GRID ORIENTATED INTEGRATION OF COMBINED HEAT AND POWER MICRO-UNITS

Christian SCHULZ
TU-Braunschweig – Germany
chr.schulz@tu-bs.de

Michael KURRAT
TU-Braunschweig – Germany
m.kurrat@tu-bs.de

ABSTRACT

The aim of the work is the integration of combined heat and power (CHP) micro-units into the low voltage network under technical and economical point of view.
As a result of the legal conditions and the trend of the energy prices the number of CHP micro-units will increase in the next years in Germany. Therefore the power supplier must know the technical and economic effects of this technology by a high penetration.
Together with the local grid operator "Power Nets Braunschweig" the whole power and gas consumption of a new residential district are measured and recorded in fifteen minutes intervals during one year. Based on these power and gas load profiles an analysis has been carried out of the technical effects of a high penetration of the low voltage network with CHP micro-units. With these results it is possible to design grid orientated integration strategies.

INTRODUCTION

Nowadays the CHP micro-units technology with the internal combustion engine technology is available. The CHP micro-units have got an electrical power output up to 20 kW by a thermal energy output up to 40 kW. The fuel is gas or oil and the whole efficiency of the system is about 90 %. In the next decade there will be CHP micro-units with fuel cell technology. The power output and the whole efficiency are the same but the advantages of this technology are the higher electrical efficiency and the higher efficiency in the part load. Furthermore the fuel cells can use directly hydrogen in a future hydrogen system.
The advantages of the CHP technology are the lower transport losses of the electrical energy and the possibility to use the lost heat for heating buildings. This is very important because it is possible to minimize the losses of the electrical energy production from about 60 % to 10 % by using the CHP technology. So it is possible to reduce the carbon emissions to save the resources and the environment.

LEGAL CONDITIONS

Combined heat and power law

In Germany there is the "combined heat and power law" which subsidizes CHP units [1]. The law has got the target to propagate the CHP technology and especially to bring the fuel cell technology onto the market. Together with the energy price trend for the consumer in Germany which supported efficient technology the number of CHP-micro-units will increase in Germany in the next years. The CHP law subsidizes CHP units to 50 kW electrical power output and CHP units with fuel cell technology. The guaranteed price consists of three parts:
The first part is a guaranteed price for every kilowatt-hour which is fed into the public grid. So the CHP unit owner gets 5.11 € cent/kWh for 10 years after the beginning of operation.
The second part is variable and is the market price which the CHP unit owner can bargain with the local grid operator. If they can not bargain a price, the price will depend on the European Energy Exchange (EEX) (Leipzig, Germany) market price of the last quarter [2].
The last one is the return of the network operator for not using the feeder grid. This return has got a height about 0.2 € cent/kWh.
Furthermore the CHP units are exempted from the mineral oil tax in Germany. The tax for gas is 0.55 € cent/kWh (H_o). If the CHP unit capacity factor is over 70 % during one year the owner gets the tax back. Depending on the electrical efficiency factor of the CHP unit, this is a support of about 2 € cent/kWh.
All together the CHP unit operator gets about 12 € cent/kWh. The increasing support of the CHP micro-units and the current energy price trend will lead to a high spread.

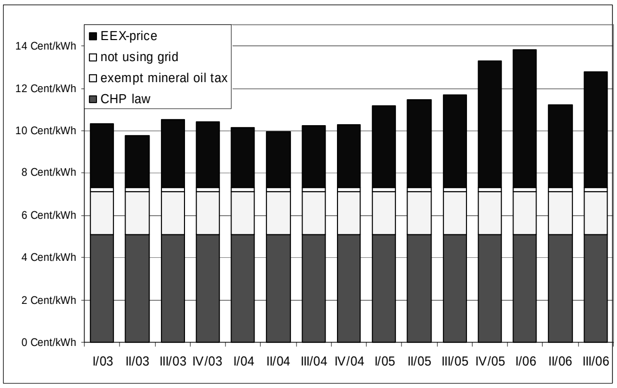

Figure 1: Trend of the subvention of CHP micro-units in Germany

SYSTEM ANALYSIS

The questions about the influence on the low voltage network are brought to the foreground, this goes beyond the safety relevant aspects valid for single units. Pre planned integration strategies for power suppliers to connect CHP micro-units into the existing electrical energy distribution grid will reduce potential problems. The unregulated feed of the CHP micro-units into the low voltage system must be examined first. Examples of possible effects include voltage distribution, short circuit, power flow and the safety systems of the net [3]. The results of the effects mentioned were gained with the simulation of the basis material measuring data and net data of a net district of the "Power Nets Braunschweig" (see figure 2). The negative effects of unregulated CHP micro-units on the low voltage network are less than expected.

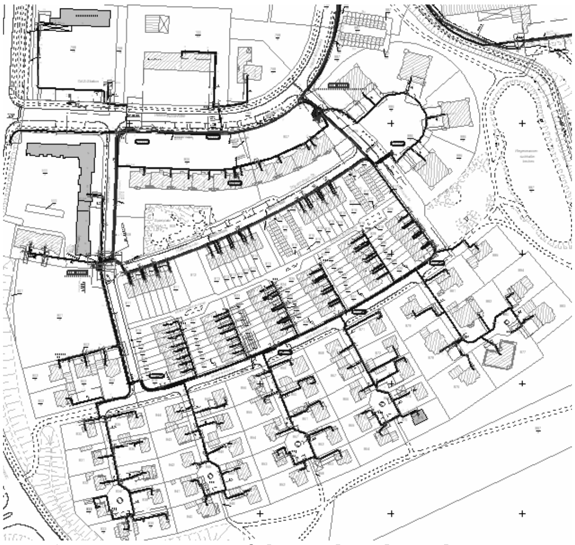

Figure 2: Picture of the analysed net district in Braunschweig, Germany

Data acquisition

In the net district are two 0.4/20 kV transformers both producing 630 kVA. The two transformers supply 137 residential buildings, made up of 120 single family houses, 14 multi-family houses as well as 3 commercial units.
From November 2003 to 2004, the electrical and gas consumption of the net district was noted at 15 min intervals.
Based on the measured data electrical and thermal load profiles were developed for the whole net district. The classification of the season is orientated on the German VDEW standard load profiles. With the individual electrical and thermal annual consumption of an object it is possible to scale the net load profile to an individual object load profile. This procedure is the same as the procedure by the VDEW standard load profiles [4]. A correlation analysis between the VDEW standard load profiles and the developed load profiles of the net district has shown that the measured electrical data are representative. For the thermal load profiles is the verification more difficult because standard thermal load profiles do not exist in Germany. On account of this the measured load profiles are assumed as representative too for this structure of the new building net district. Figure three and four show the developed electrical end thermal load profiles for the net district.

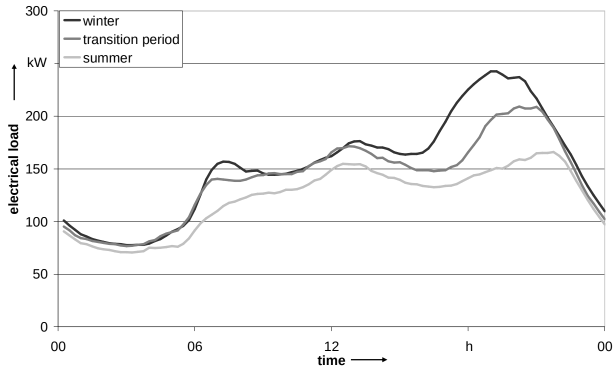

Figure 3: Average of the measured electrical load of the net district for a workday

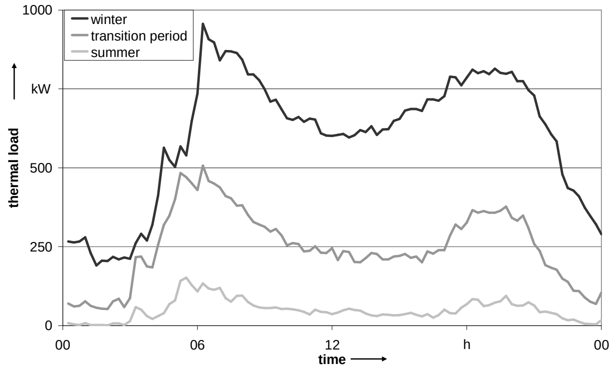

Figure 4: Average of the measured thermal load of the net district for a workday

CHP micro-unit simulation tool

The simulation tool is based on Microsoft Excel with Visual Basic. It can simulate the behaviour of a CHP micro-unit over one day or one year [5]. The technical input data are electrical and thermal consumption data in 15 minutes intervals which are known for the next 24 hours. The technical output data of the simulation are the electrical and thermal energy production of the CHP micro-unit and the boiler, the filling level of the heat accumulator, the number of starts of the CHP micro-unit and the electrical energy supply from the net. The economic input data are the price of the fuel and the price for one kilowatt-hour which is supplied from the grid or which is fed into the grid. The economic output data are the cost of operation and the profit of the CHP micro-unit system in opposite to the conventional system.
In principle the tool can simulate every type of a CHP micro-unit system. The simulated system has got an electrical achievement of 0,05-1,0 kW and a thermal achievement of 0,13-2,5 kW. The boiler has got a thermal achievement of 4,8-19,5 kW and the heat accumulator a volume of 500 litres. The equivalent network shows figure 5. The consumer of the electrical and thermal energy is an one family house. The thermal energy consumption of the whole house is about 4.700 kWh/a and the electrical energy consumption about 21.600 kWh/a.

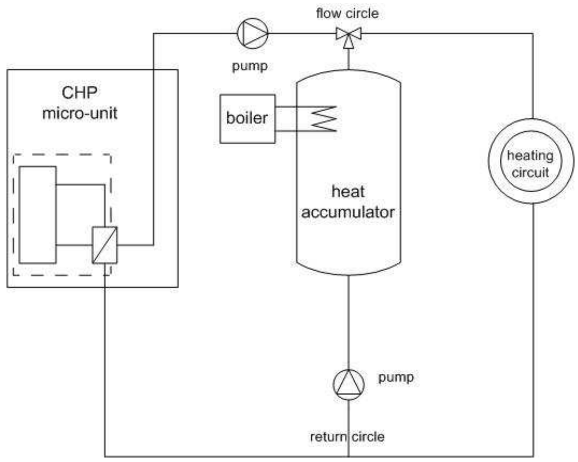

Figure 5: Equivalent network of the CHP micro-unit in the simulation tool

In a first step, the simulation tool shows how the CHP micro-unit works. Based on the load profiles the simulation tool describes at which time the CHP micro-unit produces energy (see figure 6). The CHP micro-unit orientates his power output at the heat controlled operation by the thermal need of the object. In the winter time the CHP micro-unit produces the whole energy for the object, so that it runs nearly 24 hours each day. In the summer time it produces the thermal energy only for the heat water which can be stored in a heat accumulator. In the transition period it regulates his power output in the most time.

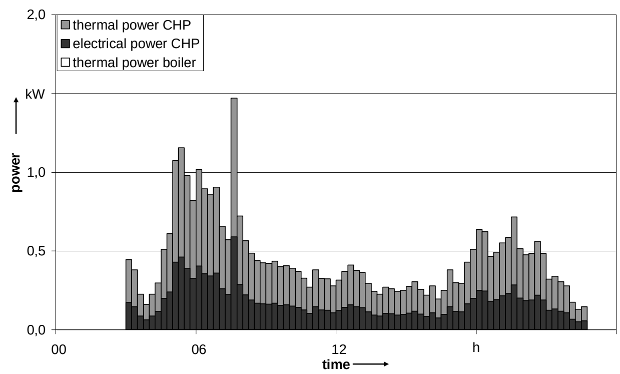

Figure 6: Electrical and thermal power output of the CHP micro-unit in the summer time

Influence on the low voltage system

For the grid operator it is interesting to know how the CHP micro-units influence the low voltage grid. Therefore three scenarios are simulated. The scenarios are different in the height of the penetration with CHP micro-units. The scenarios ten and twenty per cent are realistic scenarios. The forty per cent scenario is a worst case scenario.
In the winter time the net load will be constantly decreased because the CHP micro-units run nearly constantly with the highest power output over the day. During this time there is no potential available to optimize the energy production for the electrical grid.
In the summer time they only run a few hours each day. During this period they only have to produce the hot drinking water. But it is possible that peaks from the gas grid are transferred over the CHP micro units into the electrical grid. In the transition period the CHP micro-units regulate their power output most of the time. At both times is potential available to optimize the CHP micro-unit energy production for the grid.

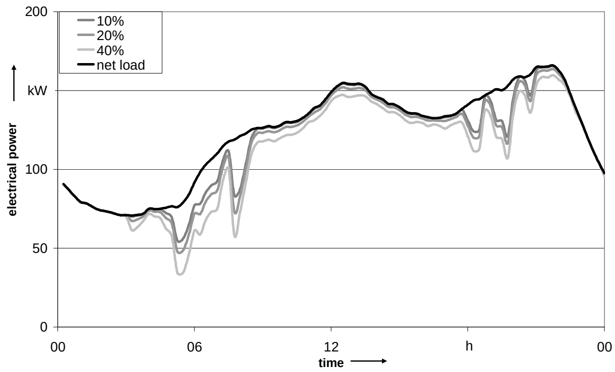

Figure 7: Influence on the net load in the summer time

Advantages of the dispersed energy production

The analysis has also got the target to get out which advantages the CHP micro-unit technology has. An advantage is that the dispersed generation technology produces the electrical energy directly at the consumer. The energy must not be transported over the high voltage transmission lines from far away power plants to the consumer. As consequence the transmission losses are smaller. It is also possible that a low voltage network with a high penetration of CHP micro-units can be designed with smaller lines and transformers. Furthermore it is feasible that the CHP micro-units can supply control power for the grid. Above all the utilisation and the profitability of the gas grid is higher because the fuel of the most CHP micro-units is gas. This is a very important point because the buildings have got a better heat insulation in the future so that the utilisation and profitability of the gas grid is lower.

GRID ORIENTATED INTEGRATION

The grid orientated integration has got the target to consider the technical needs of the electrical grid and of the dispersed generation units. So it is possible to use the positive technical effects of the dispersed generation units for the grid and to install more dispersed generation units in a net district.
The grid orientated controlled operation is an add-on on the heat controlled operation. The primary task of the CHP micro-units is it to supply the object with thermal energy. But secondary they also consider the technical needs of the grid.
To realize this integration strategy there are a different ideas. One idea is to leave a net schedule during the installation or transmitted it over a communication interface to the CHP micro-unit. The net schedule is the load profile of the net district or a profile with times where the energy supply is necessary. The CHP micro-unit includes this net schedule in its energy production for the object.

In the following example the load profiles were left in the CHP micro-units. The results show that in the summertime the net load is decreased, mainly about noon. To reduce the peak in the evening too, it is necessary to double the heat accumulator and to change the energy-management. So it is possible to reduce both peaks of the net load.

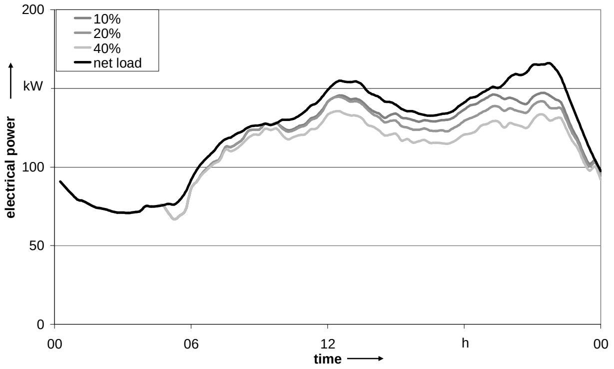

Figure 8: Passive Day-Ahead-Integration strategy

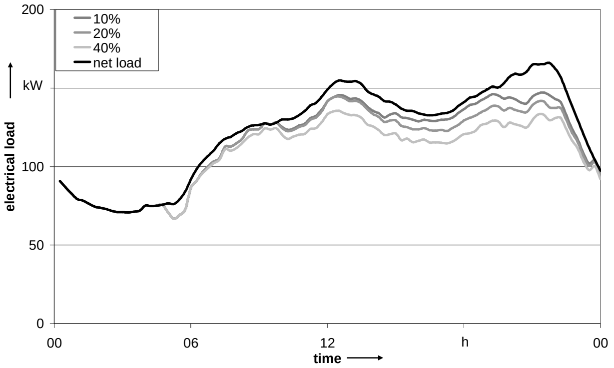

Figure 9: Active Day-Ahead-Integration strategy

Furthermore it is possible to reduce the peak load with a Day-Ahead-Net-Schedule in the transition period. In the wintertime this is not possible because the CHP micro-units already run 24 hours each day.

CONCLUSION

The CHP micro-units units are an interesting and useful addition for future energy mixes. The present economics considering the use of CHP micro-units will prevent a strong market penetration in the next few years, however current energy price developments will favour the spreading of the CHP micro-units.
With the simulation tool the behaviour of a CHP micro-unit in an object and the influence on the low voltage grid is shown. The result is that the energy production of the CHP micro-units could be better balanced with the actually net load. This is primarily important in the summer time and in the transition period.
With a grid orientated controlled operation of the CHP micro-units the needs of the electrical grid shall be better considered. With Day-Ahead-Net-Schedules in the CHP micro-units it is possible to reduce the net load. But it is also necessary to change the energy-management for the heat accumulator.
For the power supplier or the grid operator it is also important to take part in the new market. If integration strategies are used early the advantages (e.g. supply of control power) of using the CHP micro-units for the grid operation can be maximised.

REFERENCES

[1] Renewable energy law: Berlin, Germany, 2004

[2] http://www.eex.de

[3] Schulz C., Kurrat M.: Considerations for dispersed cogeneration of heat and power in low voltage networks, Cigre Symposium Power Systems with Dispersed Generation, Athen, Greece, 2004

[4] Anwendung der repräsentativen VDEW Lastprofile step-by-step, Cottbus, Germany 2000

[5] Schulz C., Röder G., Kurrat M.: Virtual Power Plants with combined heat and power micro-units. Future Power Systems 2005, Amsterdam, Netherlands, 2005