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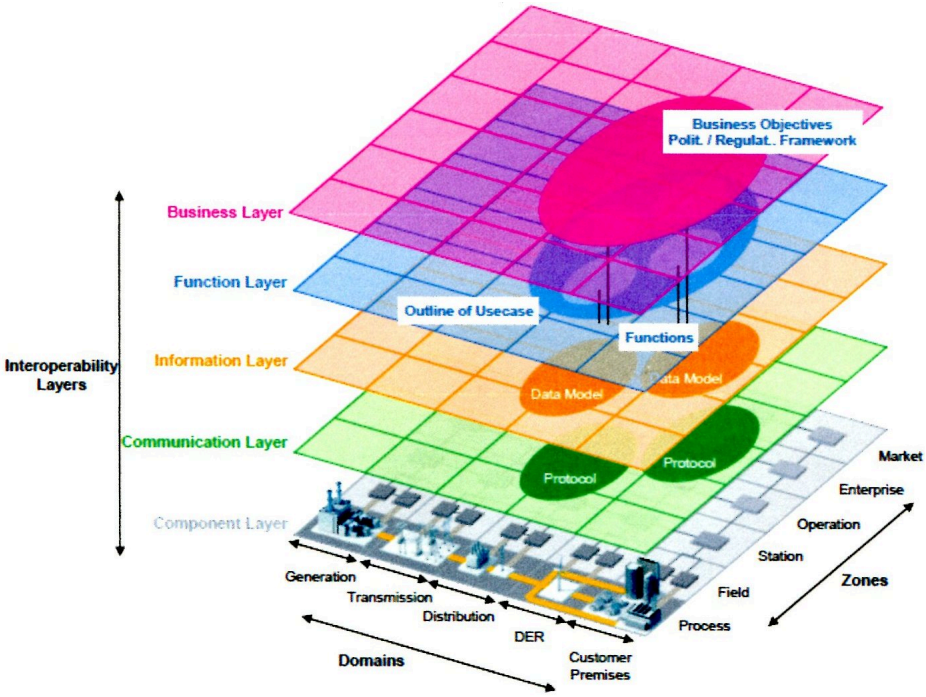
EH2741
Communications & Control in Electric Power Systems



Course Memo

6 ECTS credits

Overview

Communication and control 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 are 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 of communication and control of electric power systems, opening for continued studies in specialised subjects. It goes beyond traditional analytical control systems or power system courses, and focuses on the practical implementation of systems for communication and control. 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 model - SGAM* is used as a reference for the different 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
- Analyse 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.
- Analyse and develop basic systems for substation automation and protection.
- Analyse 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 IEC 61850
- 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-requisites, but it is assumed that course participants have completed a Bachelors degree in Electrical Engineering, computer science or related a topic and are eligible for studies on the Master level.

Course Structure

The course follows a path starting with the physical power system, its primary equipment via field devices for measurement and control to station level automation systems for protection and control. From there the course continues via central level operational systems like SCADA on to Energy Management Systems (EMS) 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. The course is divided into three modules:

- Power System Measurement, Protection and Automation
- SCADA and Communication System Architecture
- Power System Control and Energy Management Systems

Each course module corresponds to 2 ECTS credits.

Lectures and Exercise sessions

The lecture series constitutes 21 Lectures & exercises. Some of the sessions are combinations of the two - *Lecturcises*. There are also two 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 three parts:

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.

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 Canvas and project assignments must be submitted on Canvas before the corresponding deadlines published therein. Course updates, schedule changes etc. will continually be posted on the KTH canvas, please check regularly.

Literature

The course literature consists of a course book entitled:

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

This book provides an overview to the filed, and in addition to this course book, additional reading will be provided either online or as hand-outs on the lectures. Already now, these include:

Course Schedule

Date, Time		Description	Reading	Teacher
Monday 28 August 13-15 **E3**	Lecture 1	Introduction • Course administration • Overview of course topics • Introduction to the SGAM		LN
Wednesday 30 August 13-15 **B3**	-	**Cancelled**		-
Monday 4 September 10-12 **Q34**	Lecture 2	Power Systems and Substations • Power System topologies • Substation topologies • Primary Equipment		LN
Wednesday 6 September 13-15 **B3**	Lecture 3 *Hands-on*	Introduction to *Helinks* tool *Hands-on* Substation Topologies		TR
Monday 11 September 13-15 **E3**	Lecture 4	Power System Instrumentation • Instrument transformers • Characteristics and usage • SGAM representation *Hands-on* Instrument transformers		LN TR

Wednesday 13 September 13-15 **Q36**	Lecture 5 *Hands-on*	Power System Measurements • Measured quantities • Filtering & A/D conversion • SGAM representation *Hands-on* Substations and Instrument transformers		LN TR
Wednesday 20 September 13-15 **Q2**	Lecture 6	Power System Protection • Protection Principles • Protection Schemes • Protection Systems		LN
Monday 25 September 10-12 **M3**	Lecture 7 *Hands-on*	Substation Automation Systems • Introduction to IEC 61850 • System architectures *Hands-on* Designing substation automation systems using Helinks		LN TR
Monday 2 October 10-12 **B1**	Lecture 8	Guest Lecture • Building Substation Automation Systems using IEC 61850		Andrea Bonetti TR
Wednesday 4 October 13-16 **ICS Lab**	*Hands-on*	*Hands-on* Designing substation automation systems using Helinks *This is an Open Lab session, were Teachers are available to answer questions*		TR FH
Thursday 5 October 13-16 **ICS Lab**	*Hands-on*	*Hands-on* Designing substation automation systems using Helinks *This is an Open Lab session, were Teachers are available to answer questions*		TR FH
Monday 9 October 10-12 **B1**	Lecture 9 *Hands-on*	IEC 61850 and substation automation systems • Logical Nodes • Common Data classes • Communication Structures *Hands-on* Designing substation automation systems using Helinks		LN TR
Wednesday 11 October 13-15 **V35**	Lecture 10 *Hands-on*	IEC 61850 continued • IEC 61850 design cycle • SGAM representation *Hands-on* Designing substation automation systems using Helinks		LN TR
Friday 27 October 14-16	Test	Voluntary Test		

B1-3				
Monday 30 October	Assignmt	Hand-in Assignment Part #1		
Monday 30 October 13-15 **Q34**	Lecture 11 *Hands-on*	Communication Systems I • Communication basics • OSI Stack *Hands-on* Wireshark setup		FH
Wednesday 1 November 13-15 **V34**	Lecture 12 *Hands-on*	Communication Systems II • OSI stack continued • TCP/IP networks • Topologies *Hands-on* Wireshark sniffing		FH
Monday 6 November 10-12 **Q34**	Lecture 13 *Hands-on*	Communication Systems III • IEC 61850 communications • Time synchronisation *Hands-on* Wireshark sniffing		FH
Monday 13 November 10 – 12 **M33**	Lecture 14 *Hands-on*	Communication Systems IV • WAN communication *Hands-on* Wireshark sniffing		FH
Monday 20 November 10 – 12 **E35**	Lecture 15	SCADA Systems • SGAM recap • SCADA Systems		LN
Wednesday 22 November 13 – 15 **B3**	Lecture 16 *Hands-on*	SCADA & communication systems *Hands-on* Designing System Architectures		LN FH
Monday 27 November 10 – 12 **M36**	Lecture 17	Cybersecurity Guest Lecture		TBD
Wednesday 29 November 13-15 **Q34**	Lecture 18 *Hands-on*	Wide Area Monitoring and Control Systems *Hands-on* Designing System Architectures		LN FH
Monday 4 December 10 – 12 **M3**	Lecture 19	Power System Control ARISTO Introduction		LN LN

Monday 4 December	Hand-in	Hand-in Assignment part 2		
Wednesday 6 December 13 – 15 **V22**	Lecture 20	Power System State estimation Topology processing State estimation		LN PG
Monday 11 December 13 – 15 **D3**	Lecture 21	Power System State Estimation Questions and Answers		PG
Wednesday 13 December 13 – 15 **V11,V21,V23**	Test #2	Voluntary Test #2		
Friday 22 December	Hand-in	Hand-in 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 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 10 course points.
- The substation automation system configuration lab is graded as Pass/Fail

Course grades are only granted to students who pass all assignments and the lab. Grading of the course is based on the collected course points.

Grade	Course Points
E	18-23
D	24-30
C	31-37
B	38-44
A	46-50

Course Staff

The following persons are active during the course

Lars Nordström	Course Examiner
Fabian Hohn	Course Responsible Project part 2
Tin Rabuzin	Course Assistant Project part 1 Lab responsible
Pontus Grahn	Course Assistant Project part 3