ECE 422/522
Power System Operations & Planning/
Power Systems Analysis II
Spring 2014
Course Outline

Instructor:
Kai Sun
Information

• Contact:
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• Office hours:
  Thursday 3:00-4:30pm/by appointment @ MK612

• GTA:
  Nan Duan (nduan@utk.edu)

• Website
  http://web.eecs.utk.edu/~kaisun/ECE422-522
References

- Text book
- References
  - Other reports, journal papers and notes.
Prerequisite

• ECE 421/521 – Electric Energy Systems / Power System Analysis I (Chapters 1-7 in Saadat’s book)
  – Overview of power systems and electric power generation
  – Basic principles
  – Generator & transformer models, and Per-Unit system
  – Transmission line parameters
  – Line model and performance
  – Power flow analysis
  – Optimal dispatch of generation

• Slides and materials are available at http://web.eecs.utk.edu/~kaisun/ECE421-521/index.htm
Course Overview

• This course covers
  – modeling, analysis and mitigation of power system stability and control problems
  – planning and operations of a modern interconnected power grid under disturbances to ensure system performance and reliability
  – analytical and numerical methods to tackle realistic stability and control problems
  – minor work of programming in MATLAB or using professional power system software, and
  – some emerging issues and techniques on modern power systems
## Course Outline

<table>
<thead>
<tr>
<th>Content</th>
<th>Time/Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>General background on modern power systems</td>
<td>3 lectures</td>
</tr>
<tr>
<td>Power system modeling</td>
<td>6-7 lectures</td>
</tr>
<tr>
<td><strong>Midterm 1</strong></td>
<td><strong>Mid-February</strong></td>
</tr>
<tr>
<td>Control of real and reactive powers</td>
<td>6 lectures</td>
</tr>
<tr>
<td><strong>Midterm 2</strong></td>
<td><strong>Mid-March</strong></td>
</tr>
<tr>
<td>Power system stability problems and mitigation measures</td>
<td>8-9 lectures</td>
</tr>
<tr>
<td><strong>Project Presentations</strong></td>
<td><strong>Mid-April</strong></td>
</tr>
<tr>
<td>Other topics on grid operations and planning</td>
<td>2-3 lectures</td>
</tr>
<tr>
<td><strong>Final Exam</strong></td>
<td><strong>Late April</strong></td>
</tr>
</tbody>
</table>
Course Outline

1. General background
   - Structure of a power system
   - US Electric Industry (utilities, deregulation, energy resources)
   - Overview of power system reliability and NERC guidelines
   - Introduction of power system stability
     • Basic concepts and definitions
     • Examples on stability problems
Course Outline (cont’d)

2. Power system modeling
   - Modeling of a synchronous machine
     • Winding circuits
     • Park’s (dq0) transformation
     • Equivalent circuits
     • Swing equations
     • Detailed and classic generator models
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Hydraulic Units</th>
<th>Thermal Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronous Reactance</td>
<td>$X_d$</td>
<td>0.6 - 1.5</td>
</tr>
<tr>
<td></td>
<td>$X_q$</td>
<td>0.4 - 1.0</td>
</tr>
<tr>
<td>Transient Reactance</td>
<td>$X_d'$</td>
<td>0.2 - 0.5</td>
</tr>
<tr>
<td></td>
<td>$X_q'$</td>
<td>-</td>
</tr>
<tr>
<td>Subtransient Reactance</td>
<td>$X_d''$</td>
<td>0.15 - 0.35</td>
</tr>
<tr>
<td></td>
<td>$X_q''$</td>
<td>0.2 - 0.45</td>
</tr>
<tr>
<td>Transient OC Time Constant</td>
<td>$T_{d0}'$</td>
<td>1.5 - 9.0 s</td>
</tr>
<tr>
<td></td>
<td>$T_{q0}'$</td>
<td>-</td>
</tr>
<tr>
<td>Subtransient OC Time Constant</td>
<td>$T_{d0}''$</td>
<td>0.01 - 0.05 s</td>
</tr>
<tr>
<td></td>
<td>$T_{q0}''$</td>
<td>0.01 - 0.09 s</td>
</tr>
<tr>
<td>Stator Leakage Inductance</td>
<td>$X_l$</td>
<td>0.1 - 0.2</td>
</tr>
<tr>
<td>Stator Resistance</td>
<td>$R_a$</td>
<td>0.002 - 0.02</td>
</tr>
</tbody>
</table>

**Notes:**
1. Reactance values are in per unit with stator base values equal to the corresponding machine rated values.
2. Time constants are in seconds.
Course Outline (cont’d)

– Load modeling
  • Static and dynamic load models
    – ZIP and exponential models
    – Frequency dependency
    – Motor loads
  • Acquisition of model parameters
    – Component-based approach
    – Measurement-based approach
Course Outline (cont’d)

3. Control of real and reactive powers
   – Active power and frequency control
     • Speed governing system (turbine & governor models)
     • AGC (Automatic Generation Control) for multi-generator systems
     • Under-frequency protection
   – Reactive power and voltage control
     • Excitation system
     • Var compensators
     • Secondary voltage control
4. Power system stability problems and mitigation measures
   - Small-signal stability
     • Linearized model
     • PSS (Power system stabilizer) model
     • Power oscillations in interconnected power systems
Course Outline (cont’d)

– Transient stability
  • Single-machine-infinite-bus system
  • Direct methods (energy function)
  • Numerical methods (dynamic simulation)
  • Short-circuit analysis (balanced and unbalanced faults)
Voltage stability

- P-V and V-Q curves
- Short-term and long-term voltage stability problems
- Analysis methods and mitigation measures
5. Other topics on grid operations and planning
   – Mitigation of cascading events and restoration from a blackout
   – Emerging issues and techniques
     • Penetration of intermittent resources
     • Wide-area monitoring and control
Course Requirements

• Two mid-terms and a final exam
• 8-9 homework assignments
• Course project with a presentation
  – Contingency and stability analysis for a power system model using commercialized software tools

• Grading
  Homework       20%
  Course project 20%
  Exams (2)      30% (15% each)
  Final Exam     30%
  Total          100%
Course Policies

• ECE 522 students have more assignments and exam questions. ECE 422 students who also accomplish the ECE 522 assignments will receive additional credits.

• For homework assignments, you may work together in groups but each individual must hand in their own work.

• For take-home exams, please work independently