Fall 2011
EE527, Net-Centric Power System Control
E. Jonckheere

Note: This is a course developed last year (Fall 2010) on the rapidly evolving subject of the “smart grid.” This syllabus might evolve during the semester in order to follow the evolution of the field. Feel free to contact me at jonckhee@usc.edu if there are questions.

Synopsis
This course was developed in 2010 in response to the “smart grid” government-initiated program. The Southern California Edison and the Los Angeles Department of Water and Power were also instrumental in setting up this course, as both organizations perceived the need for a “crash program” to train a new breed of power engineers able to cope with the energy problems the country is likely to face in a not so distant future.

This program came at a time when there is more and more concern about the information grid vulnerability to attacks and its potential impact on the power grid, as the power grid and the information grid are more and more intertwined.

This program is also concomitant with a revival of control in the wake of Networked Control and Network Control. The two concepts should not be confused: Networked Control refers to large-scale distributed control systems borrowing the information infrastructure to transmit sensing/actuating signals through unreliable channels. Network Control refers to the control of networks to have them work properly, for example, control of the network to avoid congestion, Random Early Detection (RED).

This new course is, therefore, designed at the crossroad between the power grid and the information network. It will be taught in a way that should be of interest to the power grid, the computer networking, and the control communities. This symbiotic approach can certainly be justified on the ground that software vulnerabilities have been shown to have the potential to create blackouts, but next to this, there is the more compelling reason that congestion control techniques initially developed for information grid are in fact applicable to the line overload in the power grid.
Three parts of course

Part 1
The first part of the course will be taught from the “networking” point of view. It is heavily graph oriented. It will proceed from graph topology, and then will develop a concept of “traffic” applicable to both the power and information grids. Both grids are driven by consumers’ demands, which can be formulated in terms of the “traffic” that has to flow from “sources” (power generating stations, transmitters, resp.) to “destinations” (distributions, receivers, resp.) without creating “congestion” (line overload, packet drops, resp.).

Part 2
Part 2 is centralized around the concept of reactive power flow and voltage stability, which should be maintained despite fluctuation in the generation and the demand. This part is heavily “control oriented.” Fundamentally, it deals with stability of large-scale interconnected systems.

Part 3
Part 3 is the “fun” part dealing with “green technology:” wind farm, solar energy and the reliable integration of such technology in the so-called “smart” grid.

Technical digression
It might appear as a bit of a surprise that line overload and computer communication congestion can be treated under a unifying theme. The gist of it is a very recent research observation: It turns out that the traditional power flow equations of the bus model can be decoupled into active power flow equations and reactive power flow equations. Both the active and the reactive equations can be interpreted as relationships between currents and voltages in a resistive grid. Going to the effective resistance defines a metric, which behaves pretty much like the metrics of the information grid. This explains how resistive grid methods have recently been utilized in sensor networks.

Format

Instructor
Dr. E. A. Jonckheere
EEB 306
(213) 740-4457
jonckhee@usc.edu

Meetings
Tuesday-Thursday, 3:30-4:50 pm, in DEN

Office Hours
Tuesday & Thursday, 10:30-12:30.

Teaching Assistant:
Karan Chamsakul
Karan.Chamsakul@sce.com

Discussion Sessions
TBA

Prerequisites
We will try to make the course as self-contained as possible. No power prerequisites will be required, although basic electrical engineering background (resistors, capacitors, inductors, impedance, Kirchoff’s laws, etc.) will be assumed. No networking prerequisites will be required either, although knowledge of the basic concepts (routing, link utilization, Transmission Control Protocol, etc.) would be useful. The student will be assumed to have the very basic control background (differential equations, closed-loop stability, etc.)

Textbooks
Unfortunately, there is no textbook that puts under the same cover the wide variety of material that will be covered in this class. However, the following books might be useful, especially to those who would like to get up to speed on power systems:


To compensate for this lack of formal textbook, the instructor will put plenty of relevant papers on the blackboard.
Exams & Midterms & etc.

The final letter grade will be based on homework (60%) and a final project (40%). The final project topic will be the students’ choice, but relevant to the material covered in class, and subject to instructor’s approval.

**Time table**

<table>
<thead>
<tr>
<th>Time</th>
<th>FIRST PART: GRAPH THEORY OF TRANSMISSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2011</td>
<td>The concept of network. Information network, sensor networks, telephone network, power grid, bus model, transportation network, percolation network, quantum networks. The concepts of “flow” and “commodity;” multi-commodity flow, etc.</td>
</tr>
<tr>
<td>August 2011</td>
<td>Introduction to the power grid elements: generation, transmission, distribution. Structure of an electric power system. The deregulation issue and large-scale power transmission.</td>
</tr>
<tr>
<td>September 2011</td>
<td>Classical (non-topological) graph topology. Degree distribution, Scale-Free graphs, Small-World graph model of power grid; expander graphs, super concentrators, adjacency matrix, graph Laplacian.</td>
</tr>
<tr>
<td>September 2011</td>
<td>Resistive networks, Laplacian, effective resistance.</td>
</tr>
<tr>
<td>October 2011</td>
<td>Line overload in power grid and its metaphoric congestion in information grid. Line overload in power grid will be shown to be more likely to happen if the grid is Gromov hyperbolic. Overloaded lines will be identified as those of low graph inertia.</td>
</tr>
<tr>
<td>November 2011</td>
<td>Nonlinear loads, describing function models, introduction to voltage stability.</td>
</tr>
<tr>
<td>November-</td>
<td>Unified approach to frequency and voltage control in power grids.</td>
</tr>
</tbody>
</table>

THIRD PART: GREEN TECHNOLOGY

December 2010  Future green power grid and smart power transmission. Integration of large farms of renewable power generation. Smart grid foundations. Dynamic demand control. Smart power scheduling and transmission system. FACTS (Flexible AC Transmission System). Adaptive power generation and distribution based on fast data communication in a smart power grid.

Bibliography
The following papers, easily downloadable from the Internet, should give prospective students a very good indication as to what the course will be all about. In fact, the following papers will be discussed in the course:


