FIELD TEST OF GRID ORIENTED CHP MICRO UNITS FOR THE DOMESTIC ENERGY SUPPLY

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ABSTRACT

The Energy Research Alliance of Lower Saxony (FEN) has developed the grid-oriented operating method of combined-heat-and-power (CHP) micro units for the domestic energy supply. With this mode of operation, it is possible to adapt the power-supply of the distributed generators to the load profile of the low voltage system. There is also a decoupling of the heating supply and the power generation by a thermal storage tank.

Via a communication interface according to the international standard IEC 61850, the CHP micro unit will be controlled through the internet and thus from everywhere. In a field test with two units, the grid-oriented operating method will be tested for one year. The field test started with the beginning of 2011 in two multi-family houses of a regional building society. The Operation of the power plants happens by an intelligent power generation plan. This plan is created from measurement values of the local installation by a mainframe computer. There, the values are revised and transmitted to the CHP micro units.

1. MOTIVATION

Grid operators facing different challenges for their network especially with the dramatically increase in the penetration level of renewable energies in the medium-voltage power grid as well as in the low-voltage grid [1]. In addition to the problem of the load fluctuations during the day, the existence of the distributed generation (DG) has to be taken into consideration. These DG´s include photovoltaic systems, small wind turbines and CHP micro units. The usage of the operational supplements in power grids must be kept constant to ensure the quality of energy supply. To do that, there are different possibilities to have influence on the load profile. On one side, the peak demand of the day can be decreased and on the other side, the power supplied from DG can be controlled. The grid-oriented operating method of a number of CHP micro units together can be used to manage the supplied power to the grids and get more benefits from the point of view of the grid operator.

Previously, the requirements of power grids and the operating method of micro CHP were extensively simulated by the TU Braunschweig in recent years [2]. In addition, preparations for a field test were taken at this time. The field test began in the early January.

2. FIELD TEST OF GRID ORIENTED CHP MICRO UNITS FOR THE DOMESTIC ENERGY SUPPLY

The aim of the field test is to verify the simulation results in combination with the quality of an algorithm developed by the TU Braunschweig. The target size for optimization is the electrical load profile of the grid. In addition, other targets such as the price of electricity at the stock exchange are possible in the future. Secondly, it is important to ensure the reliability of data transmission.

Figure 1 shows the schedule management of the CHP units with the bidirectional communication.

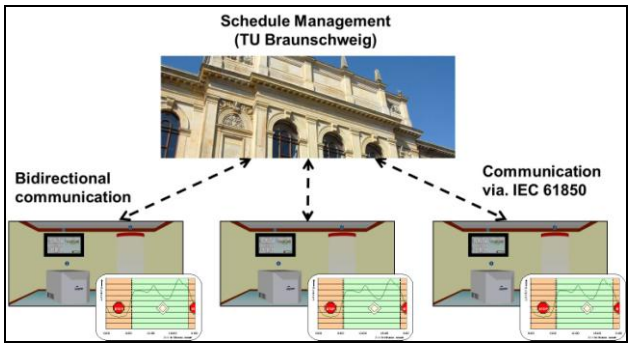

Figure 1: Grid-oriented operation method of CHP micro units

As a result of the field test, the grid-oriented combined operation mode of two CHP micro units is to be tested. The operating hours of the equipment should be based on the electrical load profile of the grid operator. The supply of electrical energy must take place, when the electrical load is high. This allows a smoothing of the electrical load. To ensure the heating supply of the residential, a decoupling by

a 1000 l thermal storage tank is performed.

2.1. Field test environment

The practical implementation of the field test is conducted by the TU Braunschweig in cooperation with the University of Oldenburg. The field test is also supported by a regional grid operator and a regional building society. Two multi-family houses will be equipped with CHP micro units of the manufacturer Ecopower for conducting the investigations.

Each multi-family house has a living space of 365 m² for four parties. The houses were heated up today with a conventional gas heater. The heater has a connection power of 38 kW. The houses are situated in the outskirts of the city of Braunschweig and are connected to the low voltage system of the local grid operator BS Netz GmbH. The CHP micro units were delivered by the company Ecopower-Vaillant and have a thermal output of 12 kW respectively an electrical output of 4.7 kW. During the field test, the CHP micro units were controlled parallel to the existing conventional heating system. This ensures the thermal supply of the buildings in case of failure.

The field test runs initially for one year. During this time, an intensive scientific monitoring is performed by the TU Braunschweig. After the field test, the recording and evaluation of the measurements is still intended.

The commissioning of the system took place on 4th January 2011. Recording and evaluation of the measurements started at the same time. After the field test, extensive modernization measures are expected. For example, the thermal insulation of the houses will be replaced in 2012. In addition, an integration of the neighbouring buildings is possible. Thus, the efficiency can be increased. It is therefore planned, to conduct the equipment in the future to detect the changes to the grid-oriented operation mode.

2.2. Measurement instrumentation, measured values

Different measured values like the temperature of the pipes (T), temperature of the thermal storage tank (T_i) and the fluid-flow (F) can be recorded by a measurement system based on a connection via the World Wide Web (Figure 2). These measured values of the installation are used to generate the roadmap for the CHP. This roadmap is transmitted through a communication interface which was developed by the University of Oldenburg. More information about the communication interface can be found in section 2.3.

The data transmission of both systems (communication interface and measuring system) occurs once a day via the mobile network using an UMTS router. This ensures the access to the communication interface and the measuring system from the internet and thus from anywhere. In addition to the installed instrumentation, smart meters can be used to analysis the supply of the CHP micro units as well as the load profile of each house.

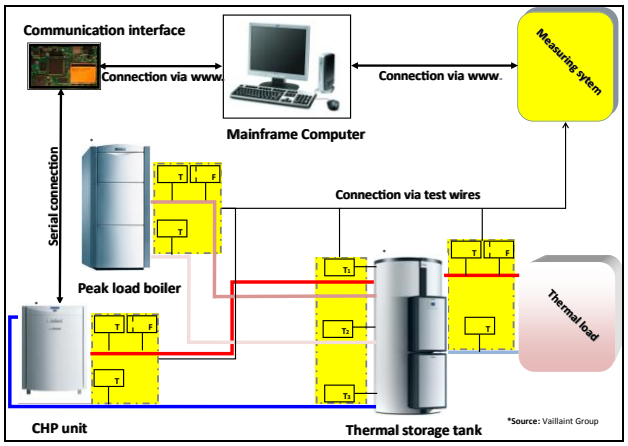

Figure 2: Structure of the measuring system and the communication links

2.3. Communication Interface

At the University of Oldenburg a communication controller was developed using the IEC 61850 communication standard for DER (part 7-420) to remotely control the CHP micro units in the multi-family houses.
In Figure 3 the hierarchical model for the CHP units in the field test, created with the help of the IEC standard, can be seen. We divided the complete field test infrastructure (the so called physical device) into the following subsystems (the logical devices), whose parameters and settings can be accessed via the aforementioned standardised interface: the controller of the CHP, the combustion engine, the generator, two heating circuits and the heat storage tank.

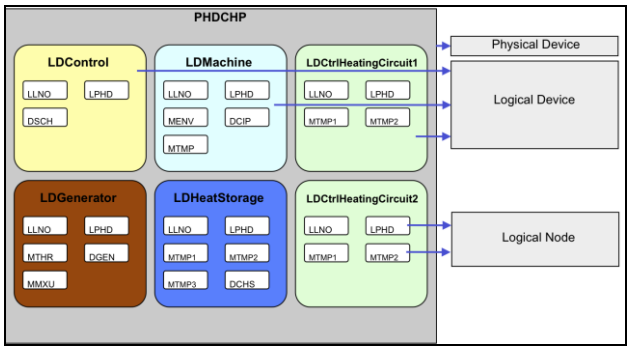

Figure 3: Hierarchical IEC 61850-7-420 model for the CHP micro unit used in the field test

Each of these logical devices contain logical nodes defined in the standard, which present functions to access the status, settings, control and measurements of the subsystem.

The controller itself is based on a reprogrammable Field Programmable Gate Array (FPGA) chip and due to its

modular approach it can be changed to support a wide range of different DGs. In Figure 4 the broad composition of these modules is shown.

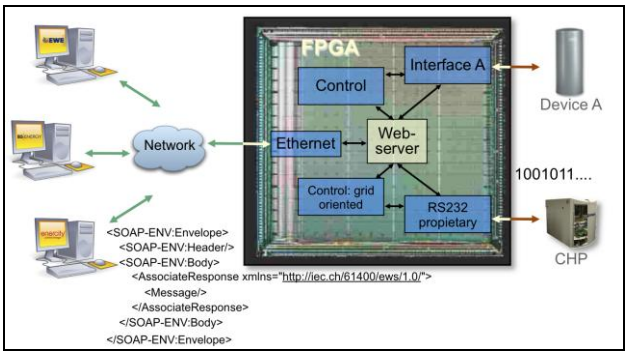

Figure 4: Modules on the FPGA for the standardised communication controller

In the centre stands a web server that represents the hierarchical model and its functions using web services. It can be accessed through the internet and is connected via an ethernet module. On the other side we connect to the DER devices and implement proprietary communication interfaces for each device. Additional functions, which are not supported by those devices, can be added as custom control modules. In the case of this field test we connect to the CHPs using a proprietary RS232-interface and we added support for 15 min schedules and the grid oriented operation mode [3].

The mainframe computer with the energy management system can now create a schedule for the next day and for every connected unit using an intelligent grid oriented day ahead scheduling algorithm developed by the TU Braunschweig. Those schedules are sent to the communication controllers and then executed by the additional control module on the controller.

2.4. Evaluation and processing of the measurements

To ensure an efficient and economic operation schedule of the CHP micro units, an intelligent algorithm is needed. The requirements of the algorithm are listed below:

- Modulation of the units must be chosen freely
- Retention of the efficiency of the system
- Primary objective: heat supply
- Secondary objective: peak load reduction
- Operation blocks of at least one hour
- Use of the peak load boiler only in certain cases
- Transfer of the smoothed load profile to the next CHP micro unit
- Neglect of energy differences when starting or stopping the CHP micro units

For the implementation of the algorithm, MATLAB© is used. The analysis and conversion of the measured values is also done in this environment. To generate the schedule, the thermal load of the houses and the electric load profile of the district network are needed. The thermal load is measured by flow measurement in combination with two temperature measurements (outgoing temperature and return temperature). This measurement is performed for the required energy of the heating and for hot water. After the measurements, these values are added together. The temperature of the thermal storage tank is measured with 10 sensor elements. This makes it possible to detect the thermal stored energy of the different water layers.

As electrical load profile of the settlement, a standard profile is given. The transformer is also measured by the grid operator. The measurements can be analysed ex post to verify the algorithm.

2.5. Commissioning and first results

As previously mentioned, the commissioning took place on 4th January 2011. The aim of the first weeks is to check the transmission of measurement data and schedules for each unit.

The thermal load profile of the multi-family house and the electrical load profile of the settlement are required as a basis for the algorithm. Figure 5 shows the synthetic electrical load of the settlement, including 10 household and the real thermal load of one multi-family house over one day. It can be seen, that the thermal load of the multi-family house varies from 5 kW to 25 kW. So the continuous theoretical thermal utilization of the CHP micro unit is close to 40 %.

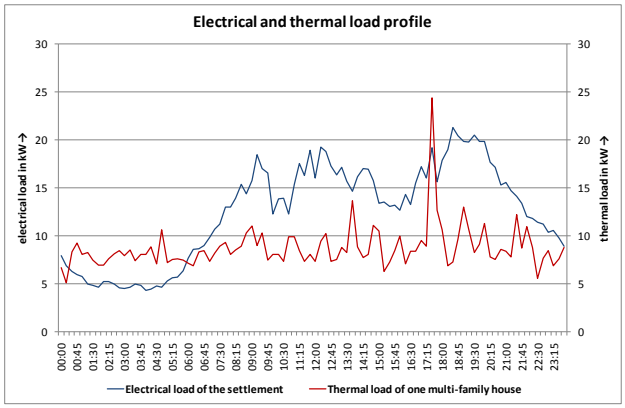

Figure 5: Electrical an thermal load profile (02.02.2011)

Based on the shown profiles of the previous day, the operation schedule for the next day is developed (Figure 6). The figure shows the proposed operating times (blue line) with the different modulation stages and the actual operating times (red line) with the output power. There are only minimal deviations from the specification. This proves that the transmission of the measured values (measurement System) and the operation schedules (communication

interface) works.

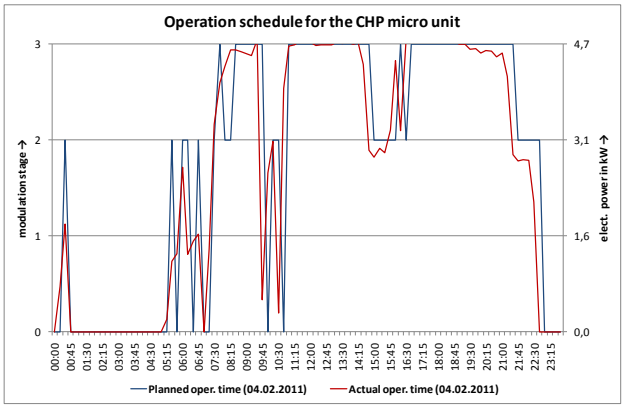

Figure 6: Operation schedule (04.02.2011)

The superposition of the actual operating time with the electric load profile shows a reduction of the peak load (Figure 7). The reduction is up to 10 % at the peak. This is the result of the analysis of only one CHP micro unit without consideration of the composite operation mode. In the composite operation mode of two CHP micro units, a further reduction is expected (Figure 7). The studies are ongoing at the present.

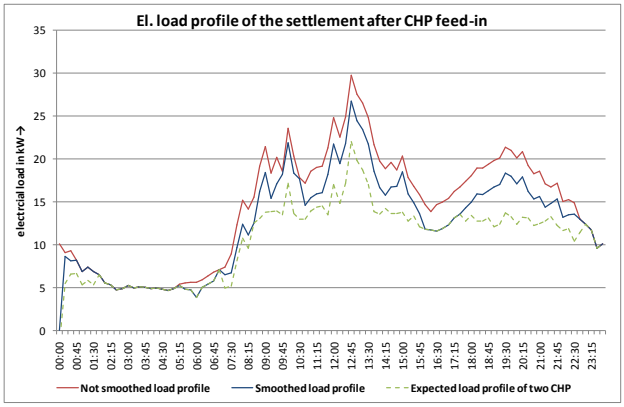

Figure 7: El. load profile after CHP feed-in (04.02.2011)

The presented results show that the grid-oriented operation mode of CHP-micro units leads to a reduction of the electrical load profile of the settlement without neglecting the thermal power supply. Because of the possibility of influencing the load-profile, there are many possible applications. For example, the grid-operator can minimize the grid-losses in times of high load. In addition, it is possible to respond to the strong supply of photovoltaic systems to prevent overload conditions and keep the voltage limits.

3. SUMMARY AND FORECAST

The field test is scheduled for one year. This ensures that each season and thus the different demand of thermal energy are captured in the measured values. The commissioning of the system took place on 4th January 2011. At the same time, the recording and evaluation of the measurements were started. Over the entire duration of the field test, the TU Braunschweig takes over the operational leadership.

The aim of the field test is to verify the simulation results of the grid-oriented operation mode of CHP micro units in combination with the quality of the developed algorithm over one year. The target size is to optimize the electrical load profile of the grid.

The first studies have shown that a reduction of the electrical load profile of the settlement is possible. Thus the functional capability of the technical equipment and intelligence is demonstrated. In further studies, the composite operation mode of at least two CHP micro units will be tested. A further reduction of the load profile is expected.

After the field test, extensive modernization measures of the multi-family houses are expected. The thermal insulation will be renewed in 2012. In addition, an integration of the neighbouring buildings seems to be possible. Thus, the efficiency can be increased.

The composite operation mode of CHP micro units is an open system, which can be applied to other applications after the end of the field test.

REFERENCES

[1] N. Hemdan, M. Kurrat, 2009, “Influence of Distributed Generation on Different Loadability Aspects of Electric Distribution Systems”, Thee 20th International Conference and Exhibition on Electricity Distribution, CIRED 2009, Prague 8-11 June.

[3] M. Pielke, 2010, “Technological and economic system analysis of integration strategies for combined-heat-and-power (CHP) micro units”, Cuvellier Verlag, 2010, PhD Thesis in German.

[2] T. Weidelt, A. Nießе, H.-J. Appelrath, M. Korte, W. Nebel, 2008, "Design and Implementation of a Standard-Compliant CHP Control Unit", Proccedings of the International Conference on Integration of Renewable and Distributed Energy Resources.