ANALYSIS OF CO-GENERATION TECHNOLOGIES AS POTENTIAL BALANCING POWER SUPPLY

Eva Marie Linne, Wolfgang Schufft

ABSTRACT

This paper deals with operation strategies for co-generation plants as balancing power supply. The aim of the paper is to examine the general technical feasibility of co-generation plants as balancing power supply. Due to the lack of heat demand in summer, co-generation plants are only promising for providing positive balancing power. Furthermore, there is a lack of seasonal similarities in balancing power demand. That's why seasonal variation of switch-on priorities for conventional and cogeneration plants seems to be most promising. Today, only combustion engines and micro-turbines are suitable as balancing power supply because of short cold-start times.

1. INTRODUCTION

Scientists all over the world discuss a totally renewable energy supply system. Obviously, such a system has to be as reliable and as practicable as today's energy supply based on fossil fuel-consuming technologies. Wind and solar energy are expected to become future's basic energy supply; hydrogen is expected as storable fuel. Beside hydrogen, biomass is discussed as an optional future fuel.

All these visions suffer from deficiencies in technology development and system experience. The existing energy supply system can only be changed step by step within a long period of time. One step is to evaluate how to provide balancing energy in future electrical energy supply systems. For instance, decentralized co-generation plants are one promising option. In order to evaluate this option, the total balancing energy demand has to be analysed and estimated in future. After that, the technical features of co-generation plants should be analysed in detail and operation strategies for co-generation plants as balancing power supply have to be developed. Finally, these strategies need to be examined under working conditions with the help of extensive simulations. The last step is not objective of this paper.

2. BALANCING ENERGY DEMAND ANALYSIS TO DEVELOP OPERATION STRATEGIES FOR COGENERATION PLANTS

In order to search for characteristics of the balancing energy demand, the grid control area supervised by Vattenfall Europe Transmission is chosen exemplarily. This area has the highest penetration of installed wind power in Germany. Therefore, it is the most interesting grid control area to evaluate the control energy demand in general and especially caused by wind power. Balancing power itself can be divided into positive and negative demand. In case of positive demand, electrical energy is momentary missing in the high-voltage grid. In case of negative demand, there is an abundance of electrical energy. Negative balancing power can be provided quite easily by reducing power in conventional power plants or by a shut-down of wind power plants. Therefore, only positive balancing power demand is considered. With the aim of detecting seasonal characteristics, the positive balancing energy demand per month is cumulated and analysed for three years (fig. 1). The characteristic of every year is different. The total balancing power demand per year is almost constant. Every year, there is one peak-demand month, but the season of this peak demand varies. Obviously, the positive balancing power demand varies stochastically. There are no seasonal similarities [1].

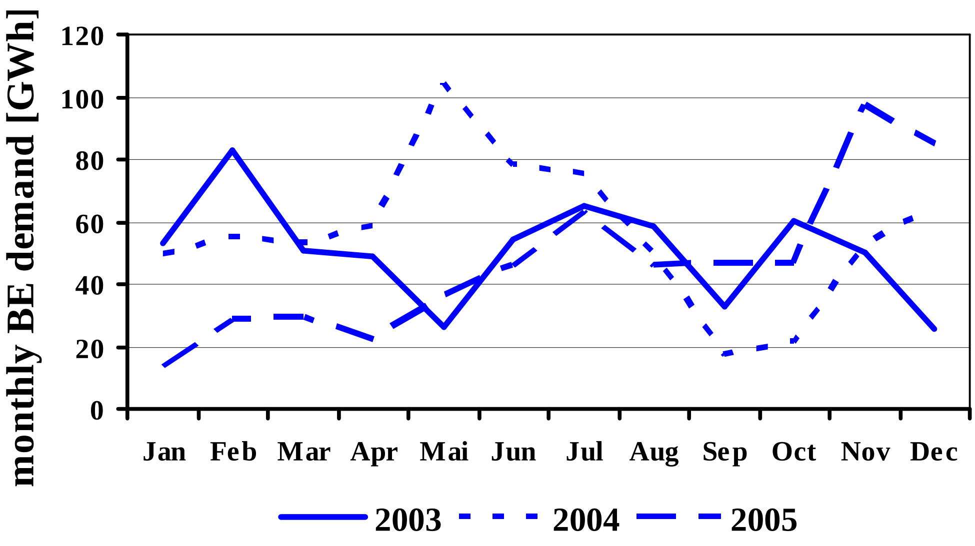

Figure 1: Monthly balancing energy (BE) demand from 2003-2005 [1]

Decentralized co-generation plants are consequently located in residential areas because of the decentralized heat demand in these areas. Therefore, the heat demand of a typical private household is analysed and compared with the balancing energy demand (fig. 2).

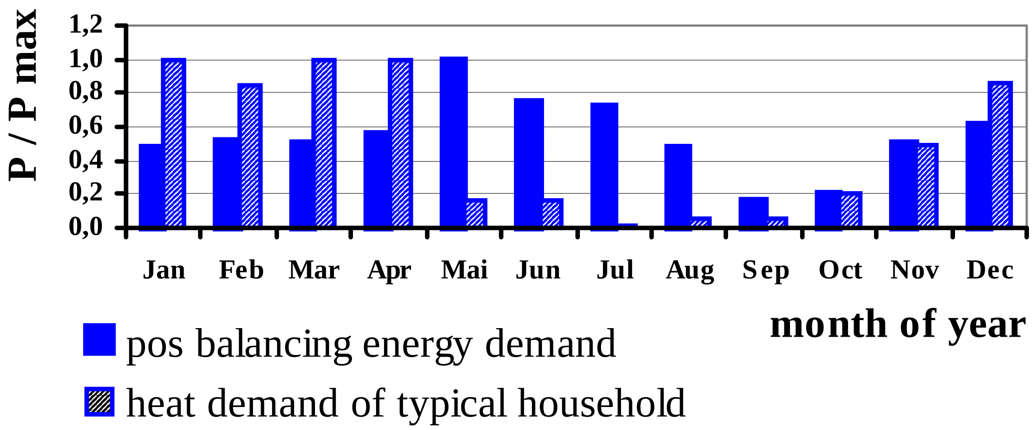

Figure 2: Correlation analysis between heat demand and balancing energy demand [1]

As expected, the heat demand of households varies seasonally. Obviously, there are no similarities in the characteristics of heat demand and balancing energy demand. Due to this, heat storages and intelligent operation strategies are required in the case of balancing power from small co-generation plants. Dimensioning heat storages is not objective of this paper, operation strategies are developed in the following paragraphs.

3. DEVELOPMENT OF OPERATION STRATEGIES BASED ON RESULTS OF CO-GENERATION TECHNOLOGY ANALYSIS

Balancing power has to be supplied within 5 minutes after activation. Therefore, both the cold-start-time and the warm-start-time of decentralized co-generation plants have to be shorter than 5 minutes. If only the warm-start time is shorter than 5 minutes, the co-generation plant has to remain in inefficient standby mode. In order to look for suited co-generation technologies as balancing power supply, the types of co-generation plants offered in the market have been analysed regarding cold- and warm-start times (table 1).

technology	cold-start time (after switch-off state)	warm-start time (after standby mode)	Usability as supply for balancing energy
combustion engine	1 min 30 sec	< 1 min	+
micro-turbine	2 min 30 sec	1 min 30 sec	+
PEM-fuel cell	30 min	15 min	-
MCFC-fuel cell	8 h	15 min	-
ORC gas engine	< 5 min	< 5 min	+
Stirling engine	> 1 h	8 min	-

Table 1: Usability of co-generation plants as balancing energy supply depending on switch-on times given by co-generation plant manufacturers [2], [3], [4], [5]

Obviously, combustion engines and micro-turbines meet the requirements of supplying balancing power. Combustion engines with an organic ranking cycle (ORC) instead of a water vapour cycle offer a higher efficiency in low-temperature-vaporization. With regard to cold- and warm-start times, there are no exact data. The producers of ORC-plants confirmed that the starting time is shorter than 5 minutes. Fuel cells and Stirling engines do not meet the requirements because of their long heating time before starting. They better fit into the electrical energy supply system as basic- or medium-load supply.

The next step in co-generation usability analysis is how to run combustion engines or micro-turbines as balancing power supply. Theoretically, they are able to supply both positive and negative balancing power (fig. 3). In case of positive demand, co-generation plants are switched on from sleep mode. While providing positive balancing power, they produce heat. Therefore, heat use options have to be examined. In case of negative demand, co-generation plants have to be switched off. That implies all-day running co-generation plants and causes an excess supply of heat, especially in summer. Therefore, providing negative balancing power from co-generation plants does not make sense. Due to this, negative balancing power will not be considered furthermore in this paper.

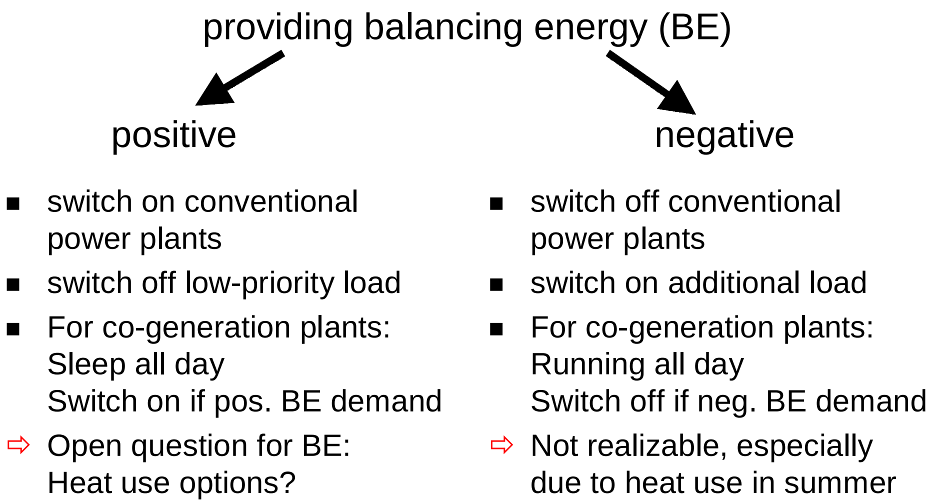

Figure 3: Operation schemes for supplying balancing energy

In general, decentralized co-generation plants offer different features than large conventional power plants. The average installed power per single co-generation plant is only 0.0001 of the installed power per central conventional power plants. Due to this, the electrical efficiency of the small decentralized power plants is low compared to large central plants based on the same technology. Therefore, maximum heat use is optimal. Therefore, it is impossible to provide the total balancing power demand from co-generation plants and to guarantee total heat use. Today, almost every power plant in Germany provides some balancing power. In fact, co-generation plants seem to fit perfectly into a mixture of different power plant technologies. In case of total heat use, small co-generation plants offer the highest energy efficiency. During winter, total heat use can be guaranteed and co-generation plants should be preferred as balancing power supply in winter. In case of partly heat use, large conventional power plants offer higher electrical efficiencies. Therefore, they should be preferred in summer. These facts lead to a seasonal supply strategy. In order to explain this seasonal variation of supply priorities, a very simple supply mix of half co-generation plants (CGP) and half conventional large gas and steam turbines (NGT) is defined (fig. 4).

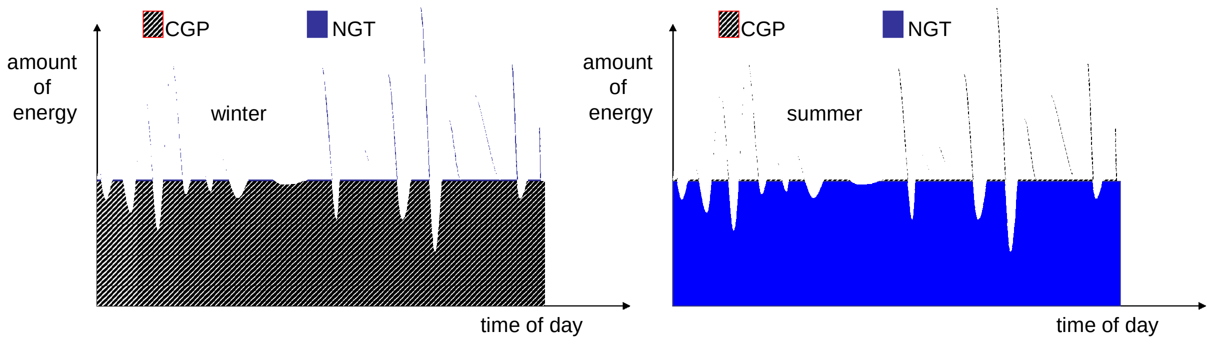

Figure 4: Seasonal variation of switch-on priorities for co-generation plant (CGP) and natural gas turbine (NGT) supply

Assuming a given balancing energy demand curve, the supply strategy varies seasonally. In winter, the basic demand is supplied by co-generation plants. In case of peak demand in winter, some conventional natural gas turbines are additionally switched on. In summer, the basic balancing demand is supplied by conventional gas turbines without heat use and in case of peak demand; co-generation plants are additionally switched on. The optimum quota of co-generation plants as part of the balancing power mix is dependent on heat demand and average balancing energy demand.

4. CONCLUSIONS

A principal usability of co-generation plants as balancing power supply is guaranteed for micro-turbines and combustion engines. Fuel cells and Stirling motors do not meet the requirements as balancing power supply due to long start times. Providing positive balancing energy demand by co-generation plants seems to be promising. Providing negative balancing energy demand by co-generation plants does not make sense because of a limited heat demand.

Obviously, co-generation plants are only promising as a part of a balancing power supply mixture. If their quota is very low, they can be run as basic balancing power supply all over the year. As soon as their quota increases, several supply strategies are eliminated because of to low heat demand. The developed season-related integration strategy into the balancing power supply mix covers the missing seasonal similarities in balancing energy demand and the lack of correlation with heat demand. Due to the need of highest possible efficiency in electrical energy generation and use, the suggested season-related strategy is the most promising option and has to be examined in detail.

5. SUMMARY AND OUTLOOK

In future electrical energy supply systems, to low offers of balancing energy supply are expected. One option to provide positive balancing energy in future are decentralized co-generation plants. Positive balancing power demand and heat demand do not correlate. That's why co-generation plants should become part of the existing balancing energy mixture and mainly supply in cases of high heat demand like in winter. Furthermore, only co-generation plants based on combustion engines or micro-turbines meet the requirements of supplying balancing power due to short starting times.

The proposed season-related integration strategy has to be investigated in detail. This investigation includes grid simulations with varying quotas of co-generation plants, system studies based on measured energy demand values, ecological evaluation and economical evaluation. Finally, the results have to be compared to the actual system data.

6. REFERENCES

[1] *Linne, E.M.; Schufft, W.: Providing Seasonal Balancing Energy from Co-Generation Plants.* WSEAS Transactions on Power Systems, Athens, May 2006

[2] Kraftwerk GmbH, personal contact, www.kwk.info

[3] e-quad power systems GmbH, personal contact, www.microturbine.com

[4] Vattenfall Berlin GmbH, personal contact

[5] Pro2-Anlagentechnik GmbH, personal contact, www.pro-2.net

Author's address:
Dipl.-Ing. Eva Marie Linne
Chair Power & High-voltage Engineering
Chemnitz University of Technology
Reichenhainer Strasse 70
D-09126 Chemnitz, Germany
e-mail: Evi.Linne@etit.tu-chemnitz.de
tel.: +49 371 531 35 11 3
fax.: +49 371 531 80 02 69