OSCOGEN
Optimisation of Cogeneration Systems in a Competitive Market Environment

NEWSLETTER

Issue 4 December 2002

Editorial

This is the fourth in a series of semi-annual newsletters on the research project OSCOGEN (Optimisation of Cogeneration Systems in a Competitive Market Environment), which is co-funded by the Commission of the European Communities (CEC), the Swiss Federal Office for Education and Science (BBW), and the district heating supplier and project partner Termoelektrarna Toplarna Ljubljana (TE-TOL). OSCOGEN was launched in November 2000 within the 5th Framework Programme (EESD), with an overall project duration of 27 months, and will expire end of January 2003. The major aim of the project is the development of a comprehensive and state-of-the-art tool for the optimal operation of cogeneration plants in a competitive energy market environment. The present newsletter covers the validation of the models developed within the project in real world situations, the use of the Langrangian relaxation technique for unit commitment and dispatching, the use of genetic algorithms in optimisation problems, and some information about the international OSCOGEN workshop to be held 22-23 January 2003 in St. Veit/Glan, Carinthia, Austria. As usual, the newsletter concludes with a list of the partners involved in OSCOGEN including contact details and an acknowledgement of the project funding sources. For more information on the project's aim, scope and objectives, project reports and discussion papers released so far, and useful links, please visit the OSCOGEN Website at www.oscogen.ethz.ch, where copies of this and previous newsletters can be downloaded free of charge. We wish you a very happy and successful year 2003!

Reinhard Madlener, Editor-in-Chief
CEPE – Swiss Federal Institute of Technology Zurich
Zurich, Switzerland

Christoph Weber, Project Coordinator
IER – University of Stuttgart
Stuttgart, Germany

Introduction

The end of the OSCOGEN project is coming nearer, and with it a clearer picture of what has actually been researched and achieved within this project, how the more concrete results and documentation look like, and how the short- and long-term optimisation models developed actually perform in practice. Hence the aim of this newsletter is to give a flavour of what has been achieved so far (final results will be contained both in a planned extra issue of the newsletter and in the Final Report), what work is currently in progress, and what is still in the pipeline. We will start again with an overview of the last consortium meeting.

The OSCOGEN consortium convened for the 8th time on 7-8 October 2002 at the Electrical Engineering Faculty of the University of Ljubljana, Slovenia (see Figure 1). The main topics covered were:

- Real world model validation for the TE-TOL and BEWAG models;
- Use of genetic algorithms (GA) in the TE-TOL model;
- Comparative GA fitness function evaluation with GAMS and MATLAB;
- Inclusion of uncertainties in the GA optimisation solver;
- First results from the bidding tool;
- Discussion on next project deliverables (incl. website updates, Newsletter no. 4, and Final Report);
- Organisation, timing, and programme of the planned OSCOGEN workshop.

The next project meeting will be held on 21 January 2003 in St. Veit/Glan, Austria (i.e. a day before the international workshop).

Figure 1. The Faculty of Electrical Engineering building at the University of Ljubljana

Designed by cepe on behalf of OSCOGEN

Using Langrangian Relaxation in Unit Commitment and Dispatching

Lagrangian relaxation is a useful approach for decomposing large unit commitment and dispatching problems into smaller sub-problems, which can be more rapidly and more easily solved. Within the OSCOGEN project, the approach has been applied to the long-term unit commitment problem. In the following, the general approach for Lagrangian relaxation is described first, and then the results of an application to a CHP system are discussed.

The basic idea behind Lagrangian relaxation is to decompose the original problem, called the *primal problem*, into several smaller problems that are easier to solve. This can be done through creation of the so-called *relaxed problem* by including the constraints (e.g. total heat demand) into the objective function. By multiplying the constraints with the Lagrange multipliers and including them in the objective function, the primal problem is transformed into an unconstrained optimisation problem, the relaxed problem.

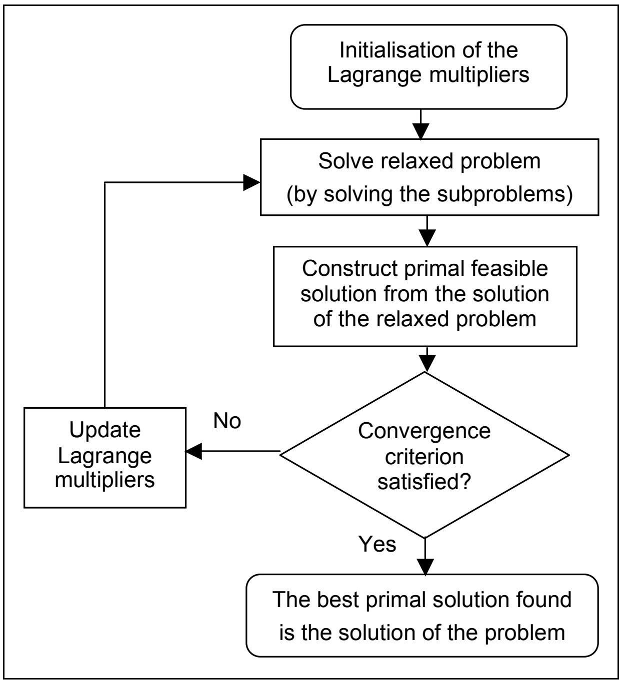

Figure 2. Procedure for solving the Lagrangian problem

Table 1. Computational performance of and results from the optimisation model with Lagrangian relaxation

Optimisation period	**Computational time (s)** (to a dual gap <=1 %)	**Best primal solution**, Profit [1] [€]
August week	16 min	-1'214'674
October week	9 min	-1'460'226
December week	1.5 min	-2'767'644
Time resolution: 1 h for real-valued variables, 9 time blocks per day for integer variables		

1) profits are negative because no revenues have been included for the electric power and heat delivered for fulfilling the electric power and heat demand (i.e. only revenues from spot market trading are considered).

The iteration procedure for solving such a Lagrangian problem is shown in Figure 2. Within our research, different starting values for the Lagrange multipliers and different methods to update the multipliers have been tested.

Moreover, the approach has been applied to various system configurations, including a part of the BEWAG heat and power system, consisting of eight turbines (six extraction-condensing turbines and two gas turbines), two boilers and two district heating systems. Additionally, restrictions for the heat flow between the district heating system and restrictions for the sum of electricity produced by two of the turbines were also included.

In order to shorten the computational time, the time resolution has been lowered for the operation, start-up and shut-down variables by introducing nine time blocks for each day. Table 1 shows the corresponding results. The calculated profits are higher throughout, compared with a conventional solver, at similar computational costs. Particularly, the improvement in profits turned out to be between 0.1 % for December to 2.6 % for October.

Genetic Algorithms – A Solution to Optimisation Problems

The short-term CHP optimisation problem considered can be divided into two sub-problems: a *unit commitment problem* (binary variables) and an *economic dispatch problem* (continuous variables). Since the genetic algorithms (GA) have exhibited significant advantages in finding solutions to non-convex problems and problems with discrete variables, we have applied some GA to solve the unit commitment problem, while for the economic dispatch problem we have implemented linear programming.

Good results from GA can be achieved only if the algorithm is tailored to problem specifics. Careful selection of the encoding scheme is the first crucial point in GA development. In our case we used a special coding system (Yang coding) to eliminate *unit (inter-hour) constraints* that are applied to each individual unit. The next step was the development of problem-tailored genetic operators (crossover, mutation), which help to accelerate the finding of sub-optimal solutions.

Due to the liberalisation of electricity markets, CHP operators are confronted with many uncertainties, two of which are related to heat demand and electricity prices. Consequently, these uncertainties ought to be included into the optimisation problem as well.

The result from the GA is not a single solution, but a population of near-optimal solutions. In the GA literature this is often mentioned as one of major advantages of genetic algorithms, as compared to other more traditional optimisation techniques. In our case we can benefit from this advantage by performing scenario analyses over the final population.

The results that are presented in Figure 3 show that including uncertainties into the optimisation problem increases the expected profit by providing more robust solutions as a result. This outcome was shown especially clearly in the TE-TOL case study for the winter season: here, the best solution was actually second best when only the most likely scenario was considered, but became the best when the stochastic nature of the electricity price and heat demand was appropriately taken into account.

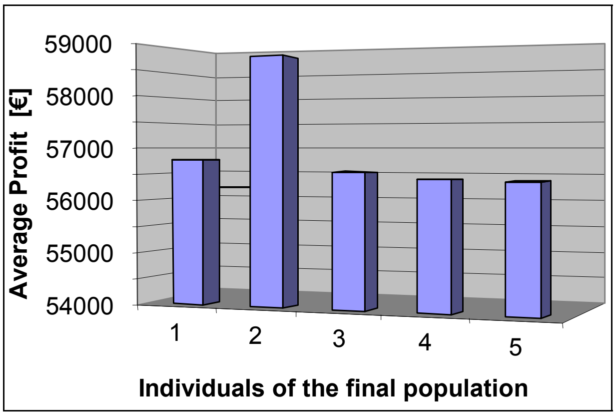

Figure 3. Average profit of the best individuals in the final population considering scenario analysis (individuals are numbered according to their fitness value only for the most likely scenario).

Model Validation

Short-Term Model (TE-TOL)

The tool developed for the short-term operation optimisation of CHP plants, based on a genetic-algorithm-based solver, is currently being verified through a case study on the premises of the Slovenian industrial partner within the OSCOGEN project, Termoelektrarna Toplarna Ljubljana (TE-TOL).

The CHP plant of TE-TOL plays a central role in the provision of district heat to the Slovenian capital of Ljubljana and covers more than 4% of electricity demand in the whole country. The configuration of the CHP system allows a variety of operation modes, despite the fact that the main fuel is coal. The flexibility is gained by three CHP blocks: two condensing steam turbines and one back-pressure turbine (all with controlled steam extraction at two pressure levels), four auxiliary peak-load boilers (two steam and two hot water boilers), and a heat storage tank.

The case study model was build based on most recent measurements, technical documentation and existing data from an on-line information system. Analysis of the available data shows that linear approximation of performance characteristics is sufficiently accurate. The system dynamics is modelled on an hourly basis. To give an example, the size of the TE-TOL optimisation model is for the case of a 3-day-ahead optimisation: 1'008 real variables, 504 binary variables, and 3'816 constraints. The tests aimed to show correctness and robustness of the model are almost finished; further testing will be performed to evaluate the effects of optimisation, and will be further elaborated in the last phase of the project.

Long-Term Model (BEWAG)

The long-term model developed within the OSCOGEN project will be validated using part of the BEWAG system as a case study. The objective is to analyse how unit commitment and dispatch would have been planned with the new tool in a real system. Therefore, the operation restrictions faced by the dispatchers will be accounted for, including restrictions on operation times (minimum up and minimum down times for power plants) and grid restrictions for electricity and heat, etc.. Forecasted electricity prices and heat demand will be used as input to the long-term optimisation model, with weekly updated forecasts during a three-month validation period. For obtaining the price and heat forecasts, the time series models developed by the partner IHS will be used. In order to obtain separate validations for the different model parts, we will conduct a whole set of model runs as depicted in Figure 4.

The objective is to analyse the effect of using new price and heat models, the effects of the new optimisation tool and the effect of stochastic optimisation separately. Through this set of validation runs, repeated weekly over a three-month period, we will hopefully be able to demonstrate the benefits of accounting explicitly for the uncertainties in cogeneration and portfolio optimisation.

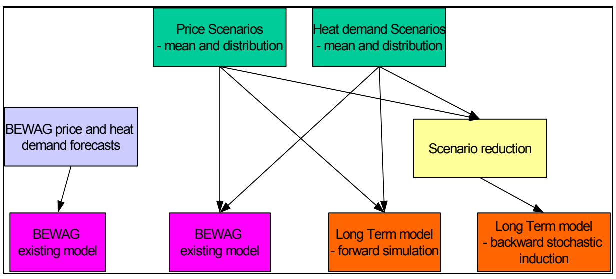

Figure 4. Validation of the long-term model – organisation of model runs

OSCOGEN Workshop Announcement

The OSCOGEN project consortium is currently organizing a 2-day international workshop on *"Cogeneration Operation in Competitive Markets"*, where CHP policy perspectives and major research results from the project will be presented to an interested audience. The workshop will be held on **22-23 January 2003 in St. Veit/Glan**, a beautiful medieval city near Klagenfurt in the most southern Austrian province of Carinthia (see Figure 5). The workshop is co-organised by the Carinthian Energy Agency (KEA) and co-sponsored by the Carinthian government and Greenone-Tec, a solar energy technology manufacturer hosting the workshop. The main themes covered are:

- CHP policy perspectives in competitive markets;
- Optimisation of CHP operation;
- Technology trends in decentralised energy supply;
- Forecasting el. price and demand and heat loads;
- Long-term planning;
- Spot market bidding;
- Model validation and practical experience.

A detailed programme and a letter of invitation can be downloaded from the OSCOGEN website at www.oscogen.ethz.ch. The registration fee is only € 30, including workshop proceedings, refreshments, and meals. The number of participants is limited (first come – first serve). For registration, hotel reservation, and additional information please contact either Mr Freddy Guggenberger (Tel. +43-664-500-4027; E-mail: guggenberger@energieagentur.at) or Ms Gabriele Messner-Mitteregger (Tel. +43-664-405-4208; E-mail: gmm@ainet.at).

Figure 5. The main square of the beautiful historical city of St. Veit/Glan, Carinthia

OSCOGEN Partner Institutions and Contacts, Acknowledgements

Partner Logo & Website	Partner Name & Address	Contacts
IER www.ier.uni-stuttgart.de (= PROJECT COORDINATOR)	Institute of Energy Economics and the Rational Use of Energy, University of Stuttgart Heßbrühlstraße 49 D-70565 Stuttgart, GERMANY	**Dr. Christoph Weber** Tel. +49-711-780 61 51, Fax. +49-711-780 39 53 E-mail. cw@ier.uni-stuttgart.de
Bewag www.bewag.com	BEWAG Aktiengesellschaft Puschkinallee 52 D-12435 Berlin, GERMANY	**Dipl.-Ing. Alfred Hoffmann** Tel. +49-40-244 308 08, Fax. +49-40-244 306 66 E-mail. hoffmann.alfred@bewag.com
cepe www.cepe.ethz.ch	Centre for Energy Policy and Economics, Swiss Federal Institutes of Technology ETH Zentrum WEC C CH-8092 Zurich, SWITZERLAND	**Dr. Reinhard Madlener** Tel. +41-1-632 06 52, Fax. +41-1-632 10 50 E-mail. madlener@cepe.mavt.ethz.ch
www.fe.uni-lj.si	Faculty of Electrical Engineering, Univ. of Ljubljana Trzaska 25 SI-1000 Ljubljana, SLOVENIA	**Dr. Robert Golob** Tel. +386-1-476 8222, Fax. +386-1-426 4651 E-mail. robert@strela.fe.uni-lj.si
IHS www.ihs.ac.at	Institute for Advanced Studies Stumpergasse 56 A-1060 Vienna, AUSTRIA	**Dr. Michael Obersteiner** Tel. +43-1-599 91-0, Fax. +43-1-599 91-555 E-mail. oberstei@ihs.ac.at
www.ijs.si	Institut "Jozef Stefan" P.O. Box 3000 / Jamova 39 SI-1001 Ljubljana, SLOVENIA	**Andreja Urbancic, M.Sc.** Tel. +386-1-5885 224, Fax. +386-61-5612 335 E-mail. andreja.urbancic@ijs.si
www.te-tol.si	Termoelektrarna Toplarna Ljubljana, d.o.o. Toplarniska 19 SI-1000 Ljubljana, SLOVENIA	**Janez Rupar, inz. str. / Me.E.** Tel. +386-1-5875 370, Fax. +386-1-5875 218 E-mail. janez.rupar@te-tol.si

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