{fd}$

(6)
\[ \dot{X} = AX + Bu \]

- Inputs
- States
- Inputs to integrators

Models
Initial conditions

SS: \[ x(0) = 0 \]

SS: \[ x(t) \rightarrow x \] in steady state

\[ 0 = A \cdot x(0) + B \cdot u(0) \]

\[ A \cdot x(0) = -A^{-1}B \cdot u(0) \]

\[ x(0) = -A^{-1}Bu(0) \]
Simulink Subsystems

- Create a Subsystem
  - Add Input to Subsystem
  - Add Output
* Bring doughnuts
* Vendor per unit may not equal your per unit -time constants or - may gains
* Get an As built
More testing

* Beware of transducer time constants

* Consider sampling rate
Areas & Schedules

A1 = Actual Interface
A = Loop flow

A Net: 1100
B Net: 100
C Net: 1200
Permanent Drop

* Share the burden of changes in $f$

* In WECC Droop

5% Speed derivation will cause 100% change in output.
B Exception to 5% Droop
Control areas w/ weak ties

C Temporary droop
Allows hydro governor to cope w/ water starting time constant.
(water hammer)