Load Management in Power Grids

Towards a Decision Support System for Portfolio Operators

The increase in decentrally supplied renewable energy sources has led to growing issues with network stability. In general, both power producers and consumers can contribute to the reduction of stability problems. To this end, we propose contributions to a decision support system. On the producer side, combined heat and power plants can be used to balance the load in virtual power plants. Based on forecasts, the operators can offer a load curve. The regulation of the combined heat and power plants is able to compensate for fluctuations. On the consumer side, price signals affect consumers and intelligent appliances. The system determines appropriate price signals. In this way, a part of the energy used in homes can be shifted: "When the sun shines, the washing machine operates". Only communication from the power producer to the consumer is required, a return channel is not necessary. The practical validation of the decision support system will be conducted later in field tests.

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1 Introduction

Production structures in the power grid are constantly changing, not only in Germany. Due to legal regulations and other factors (see for example Appelrath and Chamoni 2007, p. 329), there is a trend toward decentralized supply by small plants. These suppliers include wind power plants (WPP), photovoltaic systems (PVS), and combined heat and power plants (CHP) of various constructions. Typically these PVSs, CHPs, and even some smaller WPPs are operated privately by individual households. So far, central control has not been possible on the whole. Generally, supply occurs at subsidized rates that are guaranteed over a period of years.

In the meantime, however, just the WPPs and PVSs at peak times provide sufficient electricity to endanger the stability of the power network. At the moment, there is no incentive for operators of WPPs and PVSs, or even for subsidized CHPs to interfere with the control of their plants. For WPPs and PVSs, this is also not desirable: for these types of plants, the only control option is a (partial) shutdown of production. The combination of WPPs, PVSs and CHPs to form a virtual power plant (VPP), however, unlocks the potential to include renewable energy suppliers in a meaningful way.

On the other hand, however, demand side management can be directed towards changing household energy consumption by means of price signals. In this context, the term "smart appliance" is often used. These appliances are capable of reacting automatically to price signals. In this article, we assume that no response is required of the devices, which means that we do not need to consider data security on the return channel. The price signals are transmitted unidirectionally via power line communication (PLC). For network operations, only the aggregated overall reaction, in the form of changes in consumption, can be observed.

There are various approaches to individually manage the load on the pro-

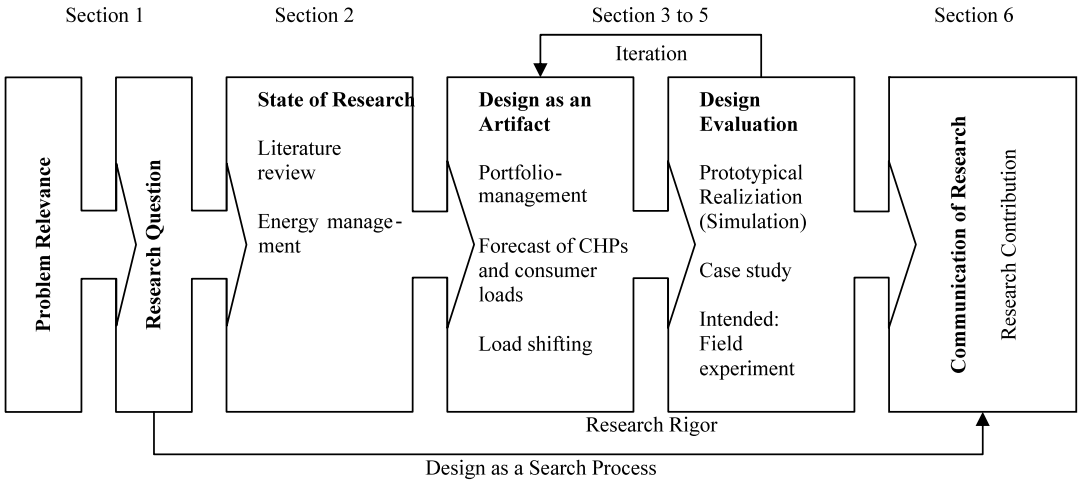

Fig. 1 Development of a decision support system with the Design Science Research approach in accord with Hevner et al. (2004, p. 83)

Table 1 Literature overview of energy management

	Producer	Transmission system operators	Energy supplier	Distribution network providers	Consumers
Appelrath and Chamoni (2007)	(✓)	(✓)	(✓)	×	(✓)
Brandt (2007)	(✓)	(✓)	(✓)	(✓)	(✓)
Tröschel and Appelrath (2009)	✓	(✓)	×	×	×
Goutard (2010)	(✓)	✓	✓	×	×
Sonnenschein et al. (2006)	(✓)	×	✓	×	✓
Eßer et al. (2007)	✓	×	✓	×	✓
Tröschel and Lünsdorf (2010)	(✓)	×	×	✓	(✓)
Molderink et al. (2010)	✓	×	×	(✓)	✓
Köpp et al. (2010)	✓	×	×	×	✓
Fluhr et al. (2010)	×	×	×	(✓)	✓
Hauttekeete et al. (2010)	×	×	×	×	✓
Stadler et al. (2009)	×	×	×	×	✓

ducer and consumer sides. We assume that in the future it will be necessary to consider the two sides simultaneously to make more efficient use of the potential of renewable energies. In this article, we are introducing an approach to a -support-system for portfolio operations that can be used to reduce short-term deviations from the long-term forecast. The remarkable thing about our approach is that the control options are offered to both producers and consumers. This leads to the following research question: "Which current and additional decision options does a portfolio operator have when considering both producers and consumers?"

To answer the research question, we used the Design Science Research approach in accord with Hevner et al. (2004, p. 83). **Figure 1** shows the approach and the further structure of the paper.

Section 2 introduces existing concepts in the area of energy management. Section 3 elaborates on the concept of the decision-support-system. Section 4 explains how the portfolio of VPPs and network operators can be optimized. Section 5 provides examples of individual simulation results and real data results. The prototypical implementation described in Sects. 4 and 5 represents an experimental design evaluation. The field test to be carried out constitutes an observational design evaluation (Hevner et al. 2004, p. 86). Sections 4 and 5 are mutually dependent, because valuable reference points for improving the model can be derived from the simulation results. Section 6 summarizes the results of the research, views them critically and provides initial recommendations for action.

2 State of Research

The state of research is summarized in **Table 1** by means of selected relevant publications, to be described in detail in the following. The table's categories are oriented around the energy flow from the producer to the consumer and the involved stakeholders. This categorization is also used in **Fig. 2** in the subsequent section. Sources whose main focus is on one of the categories carry a check mark, and those with a consideration outside of