Tuesday, August 30, 14:00, Room MA141

Kraftwerkseinsatzplanung mit gemischt ganzzahliger linearer Optimierung

Johannes Siegfried Baumann, Technische Universtät Graz

In der vorliegenden Diplomarbeit wurden verschiedene mathematische Modelle zur Kraftwerksjahreseinsatzplanung unter Berücksichtigung des Übertragungsnetzes untersucht. In den Modellen wurde dabei von einem durch ein 220kV Verbundnetz verknüpften hydrothermischem Kraftwerkspark mit zwei Dampfkraftwerken, sechs Laufkraftwerken, zwei Schwellkraftwerken und vier Speicherkraftwerken ausgegangen. Für dieses Verbundnetz mit hydrothermischer Erzeugungsstruktur wurden Vergleichsrechnungen mit einem neuen Optimierungspaket durchgeführt. Ziel dieser Untersuchungen war es, einen kostenoptimalen Einsatz der vorhandenen Kraftwerke ohne Berücksichtigung des Übertragungsnetzes bzw. mit Berücksichtigung des Übertragungsnetzes zu bestimmen. Durch die Einführung von Subintervallen zur Nachbildung des Tagesbelastungsdiagrammes konnte ein exakter Zusammenhang zwischen Leistung und Energie erreicht werden. Diese Modelle wurden im Matrixgenerator MGG des Progammpaketes SCICONIC formuliert. Dieser baut auf der gemischtganzzahligen linearen Optimierung auf. Bei der Modelleingabe wurde großer Wert auf die Erweiterungsmöglichkeiten für ähnliche umfangreichere Anwendungen gelegt. Die Optimierung wurde auf der Rechenanlage VAX 3000 (Alfa) durchgeführt. Weiters erfolgte ein Vergleich der Lösungen zwischen dem Programmpaket SCICONIC auf VAX 3000 (Alfa) und dem Programmpaket FMPS auf UNIVAC 1100/81.

Tuesday, August 30, 14:30, Room MA141

A Dual Method for the Unit Commitment Problem

Andris Möller, Humboldt-Universität zu Berlin
Werner Römisch, Humboldt-Universität zu Berlin

The unit commitment problem consists in determining a start-up/shut-down schedule and the corresponding production levels for each unit of a power generation system over a planning period such that the total system costs are minimized. The schedules and production levels have to satisfy load and reserve constraints and single unit constraints such as low and high generation limits, minimal up and down times as well as must-run and must-down time periods.
The mathematical model for the unit commitment problem is a large-scale mixed-variable mathematical program with nonlinear cost function. The dual approach for its solution is based on Lagrangian relaxation by introducing Lagrange multipliers for load and reserve constraints. We present a solution strategy where the dual problem is solved by bundle trust methods (after a suitable initialization of the Lagrange multipliers) and primal information is obtained by determining a reserve feasible solution and by economic dispatch. Numerical results of test runs for small and mid-size systems are reported.

Tuesday, August 30, 15:00, Room MA141

Economical Security Enhancement in an Interconnected Power System

E. Amthauer, Elektrizitäts-Gesellschaft Laufenburg
Ingemund Nordanlycke, Intercompro AG, Zürich

The backbone or electricity supply in Western Europe is an interconnected network operated with voltages of 380 and 220 kV. The power flow within the network is mainly determined by its topological structure together with the size and spatial distribution of the power injections and the consumptions. The objective of system operation is to achieve an optimum for economy and security, where economy is related to production costs and losses, while security is determined by sufficient margins towards the capacity limits of power production and power flow on the branches of the network in order to cover outages of power stations and branches.

This paper describes an approach which combines the objectives economy and security of operation in order to compute an optimal redispatch. The optimization problem formed by the network equations, the constraints and the objectives is solved by a generalized power flow algorithm, using active and reactive power injections together with voltage set points and transformer tap settings as control variables. The capabilities of the approach are shown by its application to real operational states of the Western European Power system.

Tuesday, August 30, 15:30, Room MA141

Sensitivity Analysis and Solution Time Reduction in MIP

Josef H. Bogensperger, Technische Universität Graz

In this paper mixed integer programming is applied to a simple hydro-thermal power system including one thermal and one storage plant. The thermal plant is represented by its cost curve. The hydro plant model contains nonlinear constraints for the possible quantity of turbine water and for the storaged water quantity. The power is calculated by $P = k*Q*H$ where H (height of fall) and Q (quantity of water) are variables. This multiplication is separated in the first model by a quadratic and in the second by a logarithmic approach. The nonlinear functions that we get because of the separation are approximated piecewise linear using special ordered sets of type 2. In such a set only two members may take a value greater than zero. A lot of calculations were done to find out how solution time and objective value change if we vary the number of interpolation points for the cost curve, in a second step for the multiplication and third for both. Finally internal function approximation was applied to the model and the solution was compared with the results of the models above. The software Sciconic was used to solve these problems. All these calculations were done with the standard control file. Further on we used the system state variables to control the search strategy of our program. We saw that there is also a heavy impact on the solution time and mostly we got even a little bit better solutions as if we did the control by the standard control file.

Semi-Plenary Lecture
Wednesday, August 31, 09:00, Room MA043

Models and Methods of the Optimization of Electric Power Systems

Hans Glavitsch, Swiss Federal Institute of Technology, Zürich

Electric power supply is a network based activity with a very high quality requirement with the emphasis on cost, availability of power, maintaining frequency and voltage, continuity of supply etc. . Due to the high value of electricity and its wide variety of applications minimization of losses is at a premium. The same is true for the conversion of thermal of hydraulic energy to electricity.

It is fortunate that the multi-level, multi-node, extended power system can be modelled easily in terms of a continuous, non-linear system which leads itself to linearization in many cases. Whenever switching operations have to be considered discontinuities have to be added. The result is a system of equations of high dimension which forms the mode of the power system in the quasi-steady state. For the ninimization of losses and costs objective functions can be formulated.

Optimization in the power system is of interest for online real-time operation as well as for planning. Techniques of nonlinear programming are the basic procedures which are adapted to the characteristics of the systems, i. e. types of nonlinearities, sparsity, etc. and the needs of a high speed response. Applications of linear and quadratic programming are common whenever linearization is possible, however, there are many specialities. The most serious problem to be encountered is the existence of a large number of inequality constraints which in many cases become partly active only. Optimization by switching operations has been achieved by special modelling and the use of techniques known from linear programming. The combination of continuous and discontinuous controls leads to non-convex problems which as of today cannot be solved satisfactorily. Another demanding topic is the optimization of a system considering the outage of a large number of system components which is the core of maintaining the security of the system. Formulations of this problem will be given and basic approaches for its solution.

Examples for the solution of the various types of methods and problems will be given.

Wednesday, August 31, 10:00, Room MA141

Some Models and Algorithms for Power Dispatch in the Eastern Part of Germany

Rüdiger Schultz, Konrad-Zuse-Zentrum für Informationstechnik Berlin

The power system in East Germany typically comprises thermal power stations and pumped storage plants. We discuss models and algorithms for the cost optimal short-term and daily dispatch of electric power. In particular, our presentation includes a short-term model for thermal units, which is solved by a specific path-following technique, a daily model for thermal units and pumped storage plants, which can be solved by convex quadratic programming and a stochastic programming model with chance constraints for daily dispatch under random power demand.

Wednesday, August 31, 10:30, Room MA141

A Two-Stage Stochastic Program for Power Dispatch under Uncertainty

Nicole Gröwe, Konrad-Zuse-Zentrum für Informationstechnik Berlin

The problem of optimal load dispatch under uncertainty of power demand is tackled via a stochastic programming model with simple recourse. The decision variables correspond to generation policies of a system comprising thermal units, pumped storage plants and energy contracts. Abstract results on the asymptotic stability of optimal solutions to stochastic programs serve to justify the procedure of obtaining demand distributions via kernel estimators. These estimators also lead to favourable numerical properties of the resulting recourse model. Test runs based on real-life data are reported. We compute the value of the stochastic solution for different problem instances and compare the stochastic programming solution with deterministic solutions involving adjusted demand proportions.

Wednesday, August 31, 14:00, Room MA141

Comparison of Approaches to Modelling Uncertainty in Electricity Planning

Anne Ku, London Business School

Electricity capacity planning has always been subject to major uncertainties, but privatisation of the industry in the U.K. has introduced the additional risks of business and market failure. This paper compares existing approaches to uncertainty analysis and proposes a new synthesis of methods to structure this problem in a more general form.

Wednesday, August 31, 14:30, Room MA141

Stochastic Optimal Coordination of River-Basin and Thermal Electric Systems (SOCRATES): Software for the Mid-Term Scheduling of Pacific Gas and Electric's Power Plants Under Uncertainty

Konstantin Staschus, Pacific Gas and Electric Company (PG&E) San Francisco
Jan Grygier, Pacific Gas and Electric Company (PG&E) San Francisco
Jonathan Jacobs, Pacific Gas and Electric Company (PG&E) San Francisco
Gary Schultz, Pacific Gas and Electric Company (PG&E) San Francisco

PG&E, the largest investor-owned energy utility in the US, obtains a significant fraction of its electric energy from hydrogeneration. Scheduling the monthly releases from its reservoirs is difficult due to the stochasticity of streamflows and the need to coordinate with the rest of the electric generating system based on realistic marginal cost signals. The SOCRATES software attempts to derive optimal monthly schedules for two-year horizons using two levels of decomposition: A version of simplicial decomposition to coordinate between individual river basin problems and the non-hydro generation, and nested Benders decomposition to solve the stochastic program, modeling multiple stages of streamflow uncertainty. SOCRATES also contains streamflow forecasting logic and is tightly integrated with a hydrological database with graphical user interfaces. In this paper, we give an overview of the modeling, algorithms and computing architecture used in SOCRATES.

Wednesday, August 31, 15:00, Room MA141

Systemtechnische Sicht der Kraftwerkseinsatzplanung beim Einsatz von OR-Methoden

Markus Hauser, Bergische Universität-GH Wuppertal
K.D. Maubach, Bergische Universität-GH Wuppertal
J. Verstege, Bergische Universität-GH Wuppertal

Kraftwerkseinsatzplanungen sind eine notwendige Voraussetzung für den wirtschaftlichen optimalen Betrieb von Energieversorgungssystemen. Sie werden von den Energieversorgungsunternehmen mit dem Ziel durchgeführt, den Einsatz der Erzeugungsanlagen und Energiebezugsquellen unter Einhaltung aller technischen, vertraglichen und durch die Verbraucher verursachten Randbedingungen bei minimalen Energieeinsatzkosten zu planen. Aufgrund komplexer Kraftwerksprozesse, einer zunehmenden Anzahl von Umweltauflagen und komplizierter Vereinbarungen in Energiebezugsverträgen gestaltet sich diese Planungsproblematik immer vielschichtiger.

Verfahren zur rechnergestützen optimalen Lösung solcher Planungsprobleme basieren im mathematischen Optimierungskern zumeist auf Methoden des Operations Research. Allerdings sind die bislang veröffentlichten Verfahrensansätze in vielen Fällen nur auf bestimmte Problemstellungen im Bezug auf die betrachteten Kraftwerkssysteme und Planungszeiträume anwendbar. Veränderte Problemstellungen sind mit solchen Verfahrensansätzen entweder gar nicht oder nur mit erheblichem Aufwand zu realisieren.

Die Autoren stellen eine systemtechnische Sicht des Problems der Kraftwerkseinsatzplanung vor, die auf alle thermischen Kraftwerkssysteme und auf Planungszeiträume von 15 Minuten bis zu 15 Monaten angewendet werden kann. Dazu wird eine systematisierte Betrachtungsweise eingeführt, die einerseits den Entwickler von mathematischen Optimierungsverfahren unterstützt und andererseits dem Anwender die Datenhaltung und die mathematische Modellbildung seines individuellen Planungsproblems erleichert. Am Beispiel eines bereits mehrfach realisierten Verfahrens auf Basis der Gemischt-Ganzzahlig-Lineare Programmierung und dessen Anwendung auf Kraftwerkssysteme mit Kraft-Wärme-Kopllung wird die Flexibilität und die praktische Umsetzung dieser systemtechnischen Sicht demonstriert.

Wednesday, August 31, 15:30, Room MA141

Mittelfristige Energieeinsatzoptimierung in Kraft-Wärme- Kopplungssystemen

Markus Hauser, Bergische Universität Gesamthochschule Wuppertal
K.D. Maubach, Bergische Universität Gesamthochschule Wuppertal
C. Schrader, FICHTNER GmbH & Co. Stuttgart
Hans-Friedrich Wülbeck, FICHTNER GmbH & Co. Stuttgart

Versorgungssysteme für elektrische Energie und Fernwärme werden mit dem Ziel einer zuverlässigen und wirtschaftlichen Deckung des Verbraucherbedarfes betrieben. Der Einsatz der Erzeugungsanlagen und Energiebezugsquellen muß bei entkoppeltem und zeitlich schwankendem Bedarf an elektrischer und thermischer Leistung sowie weiteren technischen und vertraglichen Randbedingungen unter minimalen Betriebskosten erfolgen. Für den Betrachtungszeitraum von 1 bis 15 Monaten wird ein rechnergestütztes Verfahren vorgestellt, das die komplexe planerische Entscheidungsfindung mit dem Ziel einer kostenoptimalen mittelfristigen Energieeinsatzplanung unterstützt. Als mathematische Optimierungsmethode wurde die Gemischt-Ganzzahlig-Lineare Porgrammierung (GGLP) in das Verfahren integriert. Neben der mathematischen Abbildung von Energiebezugsverträgen ist ein weiterer Schwerpunkt die Entwicklung eines Ansatzes zur Ableitung einer geeigneten Darstellung der elektrischen und thermischen Verbraucher in Form von zeitgleichen Lastganglinien. Betrachtet man den gesamten Planungshorizont in der Energieversorgung ist die mittelfristige Einsatzoptimierung Bestandteil eines integralen Energiemanagementsystems und muß dementspechend in der Systemarchitektur offen gestaltet sein. Dies ist insbesondere für den praxisorientierten Einsatz notwendig, da nur eine Einbettung in das Energie Controlling des jeweiligen Energieversogungsunternehmens den wirtschaftlichen Erfolg des Optimierungssystems sichern kann. Die Art der Integration in das Energie Controlling wird am Beispiel eines kommunalen Energieversorgungsunternehmens vorgestellt. Zweiter wesentlicher Aspekt einer praxisorientierten Systemintegration ist die leichte Handhabbarkeit des vorgestellten Optimierungssystem zur mittelfristigen Einsatzoptimierung. Die hierfür entwickelte Bedieneroberfläche wird in ihrem Konzept und dessen Umsetzung vorgestellt.

Wednesday, August 31, 16:30, Room MA141

Optimierung einer Schwellkette mit einem Genetischen Algorithmus

Matthias Hülsemann, Landis & Gyr, Leit- und Fernwirktechnik LFT, Österreich

Gegenstand des Beitrages ist die Kraftwerkseinsatzoptimierung einer Schwellkette mit einem adaptierten genetischen Algorithmus. Dieser Algorithmus ist im Rahmen zweier Projekte von Landis & Gyr für die

Optimierung der Österreichischen Schwellkettenkraftwerke an der Drau und an der Enns entwickelt worden. Grundlage für die Anwendung dieses Algorithmus war die Entwicklung einer Simulation, die basierend auf den stationären Kurvenscharen aus den Kraftwerksabflüssen der Staustufen, die Pegelverläufe und die Leistungen auch im dynamischen Bereich im Mittel richtig berechnet. Abweichend von einem Standard Genetischen Algorithmus wurden spezielle Operatoren entwickelt, um die Anforderungen der Lastverteiler an eine gewünschte Fahrweise zu erfüllen und die Performance und Konvergenz zu garantieren. Diese speziellen Operatoren kommen je nach Erfolg selbstjustierend zum Einsatz. Während der Entwicklungstätigkeit wurde ein Trainingssimulator als Testtool entworfen und realisiert, um den Einsatz der verschiedenen Operatoren und ihre Wirkungsweise online bewerten und beobachten zu können.

Wednesday, August 31, 17:00, Room MA141

Power System Static Security Assessment Using a Hybrid Architecture with Unsupervised/Supervised Learning

Tahir Kapetanovic, Technische Universität Wien
Herbert Müller, Technische Universität Wien

We present the architecture for power system security assessment, consisting of the rule-based part and the hybrid neural network. The rule-based part performs a coarse interpretation of the overall system security and of the actual problems (e.g. voltage drop over long transmission paths, insufficient power reserve, etc.). The interpretation is fed into the neural networks for the fine assessment and severity classification of potential/existing disturbances. The neural networks output is then correlated with the system external impacting factors and the necessary control actions are proposed to the dispatcher. In the paper, first the knowledge base of the rule-based part is described. State vector and other data required as an input from power system are defined. The neural networks architecture is then presented in detail, emphasizing the advantages of combining unsupervised and supervised learning paradigms together. Realization of a neural networks subsystem with Kohonen's classifiers for security operating point classification is described. Training and the run-time testing of the subsystem on the model power system are presented too.

Wednesday, August 31, 17:30, Room MA141

Prediction of Energy Demand by Neural Network Concepts

Herbert Müller, Technische Universität Wien
Gerold Petritsch, Technische Universität Wien
Sayed-Masoud Moghaddas-Tafreschi, Technische Universität Wien

Economic and secure operation planning of power generation needs load forecasts for the rest of the day or for the next day ("short term") and classification of load curves for the next year ("medium term"). Approaches for these purposes are treated in the talk.

Classification of characteristic daily load patterns is performed using a self-organized Kohonen-network with unsupervised learning. To enable different scenarios for various (fuzzy) assumptions about weather conditions or other influencing factors a correlation model is identified on behalf of a multilayer perceptron with supervised backpropagation learning mode.

A mulitlayered, feed-forward perceptron with supervised backpropagation learning mode is the neural network concept used for the short-term forecasting task - i. e. predicting in half hourly time steps the demand development for the rest of the actual day or the load curve(s) of the following day(s). The input vector comprises both weather information (temperature quantities, light intensity, wind speed), to model exogenous influences on demand, as well as type of day and past load data.

Real data from an Austrian utility were used in this study. Results and experiences obtained when tuning the networks (choice of input vector, number of layers and neurons, learning rate, selection of training and test data set) are presented.

Friday, September 2, 10:30, Room MA141

Maintenance Scheduling in Electric Power Systems and its Connections with Parallel Machine Scheduling

László Varga, Hungarian Power Companies Ltd

Several approaches are usually applied for annual maintenance scheduling. The commonly used methods are so called **reserve-levelling** ones. They aim at keeping the amount of reserve almost at the same level through the year by withdrawing units from the low load periods. The other group of maintenance scheduling techniques are the **risk-levelling** methods. These methods seek to spread risk evenly as measured by some kind of reliability indices. The maintenance scheduling in case of reserve-levelling technique can be formulated as a linear integer programming task. The task from computational point of view is much more complex at risk-levelling scheduling. Exact optimization methods need huge amount of storage capacity and the calculation requirement imposed by reliability indices is also considerable. To avoid these computational difficulties we are forced to use heuristic, sub-optimal methods.

In this presentation formulations are given for preventive maintenance of generating units. Based on the observation that the maintenance scheduling task under some simplifications can be formulated as a parallel machine problem, some heuristic algorithms are presented both for deterministic and stochastic scheduling. Demonstrative examples are shown in which the optimal and sub-optimal solutions will be compared.

Friday, September 2, 11:00, Room MA141

Energy Supply and Air Pollution in Indonesia

Manfred Kleemann, Research Centre Jülich (KFA)
Ulla Seele, Research Centre Jülich (KFA)

The aim of this three years planning study was to provide decision support for Indonesian authorities in order to develop an environmentally compatible energy supply strategy. The computer aided approach includes the following steps:

1. Forecast of economic and energy demand scenarios by using the input/output model MACRO and the simulation model DEMI.
2. Optimization of the future energy supply with the help of the multiobjective linear programming model MARKAL.
3. Calculation of concentration and deposition of the air pollutants SO_2, NO_x, H_mC_n and SPM for Jawa by applying the dispersion model DISDEP. The air quality is presented in maps generated with a geographical information system.
4. Assessment of environmental risks and health effects.
5. Development of proposals for an emission reduction strategy, based on minimum risks.

The results of the study showed that the reduction of particulate matter emissions has the highest priority. High to medium priority has to be given to the reduction of NO_x and VHC emissions of the traffic sector. The lowest priority can be assigned to SO_2 reduction.

Friday, September 2, 11:30, Room MA141

Energy Supply and Energy Demand Scenarios in Lithuania

Vaclovas Miskinis, Lithuanian Energy Institute, Kaunas

The technical and institutional structure of the Lithuanian energy sector inherited from the past does not meet the requirements which are caused by the economy oriented to a market. The security of energy supply is one of the central problems because indigenous energy resources represented only 2.5% in the primary energy balance in 1990 and 5% in 1993. It is necessary to reduce a dependence on Russian deliveries by: developing long-term contract arrangements for supply of oil and gas; making contracts with Latvia for use of the underground storage; developing co-operation among the Baltic states; promoting programmes for energy conservation; strengthening the ties with Western European countries. Energy sector development was analysed using the EFOM and Energy Toolbox as energy planning models. The forecasting of the final energy demand was based on econometric models and end-use analysis trying to study in detail all activities in which energy is finally used. It was assumed that final energy intensity drops to 49% (high energy efficiency) or to 71% (basic energy efficiency) of the 1990 values by 2015. In the year 2015, the lowest and the highest energy demand would be in the moderate economy reforms scenario: 317 PJ (high energy efficiency) and 423 PJ (basic energy efficiency). Even in this latter case the energy demand is only 1.1 time higher as it was in 1990. The lower boundary of final electricity demand is equal 9.6 TWh in 2015. Electricity substitution for fuels and heat was included in the maximum demand case (15.6 TWh).

Friday, September 2, 12:00, Room MA141

Modelling of Energy Supply to Latvia

Viktors Zebergs, Latvian Acadamy of Sciences, Riga
Juris Pastors, Latvian Acadamy of Sciences, Riga
Gaidis Klavs, Latvian Acadamy of Sciences, Riga

The energy cost forecast for the Baltic region may be based on the trends of the world prices taking in account the impact of Russia's lower prices. Despite that Latvia's industry is characterised by the lowest energy content in comparison with the other Baltic states, the imported energy amounts are large therefore important are scenarios with maximum use of local fuel and energy conservation. The cooperation of three Baltic states ought to become more closer in gas supply and. perhaps, in nuclear energy. Latvia has rather well-developed natural gas supply system with an underground storage. There is a possibility to develop storages due the favourable geological conditions and to provide storage services to neighbour states. Latvia has good sea ports that may intensify the use of western coal. The development of the energy supply modelling in Latvia may be based on such programming tools as EC-EFOM, EC-EFOM-ENV that have already been started in cooperation with the Karlsruhe University IIP.