



GAMS Energy Course 2012

Stochastic Optimization in Energy System using GAMS – With a Focus on Hydro-dominated Power Systems –

Summary

In 2012 we offer a special course (E121) together with Dr. Steffen Rebennack (Colorado School of Mines, Golden, CO) for participants interested in “Stochastic Optimization in Energy Systems using GAMS”:

I121 12.03.2012 GAMS Introductory Course for GAMS Novices & Beginners
E121 13.-15.03.2012 Stochastic Optimization in Energy System using GAMS

Location: Hotel Annaberg, Bad Dürkheim, Germany, only one hour away from Frankfurt airport. (<http://www.hotel-annaberg.com>). The hotel is located in a picturesque village at the Deutsche Weinstraße and offers free parking and free WLAN access to the course participants.

Pickup & transfer by a limousine service from/to Frankfurt airport or from/to Mannheim train station is available at a one-way cost of 90 or 35 Euro, resp.

Offering:

- course material on CD (GAMS, presentations, examples, literature)
- full GAMS software with several solvers (temporary license)
- full board (3 nights, 3 x breakfast, 3 x lunch, 2 x dinner) for E121
- full board (4 nights, 4 x breakfast, 4 x lunch, 3 x dinner) for I121+E121
- free analysis and consulting on participants' problems (send them in early)
- participants may, on request, obtain the course material prior to the course

Prices:

- specified on the registration form (last page of this document)
- discounts on early registrations

Registration:

- fax the signed form (last page of this document) to GAMS GmbH
- or send your registration data by e-mail to info@gams.de

We also offer in-house courses accommodated to the client's wishes. Contact us under josef_kallrath@yahoo.de for further details. And from Nov 05-09, 2012 we have again our Basic and Advanced Course: “Modeling and Optimization with GAMS” – see the GAMS webpage www.gams.com under Courses and Workshops for further details.



3 Days Course

- Stochastic Optimization in Energy Systems Using GAMS –
 - With a Focus on Hydro-dominated Power Systems –

Summary:

During these 3 days, we will study stochastic optimization situations. We give an overview on Stochastic Optimization in the Energy Industry, touch various topics such as oligopol models in power systems, optimal bidding and the stochastic unit commitment problem, and focus in detail on Water Storage Systems / Hydro-Thermal Scheduling. Most sessions have examples coded in GAMS to illustrate the mathematical techniques and develop a better feeling of how the methods work.

To those, who have never used GAMS before or use already another modeling or programming language, the main reason to attend this course would be to become familiar with the concepts, modeling techniques and algorithms used in energy systems with uncertain input data. For GAMS novices and beginners we offer a one-day introductory course just prior to the energy course.

This course begins by illuminating several approaches to deal with uncertainty. The most popular ones are discussed in brief and their relations, advantages and disadvantages are discussed. Special focus is given on scenario tree approaches and the usage of the scenario reduction and generation package SCENRED.

Hydro-thermal scheduling is the main focus of the course. We start with the classical models to treat inflow uncertainty and argue why Markov Chains are the way to go. This will then lead us to the two solution techniques Stochastic Dynamic Programming (SDP) and Stochastic Dual Dynamic Programming (SDDP) which we discuss in details. The classical approaches are extended to deal with fuel cost uncertainty and electricity demand uncertainty.

Expansion planning problems are very challenging in the context of Hydro-Thermal Scheduling as these problems are very large scale due to the long planning horizons. We discuss these problems and use Bender's Decomposition to solve the problem.

De-regulated electricity markets introduced new challenges for the energy industry in general – and for hydro-thermal scheduling in particular. We discuss profit maximization models and a hybrid SDP/SDDP approach to solve these problems. As a byproduct, we obtain electricity price forecasts. However, we assume to be a price taker. A price maker assumption leads to Equilibrium models which are discussed in general in a separate session.



In addition to the electricity price uncertainty introduced by the de-regulation of the electricity markets, hedging risk becomes an important task. We discuss different risk measures in the context of Hydro-thermal scheduling and their implementation in SDP and SDDP.

Yet another challenge was introduced by the CO₂ emission markets. We discuss the issue of profit maximization models in the context of uncertain CO₂ prices where CO₂ price forecasts are generated similar to the approach for electricity price uncertainty. Very important is that these models can simultaneously cope with different uncertainties (electricity price, fuel price, CO₂ emission allowance price, hydro inflow and electricity demand).

The course is most beneficial for participants familiar with GAMS and uses deeper GAMS language features such as compile time commands, modular structures and the GDX tools. These are very useful a) to built larger applications and interface to other systems, and b) to implement advanced mathematical optimization techniques, e.g., hybrid methods or stochastic optimization approaches. To those, who have never used GAMS before or use already another modeling or programming language, becoming familiar with the concepts, modeling and algorithms used in energy systems would be the main reason to attend this course.

We stress that difficult and large optimization problems require a tight connection between modeling and algorithms aspects. This leads to sequence of models, nested solve statements, and decomposition techniques – detailed examples will be discussed.

Language

All material accompanying the 3-days course will be in English.



Day 0 (09:30-18:15) - GAMS Introductory Course for GAMS Novices & Beginners

Session E1a: Opening Session (09:30-10:00)

- Get to know each other - Expectations
- Course Overview

Session 1b: Foundations of Mathematical Optimization (10:00-10:45)

- Optimization models and solution algorithms
- Algebraic modeling languages

Coffee break (10:45-11:05)

Session 1c: Overview - Modeling with GAMS (Part I) (11:05-12:30)

- The structure of a GAMS Program:
- Indices, variables, constraints and objective functions
- Model declaration, conditional operators, \$, and, or, ...
- Solve statement, interpretation of *.log and *.lst files and *.log files

Lunch break (12:30-13:45)

Session 1c: Overview - Modeling with GAMS (Part II) (13:45-14:45)

- GAMS IDE and the Cows & Pigs Example - Exercise

Session 2a: Sets (14:45-15:40)

- Simple Sets and Multi-dimensional sets
- Subsets and domain checking
- Operations on Sets, operations on set elements, Dynamic Sets

Coffee break (15:40-16:00)

Session 4b: Procedural Language Elements (16:00-16:45)

- For, If, Loop, Repeat and While
- Compile-time versus Runtime Commands - the \$ command

Session 2b: GAMS Advanced Procedural Language Elements (16:45-17:30)

- Sequences of models
- modular structures in GAMS (\$macro & \$batinclude)

Session 6a: GDX and the GDX Utilities (17:30-18:15)

- GDX and the GDX Utility
- GAMS -- Excel: Data Import and Export

Dinner (18:20-20:00)



Day 1 (09:30-18:15)

Session E1a: Opening Session (09:30-10:00)

- Get to know each other - Expectations
- Course Overview

Session E1b: Optimization under Uncertainty (10:00-11:55)

- Structure of Uncertainty
- Sensitivity Analysis, Wait-and-See Approach, 2-Stage Stochastic Optimization
- Demonstrations in GAMS

Coffee break (10:40-11:00)

- Stochastic Optimization & Value of the Stochastic Solution (VSS)
- Multi-Stage Stochastic Optimization
- Demonstrations in GAMS

Lunch break (12:00-13:15)

Session E1c: Static Approaches to deal with Uncertainty (13:15-14:30)

- Chance Constrained Programming
- Robust Optimization
- Demonstrations in GAMS

Session E2a: Hydro-Thermal Scheduling I (14:20-15:25)

- Problem description
- Linear multi-stage stochastic programming model
- Linear operational constraints: stage-decomposition

Coffee break (15:25-15:45)

Session E2b: Hydro-Thermal Scheduling II (15:45-17:00)

- Solution Methods: Classification
- Dynamic Programming (DP)
- Stochastic Dynamic Programming (SDP)
- Demonstration in GAMS

Session E2c Hydro-Thermal Scheduling III (17:00-18:10)

- Stochastic Dual Dynamic Programming (SDDP)
- SDDP Extensions
- Demonstration in GAMS

Dinner (18:15-20:00)



Day 2 (09:30-18:00)

Session E1d: Scenario Trees

(09:30-11:00)

- Generation of Scenario Trees
- Reduction of the Trees (SCENRED)
- Demonstrations in GAMS

Coffee break (11:00-11:20)

Session E2d: Optimal Expansion Planning of Hydro-Thermal Power System

- Stochastic Model for Optimal Expansion Planning **(11:20-12:40)**
- Benders' Decomposition
- Benders' Decomposition Combined with SDDP
- Demonstrations in GAMS

Lunch break (12:45-14:00)

Session E2e: Fuel Cost Uncertainty and Electricity Demand Uncertainty in Hydro-Thermal Scheduling

(14:00-15:00)

- Models
- Classification of Uncertainties Relevant for Hydro-Thermal Power Systems
- SDDP combined with Scenario Trees
- Demonstrations in GAMS

Session E2f: Hydro Thermal Scheduling in De-regulated Electricity Markets

- Electricity Price Uncertainty **(15:00-17:00)**
- Price Taker Model for Profit Maximization

Coffee break (16:00-16:20)

- Fundamental Approach to forecast electricity prices
- Hybrid SDP/SDDP Approach
- Demonstrations in GAMS

Session E2g: Risk Measures in Hydro Thermal Scheduling (17:00-18:00)

- RMin
- Value at Risk (VaR)
- Conditional VaR (CVaR)
- Demonstrations in GAMS

Dinner (18:15-20:00)



Day 3 (09:30-17:45)

Session E2h: CO₂ Emission Caps and Markets in Hydro Thermal Scheduling

- CO₂ emissions allowances caps modeling (09:30-10:45)
- CO₂ emissions allowances price modeling in SDDP via fundamental approach
- Demonstration in GAMS

Coffee break (10:45-11:05)

Session E3a: Oligopoly Models in Power Systems (11:00-12:25)

- Optimal Bidding for Single Price Maker
- Multi-Stage Bidding
- Demonstrations in GAMS

Lunch break (12:30-14:00)

Session E3b: Stochastic Unit Commitment Models (14:00-15:30)

- Two-stage unit commitment economic dispatch models and algorithms
- Multi-stage unit commitment economic dispatch models and algorithms
- Demonstrations in GAMS

Session E4b: Building Large Applications in GAMS (15:30-16:00)

- Building Large Industrial Applications
- What GAMS offers for you

Coffee break (16:00-16:20)

Session E4c: Difficult and Large-Scale Problems (16:20-17:30)

- What makes optimization problems difficult?
- Polyhedral Modeling and Solution Approaches to tackle Difficult Problems
- Hybrid methods as a special Polyhedral Solution Techniques
- Fix-and-Relax Techniques
- Evolutionary Algorithms
- Demonstrations in GAMS

Session E5: Final Session (17:30-17:45)

- Final and Concluding Remarks
- Feedback by the Participants

The agenda may change slightly !



About the Lecturers

Josef Kallrath obtained his PhD in astrophysics from Bonn University (Germany) in 1989. He is a professor at the University of (Gainesville, FL, www.astro.ufl.edu/~kallrath), and solves real-world problems in industry using a broad spectrum of methods in scientific computing, from modeling physical systems to supporting decisions processes by mathematical optimization. He has written review articles on the subject, about 70 research papers in astronomy and applied mathematics, and several books on mixed integer optimization, as well as one on eclipsing binary stars. Books relevant to this course are

Business Optimization Using Mathematical Programming (J. Kallrath & J. M. Wilson, 1997, Macmillan – now Palgrave)

Gemischt-Ganzzahlige Optimierung in der Praxis (J. Kallrath, 2002, Vieweg)

Modeling Languages in Mathematical Optimization (J. Kallrath, 2004, Kluwer)

Real Optimization with SAP APO (J. Kallrath and T. I. Maindl, 2006, Springer)

Optimization in the Energy Industry (J. Kallrath, Panos M. Pardalos, S. Rebennack, and S. Scheidt, Editors, 2008, Springer)

Josef Kallrath is an experienced consultant and course-instructor with in-depth knowledge related to modeling and optimization systems. Josef Kallrath has been providing consulting services to a wide range of industries, including energy, metals, paper, process, refineries, and telecommunication. He leads the Real World Optimization Working Group of the German Operations Research Society. His current research interests are polyolithic modeling approaches to solve large-scale or difficult optimization problems, for instance, by decomposition techniques such as column generation, or hybrid methods.

Steffen Rebennack obtained his PhD in Industrial & Systems Engineering at the University of Florida, USA in August 2010. He holds the position of an Assistant Professor at the Colorado School of Mines in the Economics and Business Division (<http://econbus.mines.edu/Steffen-Rebennack>). His research area is Operations Research with focus on applications in the energy industry. Next to deterministic optimization, such as LP, MILP, MINLP, he is interested in linear stochastic optimization. His expertise lies especially in hydro-thermal scheduling with the focus on modeling multiple stochasticities, price predictions through fundamental system modeling, expansion planning and the modeling of CO₂ quotas and markets. Books relevant to this course are

Handbook of Power Systems I+II (S. Rebennack, P. M. Pardalos, M.V.F. Pereira, and N. A. Iliadis, Editors, 2010, Springer)

Thanks for your interest.
We are looking forward to an exciting course.

Registration GAMS Energy Course 2012

in Weisenheim am Berg, Germany

Herewith, I register **bindingly** for the GAMS courses crossed below.

1. PERSONAL DATA

Name: _____
Company: _____
Street / P.O. box: _____
ZIP code, city: _____
Phone /Fax : _____
E-Mail: _____

2. WORKSHOP FEE (CROSS WHAT FITS)

FEES INCL. 19% VAT

- | | | | | |
|--------------------------|-----------|---|---|---------|
| <input type="checkbox"/> | E121 | 13.-15.03.2012 (early registration before 03.02.2012) | € | 5800,00 |
| <input type="checkbox"/> | E121 | 13.-15.03.2012 (registration after 03.02.2012) | € | 7300,00 |
| <input type="checkbox"/> | I121+E121 | 12.-15.03.2012 (early registration before 03.02.2012) | € | 7000,00 |
| <input type="checkbox"/> | I121+E121 | 12.-15.03.2012 (registration after 03.02.2012) | € | 8500,00 |

Please transfer the fee latest 5 days before the course to the following bank account:

Recipient: GAMS GmbH **Account No.** 3533320 **Bank Code:** 37070024

IBAN DE87 3707 0024 0353 3320 00 **BIC** (Swift Code): DEUT DEDBKOE

Reason for payment: GAMS Energy Course 2012 – **Your Name & course, e.g. "E121 early"**

3. ACCOMMODATION AND MEALS AND TRANSPORT (CROSS WHAT FITS)

For the participants of the courses the hotel reservation is made automatically to a single non-smoking room from the night prior to the start of the course. If it applies, please cross what fits.

- | | | | | | |
|--------------------------|------------------------|--------------------------|------------------|--------------------------|--|
| <input type="checkbox"/> | Smoking room. | <input type="checkbox"/> | Vegetarian meals | <input type="checkbox"/> | Limousine airport transfer (2x90 Euro) |
| <input type="checkbox"/> | Extra follow-up night. | <input type="checkbox"/> | Double room | <input type="checkbox"/> | Limousine Mannheim HBf (2x35 Euro) |

Terms and Conditions

1. After the registration is received by GAMS GmbH, an invoice with payment instructions is send to the participants. Early-registration participants need to pay before Feb 15, 2012.
2. Upon receipt of payment, participants are eligible to download the course material.

With my signature below I agree to the Terms and Conditions.

Place, Date

Signature

Please send your registration data to info@gams.de or fax the form to:
GAMS GmbH, Eupener Str. 135-137, 50933 Cologne, Germany
Fax: +49-221-949-9171 **Version January 14, 2012 – page 9/9**