Forecast based energy management for trigeneration subnets in smart grids

Jesus da Costa Fernandes[1], Mahmoud Eid[2]
24, Badstraße, 77652, Offenburg, Germany
Phone: +49 781 205 354, Fax: +49 781 205 45354
E-Mail: costa@hs-offenburg.de
Internet: fgnet.hs-offenburg.de, ines.hs-offenburg.de, www.hs-offenburg.de

Summary

Meeting the requirements of smart grids local, decentralized subnets will offer additional potentials to stabilize and compensate the utility grid mainly on the low voltage level. In a quite complex configuration these decentralized energy systems are combined power, heat and cooling power distributions. According to the regional and local availability of renewable energy sources advanced energy management concepts should consider climatic conditions as well as the state of the interacting utility grid and consumption profiles. The approach uses demonstrational setups to develop a forecast based energy management for trigeneration subnets by taking into account the running conditions of local electrical and thermal energy conversion units. This should lead to the best coverage of the demand and supporting/stabilizing the utility grid at the same time. For the first of three demonstrational projects the priorities of the subnet are given with the maximization of the CHP operation to substitute a major part of the heating and cooling power delivered by electric heaters or compression chillers.

Introduction

Growing impacts of renewable energy shares on the German transmission grid produced major changes in grid feeding policy. Additional potentials and storage capacities motivated therefore the development of a forecast based energy management to show that decentralized microgrids can be converted easily to smart subnets as local clusters of a smart grid. Decentralized power distributions based on renewable energy sources are mainly known as remote power distributions or microgrids. With the recent energy policy forcing the transition of the existing transmission grid and power supply structure to a smart grid the relevance of decentralized concepts becomes more important with the growing need of regulating power reserves. Power sources disturbing and unbalancing the performance of the transmission grid mainly on the MV-Level but seriously affecting the power grid quality on the LV-level. These sources are higher shares of fluctuating renewable sources like solar and wind power, the operation of peak power plants initiated by demand side management and switch commands motivated by stock exchange activities. Respectively to fluctuating contributions significant indicators should reveal

[1] INES – Institut für Energiesystemtechnik der Hochschule Offenburg - University of Applied Sciences
[2] Hochschule Offenburg – University o Applied Sciences

ISBN 978-3-943891-37-9, p.147-152

trends about power quality and the availability of renewable power sources. Therefore forecasting is becoming an important tool for an intelligent demand side management and to supply additional information to the energy management of decentralized energy subnets. In cooperation with energy providers methods are being developed to forecast a grid quality indicator for the short and medium term i.e. one to five day scope.

Trigeneration energy management concept

The developed trigeneration energy management is based on two different strategies. On one hand there is the short term oriented programmable logic based control and survey of the local subnet with the corresponding power, heat and cooling circuits. According to safety and security aspects the programmable logic control (PLC) takes over the control functions as a conventional process automation system. On the other hand the main actions of the energy management are considered to be charging and discharging commands for power, heat and cold storages as well as the start/stop-decision for auxiliary units or the choice of the most efficient power, heat or cooling source. The presented approach is based on a conventional PLC automation working with a forecast database collecting weather forecasts, time schedules and historical load profiles of the production processes and energy demands. Additional information about feed-in tariffs and utility grid states complete the indicator evaluation using internal and external sources. Figure 1 shows the processes how forecasts of energy contributions are used for an automatic decision making process initiating energy management commands and evaluating sensor signals.
The first step is the programming of common and approved algorithms of the PLC environment and a global monitoring with short measurement campaigns.

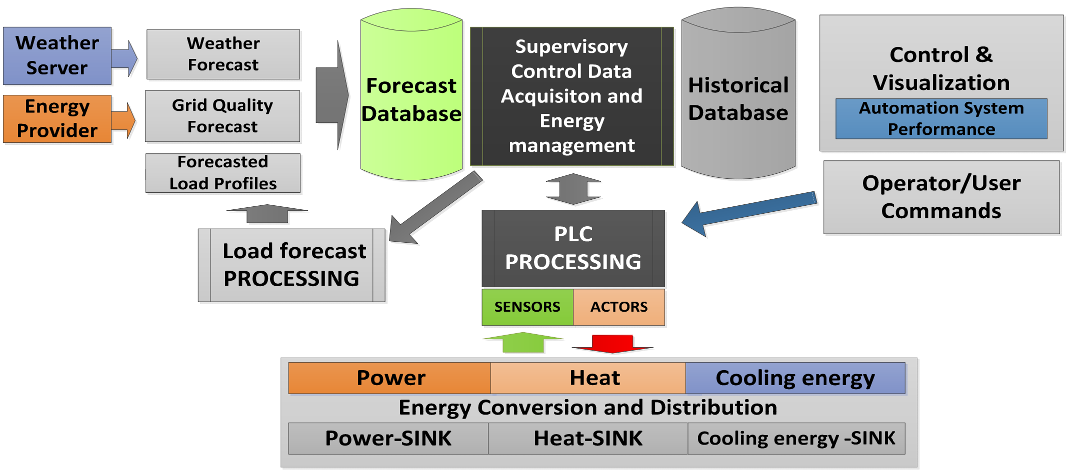

Figure 1: Schematic view of the energy management concept

© Ostbayrisches Technologie-Transfer-Institut e.V. (OTTI), Regensburg, Germany,
ISBN 978-3-943891-37-9, p.147-152

Decentralized trigeneration energy distribution of a small company

The realized trigeneration concept at the poultry farm and noodle manufactory Zapf in Schönberg near Gengenbach/Germany is mainly based on local energy sources using woodchips of own and surrounding forests. Three woodchip carburetors produce a high carbon dioxide and low methane containing gas as combustion fuel fed to three CHP units. Additionally a peak load woodchip boiler and a high temperature heat recovery (110 °C) of the CHP exhaust gases improves the overall efficiency of the CHP assembly. In summer the main part of the heat is used to run a noodle cooker at 95 °C and a resorption chiller with an ice storage. The chiller circuit extends the operation time of the CHP units making up a big economic advantage of the energy supply concept. In winter the heat is more distributed according to divergent purposes with weak emphasis on cooling power but higher demand of space heating or drying like noodle drying, dish washing, cooling down of recently cooked noodle products or the storage of fresh products like eggs and chicken meat. During the first winter period of CHP operation the woodchips were not delivered with an adequate humidity quality. An additional drying step had to be integrated to dry the woodchips to a humidity content of at least 18 %. Figure 2 gives an overview of the poultry farm with elements of the smart subnet.

Figure 2: Farmhouse, products and energy conversion units of the poultry farm

Substitution of power driven heaters and chillers

The noodle production as industrial process was mainly powered by electrical energy of the utility grid with peaks up to 120 kW. With the trigeneration concept the major part of the heat and the cooling energy will be covered by the CHP units combined with the two cooling circuits of the 80 kW resorption chiller consuming 160 kW of heat. The expected peak loads in electrical power will then be reduced to a maximum of 40 kW. The former conventional chillers will be kept within the energy

ISBN 978-3-943891-37-9, p.147-152

management concept as backup units for example in case of a failure of chiller which can still be considered as a prototype.

Power monitoring of demonstrational projects

The main contributions of the energy management concept are energy sources like PV, wind and biomass conversion units building up subnets with electrical and thermal storages. Mostly they are interacting with the utility grid on the low voltage level. The major energy source at the poultry farm is biomass i.e. woodchips of local origin supported by a grid feeding PV system and the utility grid as back-up power source. An emergency generator is foreseen for the poultry installations to secure basic functions. In Figure 3 the power consumption and the total feed-in power demonstrates the economic benefit if all CHPs are permanently running and feed power to the utility grid. The cascaded operation of the CHPs charging the cascade of heat storages at 110 °C, 90 °C and 70 °C is matter of analysis and gaining experience in order to extract operation parameters for the energy management. The power monitoring is done via M-Bus counters connected to the PLC interface.

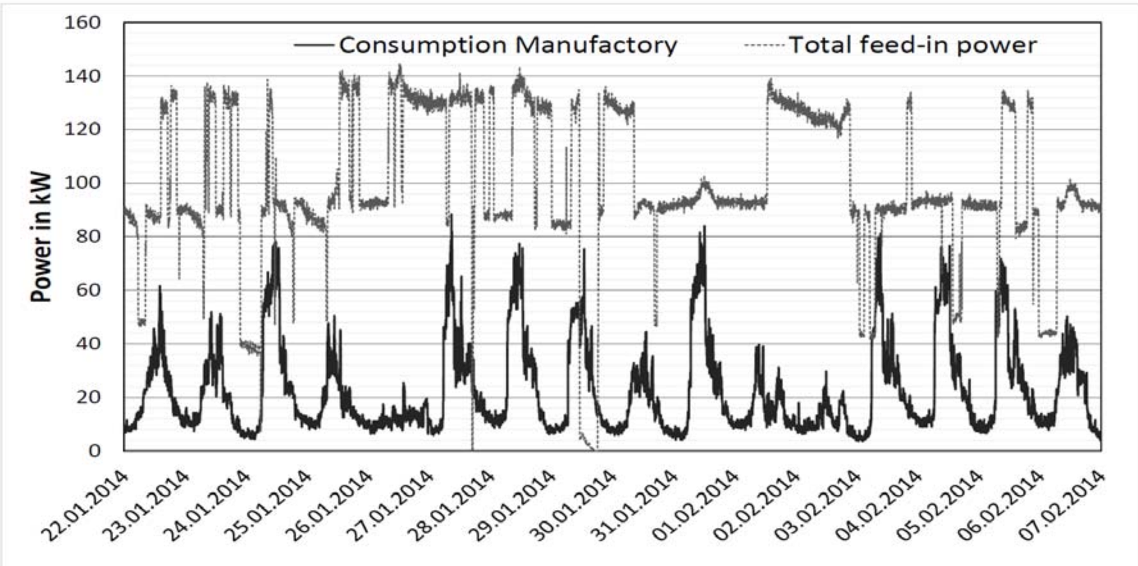

Figure 3: Power Consumption and total feed-in power of the CHPs and the PV generator

Respectively to the developments on the energy sector in Germany monitoring of the grid quality and forecasting of grid scenarios becomes very significant. The scope is set on impacts of bigger shares of renewable energy sources, short and forecast based switching of peak load power plants. Further on actions forced by stock exchange and quality related survey and assessment of the utility grid become more and more important. The test grid at the poultry farm and two lab grids of INES prepare the R&D environment to develop and improve forecast based management concepts. Validation of new models and solutions will be therefore facilitated on running subnets.

ISBN 978-3-943891-37-9, p.147-152

Load forecasts for energetic flow optimization

Forecasting electrical load profiles is one of the work packages of the management giving an indicator for the daily demand of the manufactory. The choice of the method and the forecasting concept are strongly related to the fluctuation of the load profiles depending on the company specific products and production intensity. For the demonstrational system Zapf a weak fluctuation helped to reduce errors to a reasonable level. The stable profiles allowed a basic forecasting method like Auto-Regressive Moving Average (ARMA) as very suitable and reliable concerning the forecasting accuracy. The concept works by taking the weight of each equivalent day of the 3 precedent weeks to process the profile of the forecasted day. Figure 4 shows an example how the calculations of the model are done. For the assessment of the results the calculated profile is compared with the data of the actual day. Forecasting errors are given for the average error and the absolute average error. The defined goal was reached with a mean percentage error (MPE) not more than +/- 5 % and the mean absolute error (MAPE) should not exceeding 10 %.

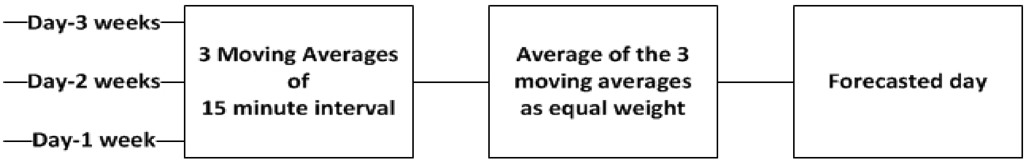

Figure 4: Forecasting concept

The real load profile is taken as reference to correct the initial ARMA forecasting of three weeks (forecasted load). That means that the measured profile (real load) of a day has a higher weight in the forecasting as follows:

$$\text{Corrected load}(t) = \frac{\text{Forecasted load}(t) + \text{Real load}(t)}{2} \qquad (1)$$

According to production schedules of the manufacturer, the production is more or less predictable for every weekday under regular working conditions. Figure 5 shows load profiles of 3 consecutive Tuesdays. The load profiles are very similar. The defined corrected load as the forecasted load of the following week improves the forecasted ARMA value up to 30 %. Figure 6 shows the non-corrected and corrected forecast profile compared to the load profile of the actual day.

A Matlab model is the core of the load forecast model realized in LabVIEW. The integration of the model to a data server allows continuous forecasting simulations which will lead to an online forecasting tool and hence eases decision making within the energy management. A short term survey algorithm is planned to handle and correct seriously affected operation of odd days.

ISBN 978-3-943891-37-9, p.147-152

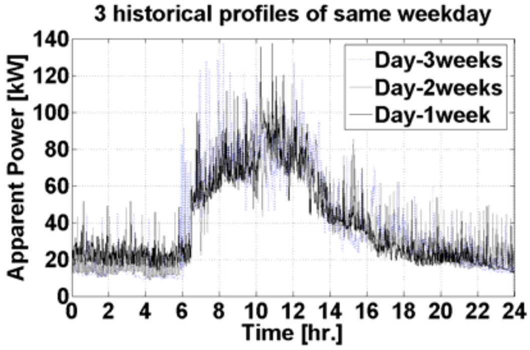

Figure 5: Load profiles of 3 consecutive Tuesdays

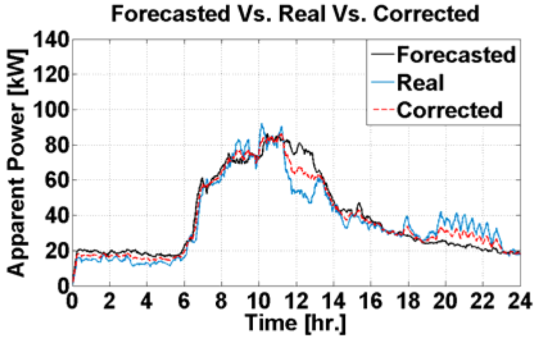

Figure 6: Corrected profile compared to forecasted and actual data

Conclusions and further steps

After the installation of all energy relevant component the trigeneration smart subnet is running on the process automation level and delivers the first datasets which are used to define expert rules for a rule based energy management as first approach. With the given priority to a maximum CHP operation time the heat delivery can be considered as sufficiently dimensioned and the power delivery as well oversized thus dedicated to grid-feeding to finance the project.
The first load forecast model for electrical profiles suits well to handle the weak modulated production profiles of a week. Survey and correction algorithms should be added to improve the reliability regarding odd days and other disturbing events.
The application of the monitoring concept[3] to realize a continuous assessment of the energy flows is well suited to develop a forecast based energy management[4]. In the further steps a database and supervisory computer will be implemented to introduce weather and grid quality forecasts to the process automation. All meter values are additionally collected and stored to gain a database for the modelling of an energy flow optimization controller.

Acknowledgements

The project is partly financed by the badenova Innovationsfonds für Klima- und Wasserschutz.

[3] Bollin, E.; da Costa Fernandes, J.; Feldmann, T., Energieoptimiertes Bauen, Teilkonzept 3: Lanzeitmonitoring des Neubauvorhabens Solar Info Center Freiburg, Phase II, Monitoring/ Betrieb, Forschungsgruppe net am INES, gefördert über das EnOB-Programm des BMBF/BMWi unter BMBF0335007U, Offenburg, 2008.

[4] Feldmann, T,; Schmelas, M.; da Costa Fernandes, J.; Bollin, E.; „Prädiktives Energiemanagement für ein Energie-Plus-Haus mit Versorgung von Elektrofahrzeugen.“, Forschungsinitiative „Zukunft Bau“, Aktenzeichen: II3-F20-11-1-, Laufzeit: 2011 bis 2013, Berlin.

ISBN 978-3-943891-37-9, p.147-152