Version 1.0 23 March 2014

EH2740 Computer Applications in Power Systems
Basic Course

Course Syllabus

7.5 ECTS credits

Overview

Control and operation of power systems is a very wide and comprehensive topic including many different fields ranging from power system instrumentation to power system modelling and control systems theory.

This introductory course provides a wide perspective on the field, opening for continued studies in specialised subjects. The course is focused on design, implementation and use of information and control systems for control and operation of restructured power systems. The topics covered include several common to technologies and applications utilised for control and operation of power systems.

Course Objectives

The objective of this course is to give an overview of control and operation of power systems in a wide sense, including generation, transmission and distribution of electric power.

After completing the course, the participants shall be able to:

- Perform basic design and evaluation of SCADA system architectures including local systems, communication infrastructure and central systems.
- Describe basic power system instrumentation technologies and principles
- Describe basic power system protection technologies and schemes
- Perform basic fault location analysis
- Analyse and evaluate current processes and technologies employed for control and operation of transmission & grids
- Analyse and evaluate current processes and technologies employed for control and operation of distribution networks
- Identify relevant standards in the area of information and control systems and evaluate their application to different areas of power system control and operation.
- Describe cyber-security threats to information and control systems used for power system control and operation.
- Describe future trends in power system control and operation with a focus on new information and control systems technologies.

Prerequisites

The following courses are pre-requisites for this course.

- EG 2020 Power Systems Basic course (recommended)

Course Structure

The course includes lectures, project assignments, individual tests, lab work and field trips.

Lectures and Exercise sessions

The lecture series constitutes 13 lectures, and 5 workshops covering the entire subject area. There are also 3 guest lectures whose content will NOT be included in the tests. The content form the guest lectures is however useful for the project assignments. Participation in the lecture series is recommended. For each lecture there is recommended reading, either a book chapter excerpt or scientific articles. It is highly recommended that course attendees read these texts before the

lectures based on the provided reading guidance. Please note that contents from the reading materials ARE included in the tests.

During the course, voluntary project hours are arranged. During these sessions, the students could work for their assignments in the classroom and teachers are available to answer questions.

Project Assignment (group)

The project assignment involves three parts, Part 1, Part 2 and Part 3. In part 1, students are required to design a substation automation system including selecting measurement devices, designing protection scheme, and communication substation automation. In the part 2, students are trained to design ICT architecture for communication between substations and control centers and perform basic calculations in terms of corresponding data volumes for the projected communication channels. The part 3 involves completing a MATLAB code for a Weighted Least Square state estimation problem solved by Newton Raphson methods. Each assignment part corresponds to 2 ECTS.

New this year is that the part 1 of parts of the project assignment shall be performed using the Helinks tool for substation automation system design. Access to the tool is unfortunately only possible at the ICS Lab in the Q building. The lab will therefore be open for studetns during longer periods as advertised on the course Social page.

Substation Automation Systems Configuration Lab (group)

Substation automation systems are connected to electrical equipment to monitor, protect and control the process at the substation. This lab involves configuring automation devices using the communication services defined in the IEC 61850 standard to implement a high-level protection function where process information, signals and commands are exchanged over an Ethernet link.

This lab is performed in the same groups that the students were assigned for the project assignments and will be held at the department lab on Osquldas väg 12, floor 7 (Q building). This lab work corresponds to 0,75 ECTS.

SCADA & Wide Area Communication Lab (group)

The SCADA & Wide Area communication lab involves configuring a Wide Area communication network to allow data capture and sending commands to field devices (RTUs) through a simulated communications network.

This lab is performed in the same groups that the students were assigned for the project assignments and will be held at the department lab on Osquldas väg 12, floor 7 (Q building). This lab work corresponds to 0,75 ECTS.

Study Visits

Study visits and corresponding Guest lecture on Fault localisation at ABB is planned for **April 10th**. Participation is voluntary but recommended.

Tests or "mid-terms"

The course also contains three short tests covering the theoretical concepts covered in the lectures, exercises and projects. The tests are individual, and voluntary. Participation in the tests is however a pre-requisite for achieving higher grades.

Course Administration

All course materials can be downloaded at KTH social and project assignments must be submitted to EH2740@ics.kth.se before 17.00 the corresponding due dates. Course updates, schedule changes etc. will continually be posted on the KTH social, please check regularly.

Literature

The literature of the course consists of a **very basic text book** complemented with a set of scientific papers that provide more detail and insight into different aspects of the field. The main textbook is:

Electrical Network Automation and Communication Systems, 2003 by Cobus Strauss.

However, the contents of the book are **very basic** and it covers the scope of the course at a high level of abstraction. For a greater level of detail, than offered by the Strauss book, the following book, available online will be used:

Network Protection and Automation Guide – NPAG, by Areva T&D,

To provide the necessary level of detail and insight in some particular subjects, the following publications - all available in the KTH Social platform - will also be used.

Paper #1. "Reliability of Substation Configurations", Daniel Nack, Iowa State, available at http://www.ee.iastate.edu/~jdm/ee653/SubstationReliability.pdf

Paper #2. Chapter 2 Central Control and Management from "*Control and Automation of Electrical Power Distribution Systems"* by J. Northcote-Green and R. Wilson.

- Read sections 2.9.1 and 2.9.2 on substation automation. There is a lot of other interesting information in the rest of the chapter which is worth reading if you have time.
- Read section 2.6 for the basics of SCADA system for lecture 7.
- Read section 2.2-2.5, *DO NOT* spend too much time on the details of Figure 2.2 and Figure 2.6. You should be able to describe *the basic applications to manage distribution grid.*

Paper #3. "*IEC 61850, IEC 61400-25, and IEC 61970: Information models and information exchange for electric power systems"* by K. Schwarz.
Read pages 1-27 for lectures 4-6 but skip section 3.2.2 (on IEC 61400-25, power quality & hydro) it is important that you understand and can define the concepts of:

- Self-description/self-identification
- Information model
- Information exchange
- Logical Nodes (LN)
- Common Data Classes
- Purpose of the IEC 61850 standard
- Purpose of the CIM (IEC 61970-301)

During lectures 8-10 we will look more closely at the contents of section 4.2 (pg. 27) onwards, ignore the explanations of the programmer DLL. You should be able to explain what is happening in figures 17-20 in terms of the points described above.

Paper #4. *"UCA and 61850 for Dummies"* by D. Proudfoot.
This is an easy introduction to the IEC 61850 standard and how it is used in practice.

Paper #5. Chapter 1 Computer Networks and Internet from "*Computer Networking A top-down Approach",* by J. F Kurose and K.W Ross.
Kurose and Ross is something of a standard text for computer networking. From chapter 1 you should be able to define the concepts of:

- Applications
- Services
- Protocols
- Physical media
- Client/server paradigm
- Circuit and packet switching
- Delay, loss and throughput

Section 1.5 is very important; it introduces the OSI model which is used universally to explain computer network theory and operation. Ignore section 1.7 unless you're very interested.

Paper #6. J. D Fernandez and A. E Fernandez *"SCADA Systems: vulnerability and remediation"*, Journal of Computer Science in College, Vol 20. Issue 4. Apr, 2005
This document gives a short history regarding cyber security for critical infrastructure and provides information about a few threats and countermeasures in the domain. The exam will involve pp. 163 ("Threats") to 165 ("Securing SCADA systems").

Paper #7. Chapter 2 Weighted Least Squares State Estimation from "*Power System State Estimation*" by A. Abur and A. G. Exposito.
Read through the provided text and ignore all the exercises. *You should be able to explain the assumptions made for WLS state estimation algorithm (section 2.5) and the construction of measurement Jacobian matrix- H together with procedures of solving WLS problems (section 2.6).* Be aware that in our course Δx^k is solved directly without any decomposition of $G(x^k)$, details can be found at lecture slides.

Paper #8. Chapter 20 and 22, "Power System Stability and Control" by Leonard L . Grigsby, CRC Press 2012. Hand-outs will be provided during the course.

Paper #9. Chapter 2. "Intelligent Automatic Generation Control", Takashi Hiyama, CRC Press 2011

Chapter 11.1 Active Power and Frequency Control "Power System Stability and Control" by P. Kundur

Course Schedule

Date, Time	Room	Description	Reading	
Mon 24 March	E52	Lecture 1 - Introduction	*Strauss*	LN

13.00 – 15.00		• Course administration • Computer applications for power systems intro.	*Ch1,2,3*	
Thu 27 March 13.00 – 15.00 **N.B New day**	Q15	Lecture 2 – Substations & Devices • Power system apparatus • Substation schemes • Substation design & reliability	*Paper #1*	LN
Fri 28 March 08.00 – 10.00	Q15	Lecture 3 - Instrumentation • Measurement devices • D/A and A/D conversion	*NPAG Ch 6 & 22*	LN
Mon 31 March 13.00 – 15.00	Q15	Lecture 4- Power System Protection I • Principles • Protection Schemes	*Strauss Ch 4* *NPAG Ch 2 & 9*	LN
Tue 1 April 15.00 – 17.00	E36	**Guest Lecture** Substation Automation Systems		Andrea Bonetti
Wed 2 April 13.00 – 15.00	E31	Lecture 5 - Substation Automation Systems I • Automation functions • System architectures	*NPAG Ch 24* *Paper #2*	LN
Mon-Fri *7-11 & 14-18* *April*	*Lab*	*Several slots for IEC 61850 Lab available, see separate schedule.*		*WY*
Fri 4 April 09.00 -10.00	Q36	**Cancelled – No test this date.**		
Mon 7 April 13.00-15.00	E52	Lecture 6 Substation automation systems II • Information modelling • IEC 61850	*Paper #3* *Paper #4*	LN
Thu 8 April 10.00 – 12.00	ICS Lab	Workshop 1 Substation Automation systems III Helinks Workshop to prepare project assignment part 1		WY
Wed 9 April 15.00 – 17.00	ICS Lab	Workshop 2 Open Lab time to work on Project Assignment		WY
Thur 10 April 13.00 – **17.00** **N.B Time**	ABB	Study visit to ABB Substation Automation Products including Guest lecture		WY
Mon 14 April 13.00 – 15.00	E52	Lecture 7- Communication networks I • Communication basics • OSI & TCP/IP stacks	*Paper #5*	NH

Tue 15 April 10.00 – 12.00	E36	Lecture 8 - Communication networks II • Power System communication • IEC WAN protocols	*Paper #5*	NH
Thu 17 April 09.00-10.00	Test 1	SAS & Protection systems		LN
Thu 17 April	Hand-in	Project assignment part 1		
Mon-Fri *21-25 April* *28 -2 (May)*	*Lab*	*Several slots for Wide Area Communication Lab*		*WY*
Tue 22 April 13.00 – 15.00	Q31	Lecture 9 – SCADA & central systems • Architecture • Alarm handling	*Paper #2*	LN
Wed 23 April 13.00 – 15.00	Q34	**Guest lecture** SCADA & EMS Anna Rådman, Ventyx		LN
Thu 24 April 13.00 – 15.00	E32	Workshop 4 SCADA & Communication network Workshop to prepare project assignment part 2		NH
Tue 29 April 13.00 – 15.00	D41	Cyber-security for power system communications	*Paper #6*	MK
Wed 30 April 09.00-10.00	Test 2	SCADA & Communication Systems		LN
Wed 30 April	Hand-in	Project assignment part 2		
Mon 5 May 13.00 – 15.00	Q15	Lecture 10 - EMS Applications I • State Estimation	Paper #7 Paper #8	DB
Tue 6 May 13.00 – 15.00	E36	Lecture 11 – EMS Applications II • Automatic Generation Control	Paper #9	DB
Wed 7 May 13.00 – 15.00	D41	Workshop 5 EMS Applications • Workshop to prepare project assignment part 3		DB
Thu 8 May 10.00 – 12.00	E35	Lecture 12 Wide Area Monitoring and Control Systems		LN

Tue 13 May 10.00 – 12.00	E51	Lecture 13 Control System Architecture and the Smart grid.		LN
Fri 16 May 09.00 – 10.00	Q34	Test 3 EMS, Wide Area Monitoring and Control Systems		LN
Fri 16 May	Hand-in	Project assignment part 3		

Assessment & Grades

The grading of the course is based on the student achievements in the assignments and on the individual tests.

- Each part of the project assignment is graded as *Fail*, *Pass* (6 course point) and *Pass with bonus* (7-10 course point).
- There are three individual tests participation which is voluntary basis. Maximum score on each test is 10 course points.
- Presentation and opposition of the final project is graded as *Fail* or *Pass*
- The Substation Automation Systems Configuration Lab is graded as *Fail* or *Pass*
- The SCADA and Widea Area Communication Lab is graded as *Fail* or *Pass*

Course grades are only granted to students who collect all 7.5 course credits. Grading of the course is based on the collected course points.

Grade	Course Points
E	18-24
D	25-31
C	32-39
B	40-46
A	47-60

Course Staff

The following persons are active during the course

Lars Nordström	Course responsible Course Examiner	larsn@ics.kth.se
Wu Yiming	Course Administration Lab responsible IEC 61850 & WAN	yimingw@ics.kth.se
Nicholas Honeth	Communication Systems	nicholash@ics.kth.se
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