Enhancing cost-efficiency of residential battery systems (RBS) in conjunction with PV, micro-CHP, and balancing power provision

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Overview

Decentralized battery systems for the application in private households have gained a lot of attention. The segment of "residential battery systems" (RBS), with capacities typically between 4 and 15 kWh (Focus, 2013), may grow rapidly over the next few years. In Germany, for example, the federal government has launched a program to incentivize battery installations in conjunction with roof-top PV (photovoltaics) for home owners (KfW, 2013). However, previous research has shown that the combination of RBS with PV alone will not become cost-efficient in the foreseeable future (Graebig et al, 2014). This paper investigates the potential of RBS as the core element of a "multi-purpose residential power management". In addition to the connection with roof-top PV, the RBS could serve two other purposes (proposed by Graebig et al (2014) as a result of previous explorative studies) which have now been considered in a joint model: First, and very similar to the roof-top PV, the RBS could be connected to a micro-CHP (combined heat and power) unit, a residential heating unit with co-generation of electricity. The micro-CHP produces electricity as an inexpensive side-product that can be stored for consumption as and when required. Second, a large number of residential battery systems may be interconnected to a "battery cloud" which then acts like one big battery, ready to sell balancing power to the TSO (transmission system operator).

Methods

In our model-based approach, Germany serves as a reference market. We also provide an outlook for other international markets.

(1) **Advanced RBS/PV model.** Based on the model-based approach presented by Graebig et al (2014), we refined the RBS/PV model substantially. We critically evaluated the time intervals for load and generation profiles (15-minute intervals vs. 1-minute intervals). Instead of standard load profiles (SLP), we used a range of high-resolution load and generation profiles which were measured and/or synthetically generated based on weather data.

(2) **RBS/micro-CHP model.** The model simulates the operation of a micro-CHP in conjunction with an RBS and has been implemented into a joint model together with the RBS/PV model. To a large extent, micro-CHP (peak loads during winter time) can complement PV systems (peak generation during summer time), hence optimizing the RBS usage.

(3) **RBS/balancing power model.** We have considered the application of RBS as part of a "battery cloud" (one kind of virtual power plant) which provides primary balancing power. To a certain extent, this application is in direct competition with the other applications (reserving battery capacity for balancing power reduces the available capacity for PV and micro-CHP).

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Results

From a methodological point of view, load and generation profiles with 15-minute intervals are sufficiently precise for our model. Results for the system performance depend significantly on the applied load and generation profiles and assumptions for the RBS performance.

In the optimistic reference scenario, each of the three pillars of the RBS application – roof-top PV, micro-CHP, and balancing power in the “battery cloud” – may contribute similar average pay-back rates in the order of EUR 100 to 200 per year.

PV and micro-CHP are well suited for the complementary use of the RBS and will enhance the system’s cost-efficiency – PV generation peaks in summer time, micro-CHP in winter time. Assuming ambitious RBS lifespans of 20 years and current RBS purchasing prices around EUR 10,000 for 4 kWheff systems, RBS are still unlikely to break even. Besides the actual monetary pay-back, customers need to value nonmonetary value propositions, such as self-sufficiency and security of supply (Graebig et al, 2014), for the RBS to become a sensible investment.

The provision of balancing power, while promising in theory, still faces serious practical challenges and hence does not appear to be a viable business model in the foreseeable future. Most fundamentally, it turns out that a synergetic integration of “balancing power” with the other RBS applications, PV and micro-CHP, is hardly feasible unless centrally managed in a sophisticated “virtual power plant” system.

Conclusions

Combining PV and micro-CHP with one RBS appears to be feasible and economically promising – even though at current prices, RBS will probably not break even without further subsidies and incentives. In theory, the provision of balancing power in a “battery cloud” could be an additional business model for RBS. However, the “balancing power” model does not appear promising in the foreseeable future since it faces fundamental practical challenges and it is hard to integrate synergetically with PV and micro-CHP.

Further research should focus on the assessment of real-world RBS installations. Since RBS are starting to spread out across the country, measured time series will likely become available soon. Also, an international taxonomy of RBS applications in different climates and different energy system contexts should be developed.

References

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