University of Cologne

Faculty of Management,
Economics and Social Sciences

Stochastic Optimization with Applications to Electricity Systems with Intermittent Wind and Solar Power

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Location:	Institute of Energy Economics (Vogelsanger Str. 321a, 50827 Cologne)
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Wind and solar power are expected to supply a large share of electricity in future electricity systems. These technologies are variable in their production meaning they are driven by weather conditions, namely wind speed and solar radiation. This brings new challenges to the electricity sector concerning the planning and operation of a reliable future electricity system. The planning and operation of electricity systems can be analyzed as an optimization problem, namely satisfying the electricity demand at the lowest cost. Due to the unique features of the electricity market, where supply has to meet demand at all points in time, and the limited predictability of production from wind and solar power, uncertainty plays a major role in the analysis of systems with a large share of renewable energies.

This course will provide students from the field of meteorology and economics with knowledge about methods and tools that are applied for the analysis of electricity systems. The focus is on stochastic optimization which is able to incorporate the uncertainty in production from wind and solar power (or other probabilistic elements) into the optimization problem. By starting with the basic concepts of stochastic optimization and applying it to real world problems, the students will gain a deeper understanding of the mechanisms in electricity markets with high shares of renewable energy.

The course is imbedded in and supported by the interdisciplinary research group “Energy Transition and Climate Change (ET-CC)” at the University of Cologne. This group brings together researchers from the Institute of Energy Economics (Faculty of Business, Economics, and Social Sciences, Cologne), the Institute of Geophysics and Meteorology (Cologne), the Meteorological Institute (Bonn), the Institute for Energy and Climate Research (Jülich), the RRZK (Cologne), and the HPSC TerrSys (Geoverbund ABC/J).

Homework 0, Due before first class.

1. Form a research team of 2-3 students with at least one from economics and at least one from meteorology
2. Download to your laptop, the GAMS software (for optimization) http://gams.com and try out the Rosenthal tutorial. If you have had experience with GAMS then ignore this part of homework 0.
3. Read Chapter 1 in *Introduction to Stochastic Programming* by J.R. Birge and F. Louveaux (1997 or later edition). We will spend time on this chapter.
4. Get access to *Decision Making Under Uncertainty in Electricity Markets* (second text book, we will spend time on certain chapters, e.g., Chapter 4), Conejo, Carrión, Morales (2010)
5. Familiarize yourself with Lecture 0 (to be provided). You are responsible for making sure you understand the concepts in these lecture slides.

Anticipated Class Schedule

- Morning lectures and in-class assignments: 9:00-12:30 (coffee break around 10:30)
- Lunch 12:30-13:30
- Afternoon lectures and in-class assignments: 13:30-17:30 (coffee break around 15:00)

Lectures and Topics

Day 1: 21 September 2015
We start the course by taking a closer look at recourse problems. A common example are two-stage problems, where a decision has to be taken in the first stage without knowing the final realization of some variables in the second stage. In electricity markets, for example, thermal power plants have to plan their operation schedules well ahead in time, without knowing the realization of generation from wind and solar energy.

- The farmer's problem from Chapter 1 of Birge & Louveaux
- More general approach
- The value of information

Day 2: 22 September 2015
Another class of stochastic optimization problems can be categorized as chance-constrained. For example, electricity systems need to be designed in such a way that a blackout can be prevented from occurring. Of course, there are always possibilities of blackouts happening but the question is how can one account for these possibilities and can they be made less frequent/less severe and if so at what costs? Also what is the contribution of renewables to a secure electricity system?

- Examples
- Approaches to model chance constraints (will provide some handouts on this)

Day 3: 23 September 2015
In stochastic systems there is always a risk for the occurrence of some severe events. This part of the lecture will provide an overview how these risks can be measured and accounted for (based on Chapter 4 of Conejo et al.+ other references).

- Variance
- Semi-variance
- Shortfall
- Value-at-Risk (VaR)
- Conditional VaR

Day 4: 24 September 2015
After learning about the basics of stochastic programming and the relevant risk measures, we will take a closer look at applications of stochastic programming to intermittent wind and solar power. The research teams will be provided with material on case studies in the areas of planning and operation of electricity systems with large shares of renewable energies.

Day 5: 25 September 2015
On the last day we will proceed with the case studies and they will be presented and discussed in the afternoon session. There is also time for a question-and-answer session relative to the exam.

2 hour exam graded by Dr. Steven A. Gabriel. The time and date for the exam will be announced during the course. The course counts as one of the courses of the doctoral programs in Economics and in Meteorology.

Registration: Please send an e-mail to **frank.obermueller@ewi.uni-koeln.de**