projektinfo 02/08

BINE Informationsdienst

Electricity grid quality – grid integration of decentralised power generators

Fig. 1

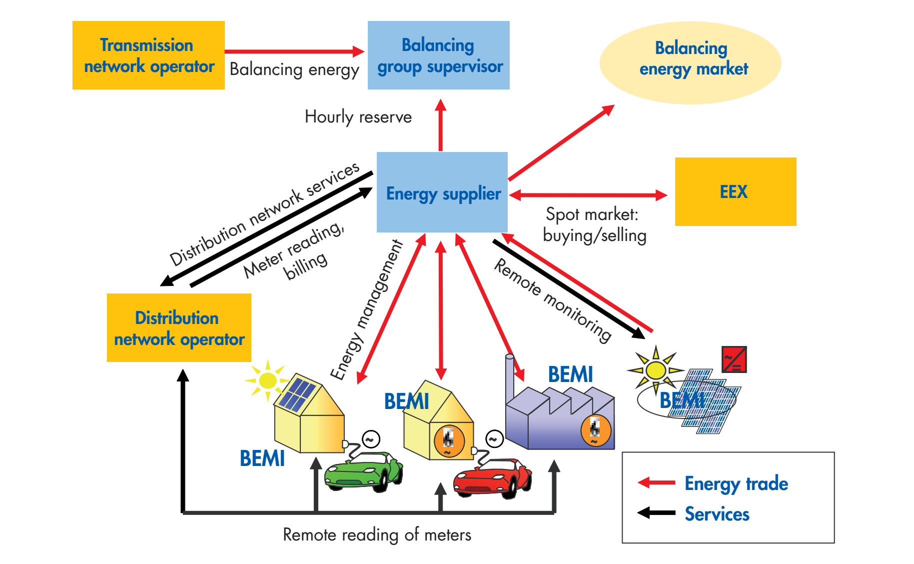
- **Management of decentralised power generators and loads improves the grid quality**
- **Automatic comparison of supply and demand through market mechanisms**
- **Decentralised energy systems provide future system services**

During the night the electronic energy manager switched on the washing machine since the electricity was at a low price. Now, during lunchtime, the electricity price has reached its daily maximum – the right time for the micro-CHP plant to fill up the hot water storage tank and feed the simultaneously generated electricity into the grid.

Small and micro-power plants such as CHP plants, photovoltaic systems and small wind turbines are increasingly contributing to power generation. In contrast to, for example, large-scale wind turbines, these mostly feed electricity directly into the low-voltage grid but do not support the grid by providing system services such as controlling the output or frequency, maintaining the voltage range, providing reactive power or improving grid voltage quality. Today, such services are almost solely provided by large-scale power plants. For grid operators, the growing number of decentralised energy systems is presenting a new challenge. They have neither control nor knowledge of the current amount of electricity fed in by the individual plants. There are no control devices connecting the decentralised energy systems to the low-voltage grid, so that the grid operators are unable to monitor or control the feed-in situation but can only make forecasts. If, under these conditions, the proportion of uncoordinated decentralised energy systems is too high relative to the overall generation, this can endanger the secure and optimum operation of the grid. Various research projects have shown, however, that decentralised energy systems can also contribute to optimum grid operation if the corresponding measurement equipment is available and suitable energy management systems control the generation and consumption in the distribution networks. Here centralised control concepts are competing with systems that optimise the electricity feed-in and consumption decentrally. The DINAR research project, funded by the Bundesministerium für Umwelt, the German Ministry for the Environment, shows how this decentralised energy management can be implemented. Together with seventeen industry partners, the Institute for Solar Energy Supply Technology (ISET) has developed a bi-directional energy management system for the low-voltage grid.

Energy management – centralised or decentralised?

Fig. 2: Overall system for decentrally organised energy management



How can decentralised power generators and loads be optimally integrated into the low-voltage grid in future? Is it better to coordinate them centrally or does decentralised energy management offer more advantages? These competing approaches are currently being examined in various research projects, whereby the focus is not on technical solutions but on whether and how the systems will be able to be integrated in the liberalised single EU market. In particular, the features of the market, such as discrimination-free grid access and the separation of grid operation and generation, must remain.

Centralised energy management

With a centralised energy management system, the bundling of various power generators in combination with storage facilities and loads creates, in an ideal situation, a 'virtual power plant'. This has the same features as a large-scale power plant (see BINE Projektinfo brochure 2/2002): it can be centrally controlled on the basis of schedules and provides system services. It can also participate in electricity markets by bundling its capacities. These advantages of centralised management also bring with them two disadvantages: the central control point represents a 'single point of failure', which means that it has to be securely designed with appropriate redundancy built in. In addition there is considerable communication expenditure in terms of issuing schedules and monitoring the plants online, with the complexity of the centralised optimisation growing exponentially with the number of generators and loads. Therefore in technical terms it is only sensible to implement centralised management for a small number of generators and loads, but not for hundreds or thousands of generators in the low-voltage grid. In addition to these technical difficulties, legal problems arise in the liberalised energy market if, for example, loads and generators involve different owners. There are also no individual market participants who have access to both the grid and the power plant data in order to optimise the generation mix and grid management.

Decentralised energy management

Decentrally organised control of power plants and loads is more robust than centralised management, less complex and has fewer communication requirements – features which are particularly important in view of the large number of generators and loads. The decisions are made by decentralised energy management systems that can optimise the electricity generation and connect and disconnect loads. In order that these optimisation decisions optimise the entire system, they are controlled using key information such as feed-in and reference tariffs. In the DINAR project, the researchers investigated the organisational and technical prerequisites required to optimise the behaviour of energy generators and loads through variable tariffs and automatic device management.

DINAR research project

In the concept developed as part of the DINAR project, the energy consumers and operators of decentralised plants become market participants who can supply or accept electrical energy in accordance with their current requirements (Fig. 2). What were previously pure energy traders now offer additional energy services. The energy service company (ESCO) conducts a bi-directional energy trade between its customers and overriding energy markets such as the EEX electricity exchange, therefore acting as both energy supplier and consumer. Additional opportunities for marketing decentrally generated electricity include selling balancing energy or participating in the balancing energy market. The ESCO supplies its customers with key information about variable consumption and feed-in tariffs, which are generated, for example, from the EEX's current spot market price. These tariffs are issued via a central control centre to decentralised decision-making units, the Bi-directional Energy Management Interfaces (BEMIs). These respond by automatically connecting/disconnecting loads or decentralised energy systems and therefore minimise the electricity costs for the customer. Because the customer response to variable tariffs within the supply area can be relatively precisely forecasted, for ESCOs this procedure represents a reliable and – for the customer – transparent and flexible instrument for influencing the load and generation process. This instrument can be used, for example, to avoid having to restrict the electricity fed in from wind turbines or photovoltaic systems when these sources exceed the current load. If the ESCO were to artificially lower the consumption tariff, the 'electronic energy manager' in the affected grid section would respond by connecting loads. In future that could also include plug-in hybrid vehicles.

Bi-directional Energy Management Interface (BEMI) For largely automated, decentralised energy management, the customers need corresponding hard and software to automatically connect and disconnect electrical loads and generators. For this purpose the researchers have developed a Bi-directional Energy Management Interface (BEMI), which, as a decentralised computer, replaces the conventional meter cupboard as part of the house connection (Fig. 3). It receives key information from the central control centre, in particular the price profile for the following day. Based on this, the optimum utilisation schedule for all connected devices is calculated. These include loads such as cooling devices, hot water boilers, air conditioning systems, washing machines, dryers and, if available, power generators such as CHP plants. In future, systems with battery banks, charging equipment for electric vehicles and fuel cell heating devices could also play an important role. A meter interface records the used and generated electricity and transmits this data to the central control centre. Recording load and generation data at 15 minute intervals makes it possible to calculate and pay for the optimised use of devices in respect to time also in the liberalised electricity market. Some devices, such as refrigerators whose internal temperature is monitored by the BEMI, can be controlled without the customer noticing. With other devices, such as washing machines, the customer must be informed of the planned use so that they have the opportunity to amend the schedule calculated by the BEMI. That is achieved with a standard handheld computer with WLAN, which the consumer uses to request information and modify the schedules and parameters. The Web interface provided by the BEMI can also be used for remote accessing via the Internet. Consumption and generation data for the billing are transferred to a central server and presented there. The same applies to measurement values for the voltage, frequency and impedance for the grid monitoring, which are provided by the BEMI's measurement and control interface (MSI).

Implementation and test operation

The BEMI was realised as a laboratory experiment as part of the DINAR project. For demonstration and verification purposes, two test households were assembled in the ISET's DeMoTec laboratory (Fig. 1). These have various types of cooling devices and tumble-dryers, which are managed by the BEMIs. Two different kinds of CHP plants are operated in the test households to simulate heat requirement profiles. In order to separate the heat requirement and electricity generation time-wise, the plants are connected via storage facilities to the heat sink. The BEMIs also optimise the use of CHP plants with regard to the content of the heat storage tanks. This system was continuously tested by the DeMoTec laboratory from July to October 2007, whereby the variable tariffs were transmitted from the EEX for one of the households and from the regional supplier, the Städtische Werke Kassel AG, for the other household. The management system enabled savings to be made, for example around 8% of the overall net costs for a cooling device per annum.

Applications

Potential applications for the BEMI system also include active energy management, which can be used, for example, to integrate fluctuating generation. In a simulated scenario, the load management was used with 6400 BEMIs for washing machines and refrigerators in order to balance out a feed-in deficit from photovoltaics and wind energy. Centralised medium and peak-load power plants are currently used for this purpose. With the BEMI management system, the necessary output from these power plants would reduce by around 30%. Remote meter reading and grid condition monitoring also make it possible to incorporate smart metering functions and distribution network services. These functions help the distribution network operators run the grid and integrate distributed generators. They include monitoring the supply situation, improving the voltage quality and monitoring grid bottlenecks. To make this possible, a large number of the Bi-directional Energy Management Interfaces (BEMIs) must be bundled together by an overriding component. This 'Pool-BEMI' forms the technical interface between the ESCO and the distribution network control centres and is currently being developed. The principle of decentralised decision-making is also used for the superordinate management. This means that the Pool-BEMI also does not directly decide on the use of decentralised generators and loads. It is intended, however, to extend the mechanism of variable tariffs used in the DINAR project so that the BEMI can supply the Pool-BEMI with information on available resources, for example potential generation sources, and thus play a more active role. The Pool-BEMI activates these resources with the help of price signals that are supplied to the BEMI as key information. In addition, it is also connected to the distribution network operator and provides a technical interface for the distribution network services. The BEMI technology also enables decentralised energy systems such as photovoltaic systems and small wind turbines to be incorporated into the system as active units.

Fig 3: Communication structure with BEMI

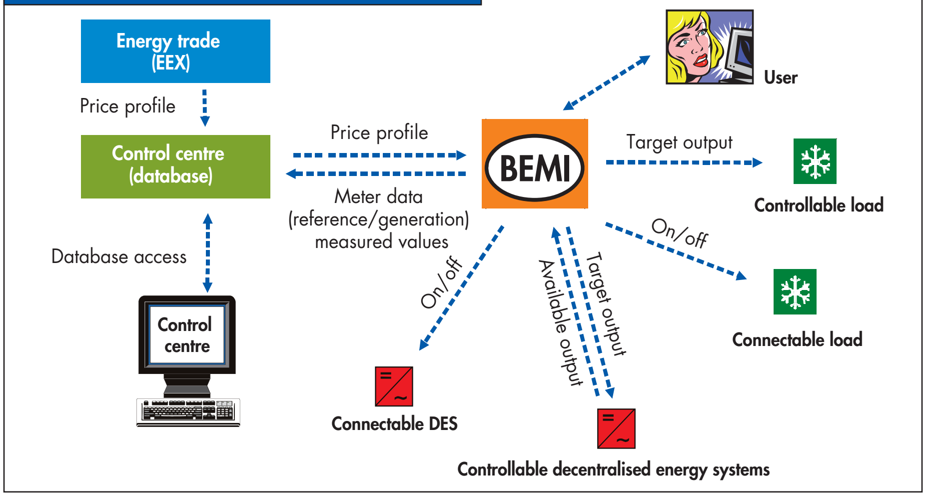
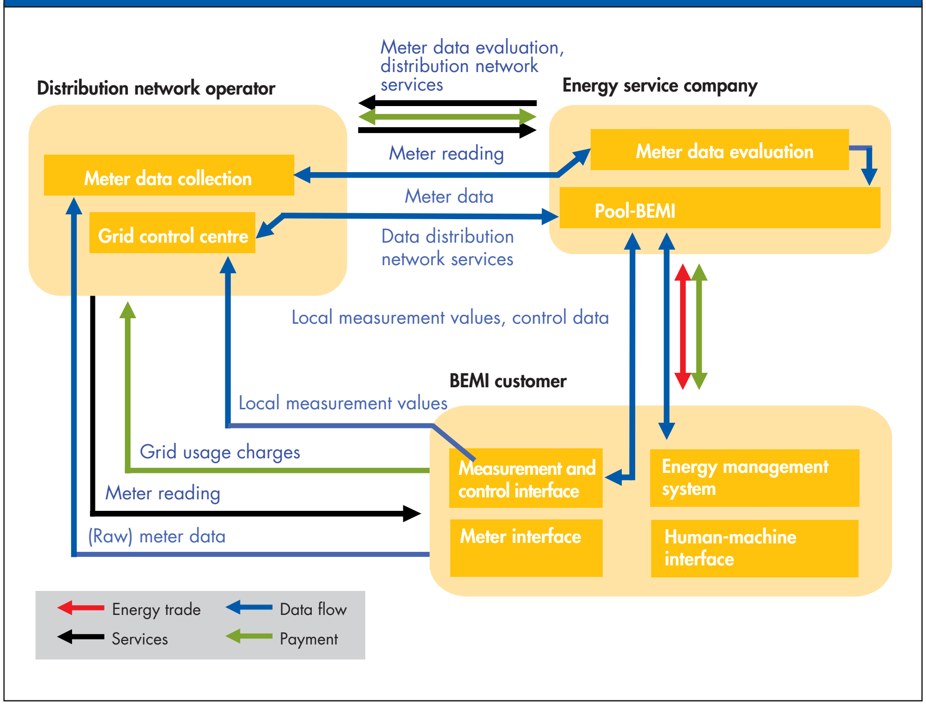


Fig 4: Market participants in the BEMI pool



Conclusion and outlook

Future electricity supplies will continue to be characterised by centralised feed-in at the high-voltage level. Decentralised power generation systems will continue to be connected to the medium and low-voltage network. In future, however, they will also stabilise the grid. The main task will be in coordinating the various decentralised energy systems by means of bi-directional communication. For this reason interconnected operation will prevail in the near future, as is already planned and is increasingly being examined in virtual power plants. Although there appear to be considerable conceptual differences between BEMI and centrally managed virtual power plants, both concepts pursue similar aims such as, for example, making it possible to forecast the complete load flow. Therefore BEMI and virtual power plants are certainly not incompatible concepts – in fact they are rather the opposite: correctly used, they mutually complement one another. The BEMI concept is aimed at managing a large number of loads and decentralised energy systems with smaller outputs, whereas the centrally managed virtual power plant is better with small loads and decentralised energy systems with large outputs. In future energy supplies, both concepts could therefore play a key role in enabling the full technical potential to be exhausted. This presupposes, however, that virtual power plants are developed with suitable interfaces for grid operation and that the grid operator strategies are open to their use.

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ADDITIONAL INFORMATION

Literature

- Bendel, C.; Nestle, D.; Ringelstein, J. u. a.: Marktmodell für ein dezentral organisiertes Energiemanagement im elektrischen Verteilnetz – Grundlage für ein internetbasiertes Managementsystem. In: ETG – Energietechnische Gesellschaft im VDE, Frankfurt (Hrsg.): Internationaler ETG-Kongress 2007. Karlsruhe, 23.-24. Okt. 2007. Vorträge. Berlin; Offenbach : VDE Verl., 2007. ISBN 987-3-8007-3064-3. S. 191-200

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- www.projektdinar.de

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- Additional information can be obtained from the BINE Information Service or can be downloaded at www.bine.info (Service/Infoplus)

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