Impact of incentive-based demand response on urban low-voltage grid operation

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Introduction and Problem Statement

Distribution grid operation and planning is facing a fundamental change due to growing amounts of distributed and fluctuating generation (DG). With this, the task of distribution grid planning – including procurement of assets with lifetimes of 30 years and more – can at best be called a big challenge. Energy system transition influences grid operation and maintenance of grid stability already today.

Decentralized energy management systems (EMS) for the low-voltage (LV) network are known to be a key smart grid component. However, their role for grid operation and planning still has to be precised considering real grid situations. This was aimed for in the European FP7 project Smart House/Smart Grid (SH/SG) [1][2].

Software simulations are a key tool for assessing impact of EMS onto grid operation. Since the practical relevance of this impact is constantly growing, distribution grid operators have high interest in according results for their own network areas. The Project SH/SG offered the first-time opportunity to study the effects of a day-ahead, variable tariff based EMS initially developed by Fraunhofer IWES ("Bidirectional Energy Management Interface" [3]) within an urban LV network.

Considered urban network and grid topologies

In order to study the impact of energy management onto grid operation parameters, simulations were carried out considering operation of a day-ahead variable tariff-based EMS used for automated demand response within part of the Mannheim-Wallstadt LV network (Fig. 2). This network features 3 MV/LV transformer stations supplying 168 connection points with a total of 309 households. It was simulated with a total of 350 kWp photovoltaic (PV) generation. Three different grid topologies resembling network deconstruction scenarios were studied: (1) all MV/LV connections closed, (2) MV/LV connection B opened, (3) MV/LV connection A opened (see Fig. 2). With this setup, 6 subsequent days with high solar irradiation were simulated.

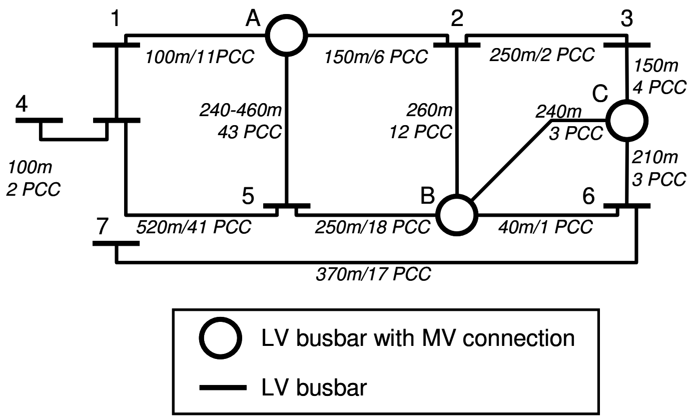

Figure 2: schematics of simulated urban grid area

Simulation system and setup

For simulation of demand response in households within the network, a software system developed by Fraunhofer IWES was used. It is a discrete steady-state simulation with equidistant simulation step-width that models the behavior of BEMI-equipped smart houses in the electric distribution network. An interface to the professional grid calculation software Power Factory from DIgSILENT enables accurate modelling of grid operation effects. The system was used to carry out quasi-stationary load flow calcutations with a simulated stepwidth of 5 minutes. Parameters of the devices, e.g. maximum switch-on and off times, were derived using preliminary results from the SH/SG field trial in Mannheim. PV feed-in was modeled using solar irradiation data measured in Kassel.

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The household EMS simulation was configured using measurements and assumptions. In the chosen scenario, 46% of each household's yearly energy consumption was attributed to controllable white goods [2]. A fictional variable tariff was designed to incentivize automatic switch on of white goods by the EMS during times of high PV feed-in power. This situation was compared to a fixed-price tariff. By pre-simulations, the fictional PV tariff was designed for maximizing LV line loss savings.

Resulting impact on characteristic grid operation parameters

It was observed that the PV tariff influenced grid operation parameters as expected. Introduction of the PV tariff increased locally used PV energy by 3-4% while decreasing energy imports into the network area. LV line losses were substantially lowered. In Fig. 2, line loss power at a single day is compared for flat tariff and PV tariff cases. It can be seen that the loss power is significantly reduced in the PV tariff case at around noon. This effect can be clearly attributed to the EMS switching on white good devices. Total line loss savings of 8-9% were observed. During times of high PV feed in, the PV tariff also caused reduction of grid node voltages by up to 1.8 V, reduction of transformer loadings by up to 8.1% and reduction of line loadings up to 5.5%. However, none of the scenarios and topologies resulted in critical grid situations, as to be expected from the strongly meshed Mannheim network.

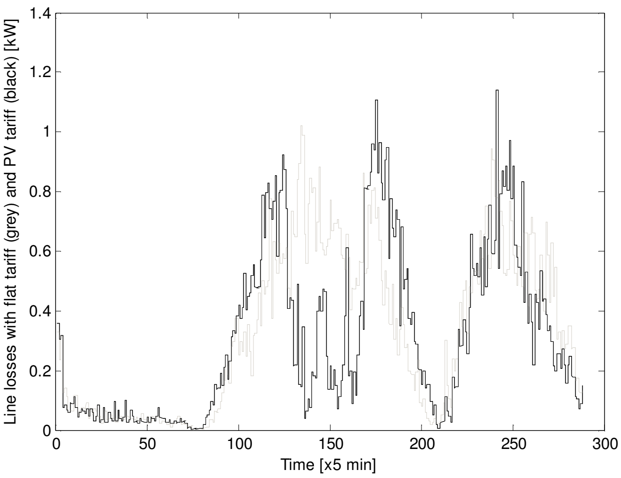

Figure 2: line losses with flat tariff (grey) and PV tariff (black), day 2, topology 2

Conclusions

Variable tariff-based energy management of household white goods was found to influence grid operation parameters according to expectations. Appropriate tariff design was found to be crucial. Benefits were observed to be higher on weaker grid topologies.

From preliminary results of another study carried out by MVV Energie AG in parallel, it was found that critical grid situations within less meshed suburban networks can occur in near future.

Thus, it is concluded that energy management of loads (e.g. EV) and controllable DG (e.g. CHP) is to be considered a valid tool for distribution grid operation support and for reducing needs for network reinforcements, thus being of high importance for future grid operation as well as grid planning. Further studies are currently carried out to refine the results and study scenarios with high amount of controllable DG and loads with automatic energy management.

Acknowledgements

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References

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[3] D. Nestle, J. Ringelstein: "Application of Bidirectional Energy Management Interfaces for Distribution Grid Services", 20th Intl. Conference on Electricity Distribution (CIRED), June 2009, Prague

[4] S. Drenkard e.al.: Case Study for 1 Million End-Users. SH/SG Deliverable 4.1, October 2010

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[2] For SH/SG deliverables, please refer to the project website: http://www.smarthouse-smartgrid.eu