THE MULTIPLE ROLES OF A BATTERY ENERGY STORAGE SYSTEM - RESULTS OF A PILOT PROJECT

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ABSTRACT

ewz, the electrical utility of the city of Zurich, investigates possible applications of battery storage units. A large battery energy storage system was installed and tested in the low voltage grid of the city. Self-consumption maximization and participation in the primary control market in Switzerland were the two main operations that were investigated. The results of these tests have shown that the two operations can be combined and that they represent complementary applications to improve the business case for the owner of the battery.

INTRODUCTION

The future developments in the energy sector pose multiple challenges and chances for the utilities but also for the consumers/prosumers. Decentralized generation in combination with continuously increasing digitalization opens new possibilities for microgrids. Prosumers aim to maximize their self-consumption on a local level and to achieve that, they often opt for battery energy storage systems (BESS) of the suitable size. Self-consumption optimization by itself cannot however finance these in most of the cases. That is the reason why an optimal combination of applications is necessary. Such applications can be:

- Maximization of yearly self-consumption
- Peak shaving
- Participation in the ancillary services market
- Grid-friendly operation (under the respective compensation scheme)
- Commercialization of the produced energy with optimal timing

The battery can also have further functionalities which cannot be directly monetized such as the usage as emergency power supply, or as corrector of voltage problems behind the meter.

APPLICATIONS

ewz has installed a Li-Ion battery in a residential area in the suburbs of the city as part of a pilot project [1]. It is a building integrated battery energy storage system at a housing complex with a photovoltaic installation on the roof. The BESS is situated in the underground car park of the building. An area of 30 m^2 is used for the installation of the system with 120 kW and 720 kWh installed power and energy respectively. The BESS plays a different role in the test grid depending on the situation. The grid-friendly operation of the battery was tested first, within the scope of the GridBox pilot project [2]. During the day, if the PV production was higher than the consumption of the building, the surplus production was stored in the BESS. In the evening, when the consumption was higher, the long feeder often caused high voltage deviations. These were considerably reduced using the BESS, which injected energy to the grid during this time to keep the voltage in the allowed band of ±10 % of the nominal voltage. The results of the tests showed that a BESS can represent a meaningful alternative to traditional grid reinforcement, if the increase in fluctuating renewable generation results in voltage problems or overloading of transformers or lines. A combination of this grid-oriented usage with the applications discussed in this paper could make a BESS economically viable.

Self-consumption maximization

Self-consumption describes the process of using all or a share of the produced solar power to supply the own demand, rather than feeding it into the grid. This is desirable if the feed-in tariff for photovoltaic and the costs of production are lower than the cost of energy from the grid. The optimization of self-consumption is one of the applications investigated within this study.
The simplest, but least flexible case is the direct consumption of produced PV energy. By adding energy storage, excess energy that cannot be used directly, can be stored. In periods of low solar energy production, this can be used to supply (parts of) the own demand. Consequently, the share of self-consumption and the degree of self-sufficiency can be increased, depending on the installed solar power and energy storage capacity. The following figure illustrates this concept

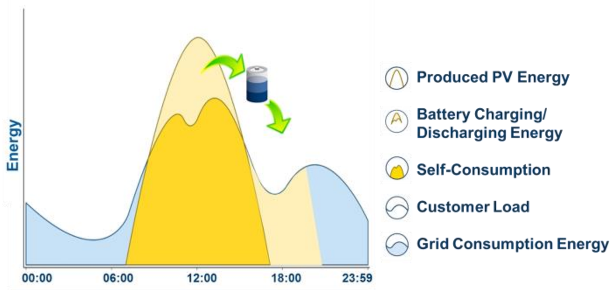

Figure 1: Concept of self-consumption optimization of produced PV energy, using a battery for temporary storage

The share of self-consumption (s) describes, how much of the total produced PV energy E_{PV} is used by the producer itself (directly used (E_{DU}) or stored in a battery

(E_{BC})) compared to the total amount of produced PV energy. It can be described by the following formula [3]:

$$s = \frac{E_{DU} + E_{BC}}{E_{PV}}$$

The degree of self-sufficiency (d) is a measure of independence from the grid. It is defined as the percentage of the total energy demand E_L, which is covered by self-produced PV energy and can be determined by using the following formula [3]. E_{BD} is the energy that is discharged from the battery:

$$d = \frac{E_{DU} + E_{BD}}{E_L}$$

Since April 2017, the battery serves the self-consumption maximization of a neighbouring housing complex in combination with the ewz solar allocation service, achieving a self-consumption share of almost 100 %.

The ewz solar allocation system is a billing system using smart metering technology. It enables the owner of a PV system to directly sell the produced energy to the tenants of the respective building. Consequently, the tenants can cover (parts of) their demand with energy sourced directly at their location. The following figure illustrates this system.

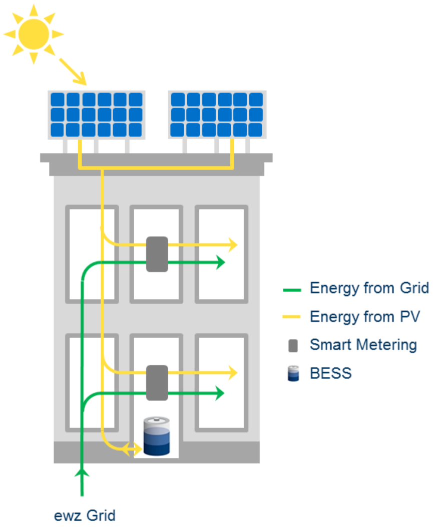

Figure 2: ewz solar allocation service with smart metering technology and a BESS

The building complex, where the BESS is, has photovoltaic installations in all buildings but only a part of them can be used for self-consumption. The rest is bound in long-term contracts for selling the produced energy to the grid. At the same time, the consumption of the 280 apartments of the complex is much higher than the produced energy. These characteristics explain the high self-consumption share as that can be seen in Figure 3.

For the same reasons, the self-sufficiency share is significantly lower, mainly in the winter months with low photovoltaic generation and high energy consumption due to heating.

Consequently, during these months the self-consumption share is higher than during summer time. The increased PV production between January and March due to better weather conditions is mirrored in a slight increase in the degree of self-sufficiency.

In May and October the battery was out of operation due to maintenance work for some days explaining the drops in the curve.

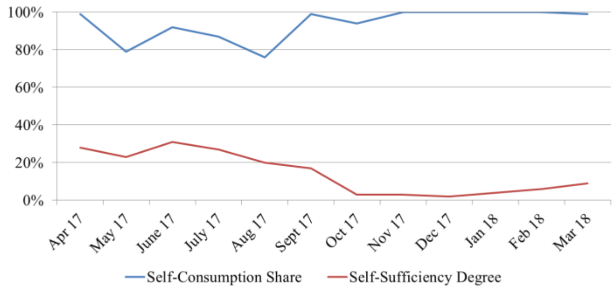

Figure 3: Share of self-consumption and degree of self-sufficiency of the housing complex using the BESS

The effect of the reduced sunshine, and consequently the reduced photovoltaic production in the winter months is obvious in the above figure.

To illustrate the behavior of the system, the data of a sunny summer day is illustrated in Figure 4. All displayed values are energy values of 1-minute intervals.

For the time before sunrise, the load of the consumers is covered by energy from the grid. In the time between about 6 am and 9 am, the solar energy produced is still smaller than the load; hence, additional energy is taken from the grid. During noon and in the afternoon, the consumers are supplied 100% by self-produced energy. Excess energy is fed into the battery storage until this is fully charged or the charging power of the battery is exceeded and the rest is fed into the grid. In the late afternoon, solar generation becomes smaller and load increases. From this time on, the gap between produced energy and consumption is filled with energy from the storage system. Missing energy can be imported from the grid. In the late evening, the energy available for self-consumption has been used completely and the system transits to full grid reliance. Mainly depending on the weather (solar energy production), multiple changes between the presented phases are possible during one day.
The illustration shows that the BESS is working in the mode presented in Figure 1.

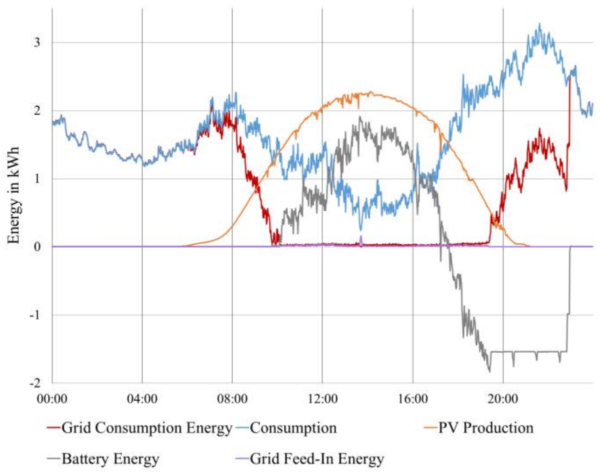

Figure 4: Self-consumption optimization using a BESS on a sunny summer day

Participation in the primary control market

The specific battery is rather over-dimensioned for the photovoltaic unit and the consumption of the complex. That left ewz the potential to also participate in the primary control market in Switzerland since December 2017. In contrast to the previous case, this will cause a direct interaction between the battery storage system and the grid.

To combine both services, the battery has been split virtually into two parts, one for the maximization of the share of self-consumption and the other for participation in the primary control market.
The battery is in a pool with other energy sources to cope with the minimum power requirement of 1 MW for the primary control market. For this service, 70 kWh of energy and 70 kW of power are reserved for positive and negative primary control.

Figure 5 shows a sunny winter day as an example to illustrate, how the two services work in parallel without influencing each other. In general, the development of the individual curves is very similar to the previously presented example of a sunny summer day (cf. Figure 4). Again, all presented values are energy produced in 1-minute intervals. The increased fluctuation in PV production that can be observed during noon is most likely caused by clouds that block direct sunlight.
Compared to the self-consumption related data, the energy used for primary control is rather small. Before sunrise, no energy is available for self-consumption in the battery. At the same time, the primary control unit is active, providing positive and negative control energy to the grid. During the day, both systems work in parallel to each other. After PV production sinks below load, the excess energy from PV production during noon that was stored in the self-consumption part of the battery is now consumed. Shortly after 4pm, the available energy from this part drops to zero and the load is fully supplied from the grid again. Still, the battery energy storage system is able to fulfill its duty delivering primary control energy, as can be seen from the respective parts of the Figure 5.

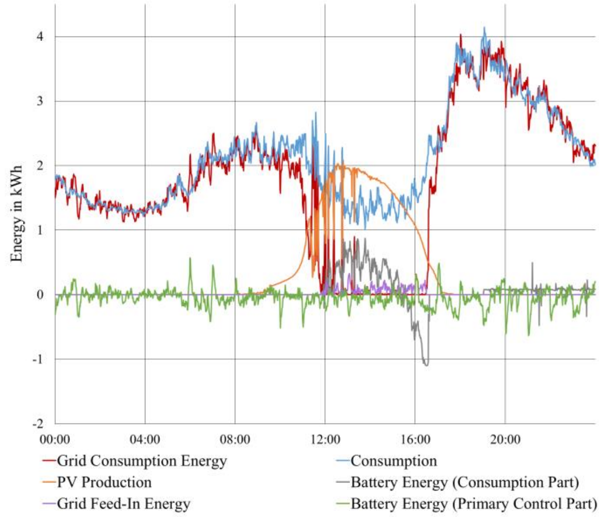

Figure 5: Combination of self-consumption optimization and primary control power on a sunny winter day

Economic analysis

For the tested configuration, the economic benefits for the BESS owner are almost 60% from the extra self-consumption with the ewz allocation system thanks to the battery and 40% from the participation in the primary control market. The yearly earnings are not high enough to have Return on Investment (ROI) during the life span of the battery; however, it shows the considerable potential of combining multiple services with one BESS. Further applications could contribute to that.

Further applications

Since there is no load tariff for small private customers in Zurich and the possibility for direct commercialization is restricted to big customers with yearly consumption over 100 MWh, testing the other two applications with the specific battery would not make sense. The impact of regulation is significant, influencing the viability of the business model.

Inputs from larger customers with load tariff indicate that reduction of energy costs by means of peak-shaving, an increase of self-consumption as well as an uninterrupted power supply are the most interesting applications. If a combination of these services can be realized, it could have a beneficial impact on the economic feasibility of battery energy storage systems. These have to be tailored to the individual customer requirements.

CONCLUSION

With the creation of microgrids, batteries gain importance. They are not used for the technical and economical optimization of a single customer anymore, but for whole neighbourhoods.

Within this project, it has been shown that the investigated battery energy storage system is able to increase self-consumption and provide primary control power at the same time. To achieve this, the battery has been virtually split into two parts, each serving one of the two applications.

In the presented case, self-consumption reached up to 100 % due to the large size of the battery.

To achieve complete self-sufficiency in a micro grid, a very large and expensive battery is necessary, which does not present a viable business model. Participating in the primary control market can create additional income. Still, at least in the investigated case, this is not sufficient to compensate for the large investment costs of the system.

For future micro grids, smaller battery energy storage systems appear to be a promising solution to reduce investment costs. If designed correctly, those can still lead to a high degree of independence from the grid, optimize energy consumption and at the same time support the local grid. Additionally, the integration of further services, like peak-shaving or uninterrupted power supply have the potential to make such a system profitable.

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