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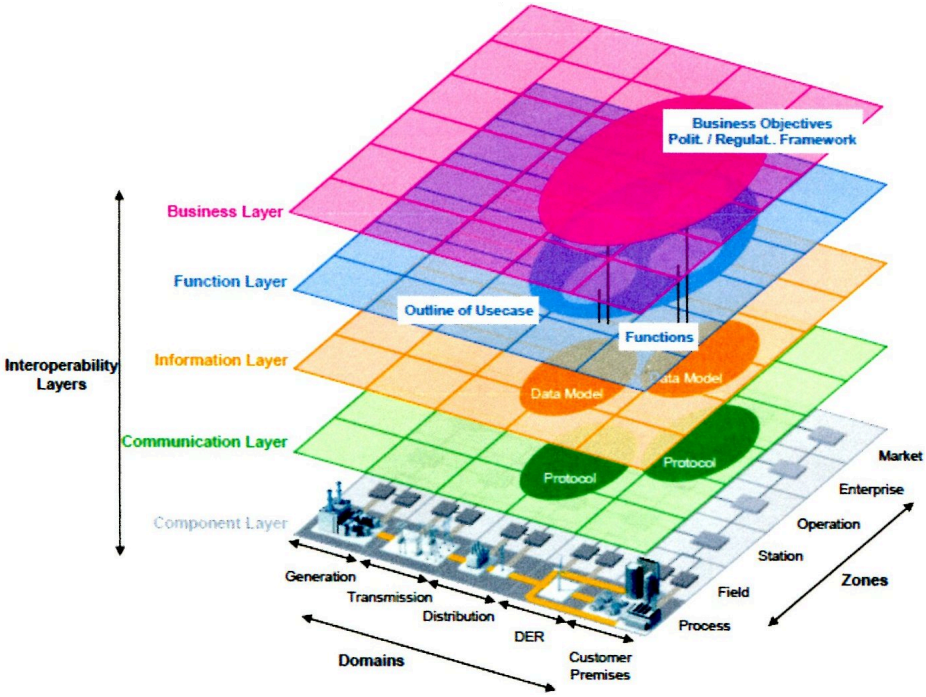
EH2741
Communications & Control in Electric Power Systems



Course Memo

6 ECTS credits

Overview

Control and operation of power systems is a wide and comprehensive topic including many different engineering fields ranging from power system instrumentation to power system modelling and control systems theory. To manage and optimise the control and operation of the power system, information and control systems are used throughout the power system Actually, the information and control systems so tightly integrated with the physical power system, that together they constitute a *cyber-physical* system.

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 the physical power system. As a framework for the course, the Smartgrids Architecture (SGAM) model is used to present the many aspects of communications and control in power systems.

Course Objectives

The objective of this course is to give an overview of technologies and concepts used for communication and control 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:

- Describe the functions of the primary equipment in the power system that is relevant for protection, automation and control
- Analyze substations and simple power systems in terms of reliability protection, automation and control needs.
- Describe the function and architecture of information and control systems used for protection, automation and control of power systems.
- Describe the function and architecture of communication systems used for information & control systems for power system control.
- Describe the importance of information & control systems for the ability to connect large amounts of renewable power sources.
- Analyze and develop basic systems for substation automation and protection.
- Analyze and develop basic information & control systems for system-wide control from control rooms, e.g. SCADA systems and EMS applications.
- Construct a state estimator for power systems.
- Describe relevant interoperability standards in the field, such as the Smartgrid Architecture Model – SGAM.
- Describe the threats and risks associated with the use of information & control system for controlling the electric power system, known as Cyber Security.

Prerequisites

The course has no explicit pre-requisities, but it is assumed that course participants have completed a Bachelors degree in Electrical Engineering, computer science or related topic and are eligible for studies on the Master level.

Course Structure

The course follows a path from from the physical power system, the primary equipment via field devices for measurement d control to station level automation systems for protection and

control. Form there the course continues via central level operational systems like SCADA on to Energy management Systems used for central power system stability and control. The course is focused on the communication and control systems utilised at the individual levels of the combined cyber-physical system.

As a guideline and framework for the course, the Smartgrid Architecture Model (SGAM) is used. The SGAM provides an overview of the communication and control systems ranging from field level to central application level. In the course, the physical, field and station levels constitute a first block of lectures and project assignment. The operational and communication layers constiute the second level of the course, finally the operational and functional levels are covered in the third block of lectures and assignments. Each course block consists of 2 ECTS credits.

Lectures and Exercise sessions

The lecture series constitutes 15 lectures and 5 workshops covering the entire subject area. There are also guest lectures whose content will NOT be included in the tests. 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 two parts, Part 1, Part 2 & 3.

In part 1, students are required to design a substation automation system including selecting measurement devices, designing protection scheme, and communication substation automation. Part 1 is concluded with a practical configuration assignment, in which parts of the designed system is implemented in real controllers

In part 2, students are trained to design an information and communication systems architecture for communication between substations and control centres using the tools and templates from the Smartgrid Architecture Model (SGAM).

Part 3 involves designing a State Estimator, which is the key application for Energy Management Systems (EMS) in Electric Power control centres.

The project is conducted in groups of four (4) students per group.

Power System Control Computer Lab (group)

At the Power system control computer lab, students works in groups to solve set of typical power system control problems using the power system simulator ARISTO. The lab requires no specific preparation, and is conducted in the lab at the Department of industrial information & control systems, Osquldas väg 10 floor 7 (Q building). The goal of the lab is to provide insights into basic power system control problems.

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 through a simulated communications network.

This lab is performed at the department lab on Osquldas väg 10, floor 7 (Q building).

Study Visits

Study visits are not completely finalised at this time and more details will be provided during the lectures.

Tests (individual)

The course also contains **two** voluntary 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 grade than E.

Course Administration

All course materials can be downloaded at KTH social and project assignments must be submitted to EH2741@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 course literature consists of brand new course book entitled:

"Power System SCADA and Smartgrids" by Mini Thomas & John D McDonald, available in the KTH eLibrary,

In addition to this course book, additional reading will be provided either online or as hand-outs on the lectures. Already now, these include:

A. Fundamentals of Power System Protection, M. Kezunovic.
B. Chapters 11.1 and 11.2, "Power System Stability and Control",Kundur.
C. Chapter 2 – Power System State Estimation Theory and Implementation, Ali Abur, et.al.
D. Chapter 2 – Intelligent Automatic Generation Control, H. Bevrani, T. Hiyama

Course Schedule

Date, Time		Description	Reading	Teacher
Tuesday 30 August 15-17 **L52**	L1	Introduction • Course administration • Communication & Control in Power Systems.	Ch. 1	LN
Thursday 1 September 15-17 **L51**	L2	Power System Control Overview • Power System Equipment • Principles of control • ARISTO introduction		LN
Tuesday 6 september 08-10 **ICS Lab**	Computer Lab	Power System Control Lab • ARISTO Hands-on lab **N.B.** Pick one of these 6 slots		DB

Tuesday 6 september 10-12 **ICS Lab**	Computer Lab	Power System Control Lab • ARISTO Hands-on lab **N.B.** Pick one of these 6 slots		DB
Tuesday 6 september 13-15 **ICS Lab**	Computer Lab	Power System Control Lab • ARISTO Hands-on lab **N.B.** Pick one of these 6 slots		DB
Tuesday 6 september 15-17 **ICS Lab**	Computer Lab	Power System Control Lab • ARISTO Hands-on lab **N.B.** Pick one of these 6 slots		DB
Thursday 8 september 08-10 **ICS Lab**	Computer Lab	Power System Control Lab • ARISTO Hands-on lab **N.B.** Pick one of these 6 slots		DB
Thursday 8 September 15-17 **L51**	L3	Power System Instrumentation • Measurement devices • D/A and A/D conversion • SGAM representation		LN
Friday 10 september 08-10 **ICS Lab**	Computer Lab	Power System Control Lab • ARISTO Hands-on lab **N.B.** Pick one of these 6 slots		DB
Tuesday 13 September 15-17 **L52**	L4	Power System Protection • Principles of protection • Protection Zones & Schemes • SGAM representation	A	LN
Thursday 15 September 15-17 **V22**	L5	Substation Automation I • Automation Functions • SGAM representation • Substation Communication Introduction	Ch 4.1 – 4.8	LN
Tuesday 20 September 15-17 **V34**	L6	Substation Automation II • IEC 61850 Introduction • Helinks introduction		LN WY
Tuesday 27 Sept 08-10 **V43**	Ex 1	Exercise • Substation Design using Helinks and IEC61850 • SGAM representation		WY

Tuesday 4 October 08-10 **Q33**	L7 - Guest Lecture	Guest lecture • IEC 61850 and substation automation systems		Andrea Bonetti FMTP
Tuesday 11 October 15-17 **Q34**	L8	IEC 61850 continued • Logical Nodes • Common Data classes • Communication Structures		LN
Thursday 13 October 15-17 **M33**	Ex2	Exercise • Substation Design using Helinks and IEC61850 • SGAM representation		WY
Friday 28 October 17.00	Project	Hand-in Project Assignment Part #1		
Friday 28 October 08.00 – 10.00 **D33, E31, E34**	Test 1	Voluntary Test #1		
Tuesday 1 November 8-10 **M33**	L9	Communication networks I • Communication basics • OSI stack **Wireshark Hands-on** •		FH
Thursday 3 November 15-17 **Q33**	L10	Communication networks II • OSI stack continued • TCP/IP networks • Topologies **Wireshark Hands-on**		FH
Tuesday 8 November 08-10 **L51**	L11	Communication Systems III • Power System Communication **Wireshark Hands-on**		FH
Tuesday 8 Nov 15 – 18 **ICS Lab**	Lab	SCADA and communication system lab **N.B.** Pick one of these 6 slots		WY
Thursday 10 Nov 15 – 18 **ICS Lab**	Lab	SCADA and communication system lab **N.B.** Pick one of these 6 slots		WY

Friday 11 Nov 9 – 12 **ICS Lab**	Lab	SCADA and communication system lab **N.B.** Pick one of these 6 slots		WY
Tuesday 15 November 08 – 10 **L51**	L12	SCADA & Communication Systems • SGAM recap • SCADA Systems		LN
Tuesday 15 Nov 15 – 18 **ICS Lab**	Lab	SCADA and communication system lab **N.B.** Pick one of these 6 slots		WY
Thursday 17 Nov 15 – 18 **ICS Lab**	Lab	SCADA and communication system lab **N.B.** Pick one of these 6 slots		WY
Friday 18 Nov 9 – 12 **ICS Lab**	Lab	SCADA and communication system lab **N.B.** Pick one of these 6 slots		WY
Tuesday 22 November 15 – 17 **Q31**	L13	Exercise • System architecture Design		LN FH
Thursday 24 November 15 – 17 **L51**	L14	Communication Systems V • Cybersecurity		MK
Tuesday 29 November 08-10 **Q33**	L15	Power system control centers • Energy Management Systems	Chapter 5 and 6	DB
Thursday 1 December 15 – 17 **Q31**	L16	Power System control applications • State estimation	C	DB
Tuesday 6 December 08 – 12 **M33**	L17	Power System control applications • Automatic generation Control	D	DB
Thursday 8 December 15.00 – 17.00 **L51**	Ex5	Open lab Question and Answers for solving Project Assignment part #3		DB
Tuesday 13 December 08-10 **Q31**	L18	Course Wrap-up		LN
Friday 15 December	Test 2	Voluntary test #2		

15-17 **D32, D41, D42**				
Friday 18 December	Hand-in	Project Assignment Part 2&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 points) and *Pass with bonus* (7-10 course point).
- There are two individual tests, participation which is on a voluntary basis. Maximum score on each test is 15 course points.
- The Power System Control Lab is graded as *Fail* or *Pass*
- The SCADA and Wide Area Communication Lab is graded as *Fail* or *Pass*

Course grades are only granted to students who pass all assignments and labs. 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 Examiner
Wu Yiming	Course Responsible Project part 1 Lab responsible
Fabian Hohn	Course Assistant Project part 2
Davood Babazadeh	Course Assistant Project part 3