### Lecture ETHZ

<table>
<thead>
<tr>
<th>Lecturer ETHZ</th>
<th>SmartGrids: System Optimization of Smart and Liberalized Electric Power Systems</th>
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<tbody>
<tr>
<td><strong>Lecturer</strong></td>
<td>Dr. Rainer Bacher</td>
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<tr>
<td>No ETHZ</td>
<td>227-0529-00</td>
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<tr>
<td>ECTS</td>
<td>6 ECTS</td>
</tr>
<tr>
<td>Time period</td>
<td>Spring semester 2015 (20 Feb 2015 – 29 May 2015)</td>
</tr>
<tr>
<td>Hours</td>
<td>Friday mornings, 08:15- approx.12:00 (incl. exercises, seminar works)</td>
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<tr>
<td>Place</td>
<td>ETH Zürich: ETZ E8</td>
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**ETZ E 8**

Fr 08-12 Weekly 20.02.; 27.02.; 06.03.; 13.03.; 20.03.; 27.03.; 17.04.; 24.04.; 08.05.; 15.05.; 22.05.; 29.05.

### Objectives

- Understanding the legal, physical and market based framework for Smart Grid based electric power systems
  - Electricity Transmission Systems
  - Electricity Distribution Systems
- Understanding the application of mathematical optimization models and solution algorithms for a secure and market based operation of today's and the future Smart Electric Power Systems.
- Gaining experience with the formulation, implementation and computation of constrained optimization problems considering Smart Grids technologies and market based electricity systems.

### Contents

- Security of Supply, economic and environmental goals of a future energy / electric power system.
- Modelling Physical laws and constraints in electric power systems.
- Optimization for matching market goals and storage / network based electric power system constraints.
- Various electricity market models, their advantages and disadvantages and price determination.
- SmartGrids: The future electricity/energy system

### Prerequisites

Motivation, Active participation (discussions). Linear numerics, power system basics and modeling, optimization basics

### Participants:

<table>
<thead>
<tr>
<th>ETHZ departments recommending this course</th>
<th>This class is ...</th>
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<tbody>
<tr>
<td>Electrical Engineering and information technology Master</td>
<td>Recommended Core Course in Electrical Power Systems and Mechatronics</td>
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<tr>
<td>Energy Science and Technology Master</td>
<td>Choice among Core Courses</td>
</tr>
<tr>
<td>Robotics, Systems and Control Master</td>
<td>Core Course in Systems Engineering: Design and Optimization of Products and Systems</td>
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<tr>
<td>Systems and Control</td>
<td>Recommended Course</td>
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PhDs interested in the subject are very welcome.

### Class text

English language Class text is continuously updated. Parts are distributed to students as pdf, Exercises (Simulations with Matlab) with solutions.

### Literature

Internet (Congestion management, Electricity markets, SmartGrids, etc); see literature list of class text

### Exercises

The exercises are mainly computer simulations of small problems including the programming of optimization algorithms with grids models. Exercises are held either jointly with the instructor and supervising assistant or individually. Matlab is used as programming environment. The exercises usually take place after the lecture (08-10), i.e. from 10-12.

### Scientific assistant

Olivier Mégel, EEH - Power Systems Laboratory, ETH Zürich, Physikstrasse 3, ETL G 22

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1 Postal address of lecturer: Dr. Rainer Bacher, Baldeggstrasse 27, CH-5400 Baden (Switzerland); Tel.: +41 56 493 59 30; Email: Rainer.Bacher@BacherEnergie.ch
2 Class Location ETHZ: [http://www.ee.ethz.ch/fileadmin/user_upload/plasmadesign/map_01.jpg](http://www.ee.ethz.ch/fileadmin/user_upload/plasmadesign/map_01.jpg) (Room ETZ E8)
Exam is as follows: Exam consists of two parts on different days:

- Part 1) All students together during the examination session: A 60 minute written exam.
- Part 2) Each student individually (15 Min. oral exam with lecturer (each candidate answers questions, alone in a room with lecturer and assistant). The oral exam is used only to improve the written exam.

After the written exam and before the oral exam, each student has the option to skip the oral exam by sending a written message to the examiner. In this case, the mark from the written exam counts as final mark. Written exam marks are, however, not communicated to the students before the oral exam session.

If a student decides to make both the written and the oral exam, the final mark is the better of written exam and the average of written + oral exam.

CV Lecturer - Dr. Rainer Bacher
Dr. Bacher is Managing Director at BACHER ENERGIE AG (Baden, Switzerland) since April 2008. BACHER ENERGIE AG is a management consulting company for the electricity industry and energy policy makers. Before that - from July 2002 to March 2008 - he was with the Federal Office for Energy (SFOE/BFE) as project director of the networks section where he was responsible for the coordination of processes leading to the Swiss Federal Law on the Secure Electricity Power Supply (StromVG, Stromversorgungsgesetz). He lectures at the ETH Zurich since 1990 in particular on "electrical energy control systems and networks." Between 2000 and 2002, he consulted the Electric Utility management in preparation of the upcoming Electricity Market Opening. Before, he was assistant professor at the ETH Zurich (93-99) for: Energy Management Systems, consultant and product manager at Power Consulting Colenco (90-93) and in industrial research at Control Data Corporation (Energy Management System Division) in Minneapolis, United States (86-90). Prior to his doctoral thesis at the ETH Zurich (82-86) with Prof. Glavitsch he obtained title of Masters in Electrical Engineering (Dipl. El.-Ing. ETHZ) (82).

Dr. Bacher is the author of more than 50 scientific papers, books and policy making reports including those of the SFOE about the blackout analysis in Italy in 2003. He has consulted the Swiss Parliament and the Swiss Federal Council on the electricity supply law and managed several national and international conferences in the field. Today, he supports the electricity industry and European energy policy makers in the implementation of the Electricity Supply Act and the design and implementation of Smart Grid and Smart Market solutions towards the new energy policy for the years 2035+ and beyond.

CV Scientific Assistant - Olivier Mégel:
06/2004 High School Diploma at the Gymnase Français de Bienne, Switzerland
10/2006 – 02/2011 Studies of Mechanical Engineering, EPF Lausanne, (BS+MS)
08/2008 – 05/2009 Exchange program, UC Berkeley, California
2009 – 2010 Several Internships at Berkeley National Lab and Gold Standard Foundation
Since 03/2012 Phd-Student, Power Systems Laboratory, ETH Zürich
Lectures SOLEPS – Lecture and Exercise Plan, Location: Fr, 08:15-12 Uhr, ETH-ETZ E8
(status as of 2/23/2015: to be updated/revised during semester)

NOTE: THIS PLAN IS ONLY TENTATIVE and MIGHT BE REVISED IN THE FIRST WEEKS OF THE SEMESTER

<table>
<thead>
<tr>
<th>Date</th>
<th>20.02</th>
<th>27.02</th>
<th>06.03</th>
<th>13.03</th>
<th>20.03</th>
<th>27.03</th>
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<tbody>
<tr>
<td>Lecture #</td>
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<td>11</td>
<td>12</td>
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<td>Exercise #</td>
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<td>2</td>
<td>(3)</td>
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Depending on availability, a conference or other event might be integrated during any of the class days.

Overview of planned Lectures and Exercises

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Exercises</th>
<th>Summary</th>
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</table>
| L1 – L3  | E1: Matlab and optimization – Total generation costs and value optimization by a QP | ⇒ Introduction: Overview and objective of the course, prerequisites, lectures and exercises, exams.  
⇒ The change from today’s Energy System and the underlying Electricity System towards a SmartGrids based System  
  o Smart Liberalized Electricity Markets, SmartGrids for a secure and sustainable electricity system, Why SmartGrids? What are SmartGrids? Stakeholders, SmartGrids characteristics  
  o The Electricity Value Chain.  
  o Legal Aspects of a grid base system.  
  o The economic viewpoint towards electricity markets, electric network regulation and consumer liberalization.  
⇒ Electricity Systems: Core Functionalities  
  o Technical and operational requirements for electricity markets, network regulation  
  o and market opening for end-consumers  
  o SmartGrids Functionalities  
  o European Transmission SmartGrids in the future |
| L4 – L8  | E2: Flow constrained wholesale electricity market | ⇒ Constrained Markets: Congestion Management in the electricity transmission system  
⇒ CONNECTED AREAS BASED ELECTRICITY MARKETS  
  o Optimization models of a single electricity spot market without any internal physical flow limits  
    o From a QP (Quadratic Programming) towards market prices in a constrained wholesale electricity market. Electricity markets and grid bottleneck auctions: Spot market principle without grid limitations; spot markets with bottlenecks, Concept of combining day-ahead spot markets, intra-day markets and grid bottleneck auctions  
    o Karush-Kuhn-Tucker (KKT) optimality conditions, Lagrangian function and solutions, Grid Con- |

³ (x) meaning: Exercise x to be distributed to students. First preparatory steps by students (self-study) recommended

⁴ Status as of 2015-02-23: Changes are possible.
<table>
<thead>
<tr>
<th>L9 – L11</th>
<th><strong>E3: Market prices and prosumer scheduling in a 24 hour future SmartGrids based market considering system constraints</strong></th>
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<tr>
<td></td>
<td>strained Power Markets: Application of the equality constrained optimization [g(x) = 0, f(x) \Rightarrow \text{min}]; Lagrangian function, understanding electricity markets with two grid limited and interconnected market areas.</td>
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<td></td>
<td>o Models of electricity markets: Three or more areas connected export-type bottlenecks</td>
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<td>o Network-based models of an electricity market</td>
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<tr>
<td>L12</td>
<td><strong>⇒ Summary of the past lectures; outlook; exam preparation</strong></td>
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