BIDIRECTIONAL ENERGY MANAGEMENT INTERFACE (BEMI) INTEGRATION OF THE LOW VOLTAGE LEVEL INTO GRID COMMUNICATION AND CONTROL

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ABSTRACT

Decentralized electrical generation units (DG units) are connected to the network in Europe with an increasing number and generation capacity, which requires new intelligent grid control strategies including energy management with controllable generators as well as controllable loads. Today, however, this potential in most cases cannot be activated due to lack of standards and missing economical incentives.
In the concept presented in this work the grid connection point is extended by intelligent components to a Bidirectional Energy Management Interface (BEMI). This allows a technically efficient design of an energy management system and avoids fundamental organizational changes to the current grid regime.
The concept of decentralized decision based on information from a central control station covers the requirements of the system operator as well as the local customer. An approach for the management of a pool of DG units using this concept is outlined as an outlook.

INTRODUCTION

The installation of DG units in the low voltage (LV) grid is strongly increasing currently. Usually the variation of power in time is determined by the maximum power installed and by the supply of primary energy (renewable energy sources; in the LV grid mainly photovoltaics and biomass) or by the demand for heat (cogeneration, fuel cells and micro gas turbines are available in field tests). The time of energy delivery by DG units in the LV grid is neither regulated nor billed as far as the grid connection rules are complied with.

Controllable loads can help to operate the grid as well as controllable generators. So another important background for the introduction of controllability to the LV grid is the fact that about 50% of the total consumption of electricity in Germany takes place in this grid level (mainly private households and small businesses). This demonstrates a great potential for the installation of DG units as well as an enormous potential for load management in the LV level.

The research project DINAR, funded by the German federal ministry for the environment, nature conservation and nuclear safety (BMU) together with 17 corporate partners [1] aims at finding a technically and economically suitable solution for a bidirectional energy management in the LV grid considering both generation and consumption. Strategically, however, a new path is being followed differing from previous solutions. Central control (like the virtual power plant) is replaced by decentralized control enabling operation of the energy management system without permanent online communication. At the same time this strategy gives additional relevance to measurement information from the grid connection point.

STATE OF THE ART

For an optimal strategy of integration of renewable and DG units several sub-strategies have to be included. The complexity of the issue requires also consideration of the ongoing transitions of energy markets and different integration options.

Forecast

A decisive factor for grid control with high share of fluctuating generators like wind and photovoltaics (PV) is to forecast the profile of the fluctuating generation within the grid area observed. Aggregated with a load forecast, the remaining load to be covered by other sources can be calculated. For the prediction of wind power solutions exists that have been proven in practical operation [2], for the prediction of PV generation similar tools are under development. Still, the power available from these sources at a certain time cannot be influenced, so generation may at times exceed current load. Without possibilities of electrical energy storage and/or energy management that help to switch on loads specifically at such times the only solution to maintain a stable grid operation would be to derate those generators, which would have to be done without any savings in primary energy. This situation is expected to occur in Germany for the first time between 2015 and 2020, which demonstrates the urgency of the development of appropriate measures.

Storage and large-scale distribution

Levelling effects of power generation within a large geographical area but also among different generation technologies help to produce a more constant profile of the total generation, which allows for savings regarding storage and control efforts. Given appropriate electrical transmission systems (e.g. HVDC), the transmission of energy from fluctuating sources even over large geographic distances is usually more cost-efficient than local electrical energy storage [3]. Practical experiences show, however, that the construction of high voltage lines is often heavily opposed by the public. Nevertheless large-scale distribution as well as storage of electrical energy from fluctuating sources must be considered an important option for the control of a grid with high share of renewable generators like wind and photovoltaics.

However, the activation of potentials for shifting power consumption into times of high production from fluctuating generators using energy management should have priority before the use of energy storage systems or long-distance distribution in order to reduce power losses. For levelling remaining seasonal differences between generation and consumption it can be expected that in the first step the scheduling of remaining conventional power plants will be used – which decreases their economical efficiency, however. Seasonal scheduling of large industrial electrical energy consumers is also a possibility. In the short to medium term, however, potentials of energy management should be exploited first for reasons of efficiency as described before without neglecting the need for storage and transmission in the long term.

Energy management

Energy management has been used in the industrial sector for a long time. Currently, in this area even potentials for the delivery of control energy are activated [4]. Technical and economical requirements and prerequisites for the activation of this potential are generally set. In contrast, the potential for energy management in the area of private households and small commercial customers is not activated at all except for the usage of ripple control. In this area the management of loads and cogeneration units can contribute significantly and additionally to grid control and delivery of ancillary services. This must be valued considering that approximately half of the energy consumption in Germany takes place in the LV grid [5].
The integration of the huge number of devices installed in the low voltage grid at independent customers' sites requires an efficient system for communication, trade and transactions between the market participants of the liberalized energy market (s. figure 1). As the price of electricity varies dynamically based on demand and generation capacity available, the application of this market price representing the marginal cost of electricity generation is economically efficient. This is also generally true for customers connected to the LV grid. As the aggregated customers' reaction within a certain grid region to a certain tariff profile can be predicted robustly, a system of variable tariffs can be a reliable instrument for grid operators and energy suppliers for demand and small generation management though being very flexible towards the single customer.

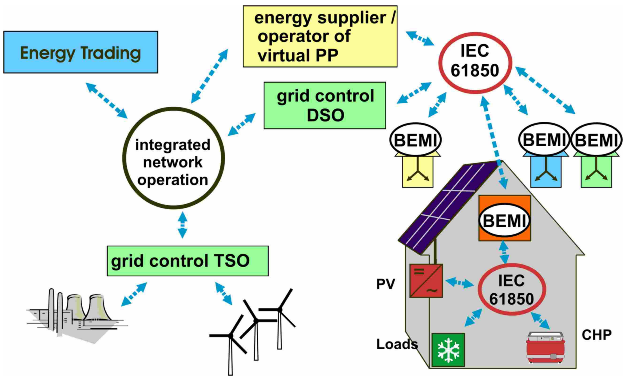

Figure 1: Communication and trade in the liberalized energy market with integration of distributed generation

CONCEPT AND PRACTICE

BEMI

Today the grid connection point is represented by a metering cabinet including protection devices. This technical as well as legal interface between the public grid on the one side and the local grid of the customer on the other side is extended by intelligent components (figure 2). The concept of placing the energy management intelligence into the grid connection point allows integrating all technical components that are necessary for the implementation of energy management strategies. This includes a core processor, grid surveillance, metering, communication and switches. Grid operator and energy supplier, which are involved in the energy management of the customer, have access to these components according to their rights fixed by the agreements made between the parties. By maintaining the existing technical and legal interface BEMI allows for clear and efficient agreement structures between grid operator, energy supplier and customer.

Figure 2: BEMI test setup in DeMoTec laboratory

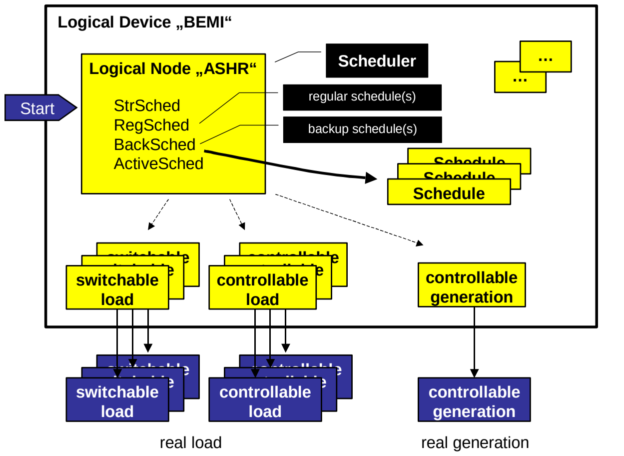

Figure 3: Data models for BEMI corresponding to IEC 61850

Standardization as a prerequisite for technical and economical realization

To realize cost efficient communication, standards are decisive that define a common language between the communication partners. In this way effort for individual development and engineering is reduced to a minimum. BEMI communicates bidirectionally to the central control station based on IEC 61850, which is preferred by IEC as "seamless Telecontrol Communication Architecture" for the future communication within the electrical energy supply (figure 3) [6].

At the same time BEMI is open for various in-house communication systems, e.g. EIB/KNX, CAN, but also Ethernet, WLAN and PLC communication. In this way an open communication system is developed (figure 4).

Technical implementation

The computing core of the BEMI implements the decentral intelligence. It receives certain information from the central control station, usually the tariff profile for the following day. Based on this information the computer calculates optimal schedules for each device in the management system using a specific algorithm for each device type.

Such devices are freezers and fridges, electrical heating and warm water generation, air conditioning and ventilation, washing machines, dryers and dish washers as well as cogeneration devices. In the future this list may include uninterruptible power supplies (USV), electrically driven vehicles and photovoltaic inverters equipped with additional battery storage. Three basic types of devices must be differentiated regarding energy management:

- devices with thermal or battery storage, which state-of-charge (SOC) must be maintained within a certain range
- devices which carry out a fixed program with shiftable starting time (e.g. washing machine)
- devices which can reduce their power at high electricity prices (e.g. a dimmable lighting)

Algorithms for each device type must be designed in a way that avoids avalanching effects by switching all devices at the same time. This can be achieved by small, random shifts of switching times [7]. Furthermore not all customers should receive exactly the same tariff, but tariffs should be varied so that the aggregated reaction of all customers supplied by the system follows a given power profile within the usual forecast uncertainty.

The optimization algorithm decides considering the preferences of the inhabitants of the building, the parameters of the devices included in the management and the information received from the central station. This means BEMI decides locally based on local and central information. No permanent online communication is required which would be necessary in a strategy with central decision and scheduling of the devices.

Via a display the customer is able to obtain information and perform modifications to the schedules produced by the optimizer as well as the device parameters used by BEMI. Based on a PDA handheld device with WLAN communication such as used by many customers already today a user-friendly HMI (human-machine interface) is implemented. The web interface provided by BEMI can also be used for remote control.

BEMI also contains load and generation profile metering, which is decisive for billing and compensating the optimal operation of devices within the liberalized energy market. This is a fundamental requirement for the economical operation of the system. Furthermore BEMI includes a grid measurement device (BiSi) [8], which can implement unintended islanding detection. The unit enables additional functions such as frequency-based energy management for an intended islanding operation in case of grid failures. Local grid measurement values, metering data etc. is transmitted to a central server and graphically represented.

The current implementation uses a Linux-based server system. Because of its modular design, BEMI can be extended by additional functions, e.g. monitoring of a PV plant, which makes monitoring data accessible password-protected worldwide via the internet.

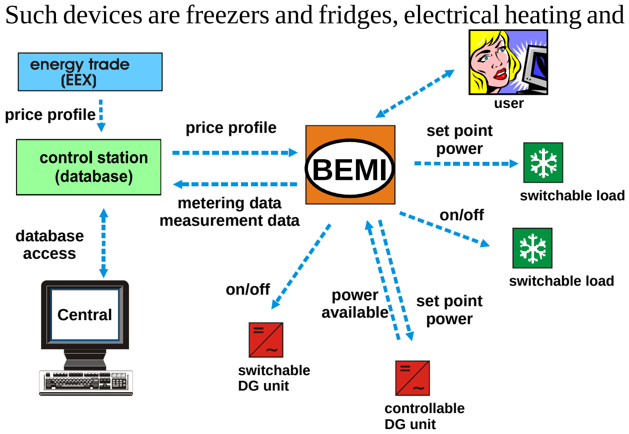

Figure 4: Communication structure for energy management by BEMI

TECHNICAL FEATURES AND OPERATIONAL RESULTS

After first operational tests in November 2005 additional features have been developed and implemented into the BEMI system:

- Automatic estimation of device parameters
- Wireless control of devices
- Extension of optimization algorithm to take into account special behaviour of thermal storage and cost of switching
- Transmission of outdoor temperature forecast from central control station to BEMI
- User accounts defining read/write permissions
- Data logging of all values relevant for the local decision making process and energy management of BEMI (s. figure 5)

Figure 5 shows that the SOC (state-of-charge) of a cooling device changes based on its operational state. When the device is in operation (drawing power), the SOC increases. For economic efficiency, the SOC is held high during low price times. In the test shown here a deviation between the real SOC (measured by inside temperature of the device) and the planning occurred due to insufficient information on the device parameters. This made reoptimization necessary. Such graphical evaluation tools are decisive to develop and improve an energy management system.

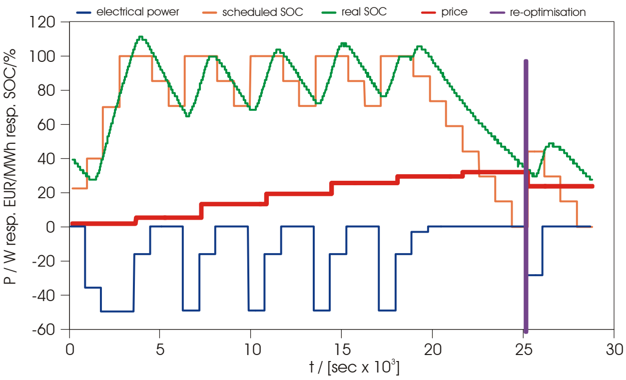

Figure 5: Management of a cooling device based on a variable tariff

SUMMARY AND OUTLOOK

By extending the existing technical and legal interface between system operator and customer, BEMI provides a platform on which generators and loads in the LV grid can deliver a substantial contribution to the integration of DG units. This was demonstrated by the presented experimental assemblies. The concept of decentralized decision will also remain a basic principle in ongoing research on the management of a pool of devices containing BEMI-equipped households, commercial enterprises and industrial facilities as well as other DG units. The approach here is to develop a new concept for managing the pool. This will require a device called “Pool-BEMI” acting as manager in place of the central control station. The “Pool-BEMI” shall exploit decentral information about free resources for local generation and load switching provided from the BEMI and use these resources via tariff signals. In addition, the “Pool-BEMI” is to provide ancillary- and measurement-services, therefore acting as technical interface between DG units and system operator in order to enable the effective integration of DG units in the distribution system.

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