APPLICATION OF ENERGY STORAGE SYSTEMS MINIMIZING EFFECTS OF FLUCTUATING FEED-IN OF PHOTOVOLTAIC SYSTEMS

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ABSTRACT

This paper presents a possible system approach to integrate storage system into the electrical grid. The simulation tool which has been developed bases on a real storage system that has been established at the Institute of High-Voltage Technology and Electrical Power System (HTEE). Besides the technical boundary conditions economic aspects are another important topic of this survey.

INTRODUCTION

Renewable power generation is important to reduce the dependencies on fossil fuels. In some decades we will run out of oil and gas; coal will be in use for some centuries. In the long run energy utilities need alternative or renewable fuels to have the continuing ability to provide their products.
But wind energy and photovoltaic do not behave like conventional power plants. Wind and sun are not that available that fossil fuels are. Thus, renewables are not able to produce electricity demand-driven. Electricity which is generated in power plants that are aided by the “Act on Granting Priority to Renewable Energy Sources” has to be integrated in the grid with the highest priority. Simultaneously the system operator has to balance the stochastic fluctuations of these generators with reserve power plants.
Up to now there had been no significant net failures driven by these stochastic fluctuations. Nevertheless the growing number of wind and solar power plants in Germany and Europe forces net operators to invent and implement new solutions for this problem. Apart of investments in the extension of grid and power capacity as well as selective shutdown of wind parks the integration of electricity storage systems is a more innovative idea.
In a first step the dimension of the storage system has been analysed to make sure that it is able to balance the differences between energy demand of a single household and solar energy production. Afterwards a control algorithm has to be developed to affect the system’s behaviour in a grid oriented way.

POSSIBLE SOLUTIONS

To minimize the identified problems in the grid, there are different strategies followed in Germany.

Net safety management

In northeast Germany the highest feed-in of wind energy plants is higher than the maximum electricity demand. In situations of high wind power generation and low consumption in this region, electricity has to be shifted from the high-voltage system (110 kV) to the transmission network (400 kV) to be transported to another region. To avoid bottlenecks in both the high-voltage system and the transformer stations (110 kV – 400 kV), a so called net safety management (Netzsicherheitsmanagement – NSM) has been established. TSOs are allowed to reduce the renewable feed-in if required by the situation in the grid. Even if there is more renewable energy generation possible, the power can be reduced to a share of 70 %, 40 % or even 0 %. [1]

Variations in the grid

Strengthening and expansion of the grid could also solve the problem of bottlenecks. This is certainly the easiest way to guarantee the priority of renewable energy sources. Bottlenecks could be avoided and the whole amount of renewable energy could be used. But this solution leads to higher provisions of system usage on the one hand and can be put in practice in circa ten years because of the authorisation procedure on the other. This is too long to react on the fast developing renewable energy sector. [2]

Energy storage system

Nowadays there is no financial benefit for wind and solar power plant operators to install a storage system for electricity. But a system that stores the (positive or negative) peaks of electrical power generation or the difference between forecasted and real value could also minimize the negative effects of stochastic fluctuations to the grid. A study case carried out at the HTEE regarding this problem has shown that a 4 €ct/kWh additional duty for a wind energy storage system can allow an economic operation. This would directly lead to higher electricity tariffs. But if negative effects of wind and solar energy or other stochastic fluctuating power generation could be minimized, the provision of system usage might decrease and an increase of EEG-duty might be accepted by public. This last approach has been implemented at the HTEE to quantify the effect on the grid using storage devices in combination with an energy management system.

ENERGY MANAGEMENT SYSTEM

This energy management system will help reducing the fluctuation in low voltage networks in two ways. Due to the installation of PV systems on rooftops of residential buildings the fluctuating feeding can be managed in cooperation with the fluctuating demand of the household. Therewith the resulting fluctuations at the point of common coupling can be reduced.

To illustrate the effectiveness a simulation of the energy management with an energy storage system for a 0.8 kW PV system has been developed. The analysis shows that the maximum load of the point of common coupling can be reduced significantly. Furthermore the fluctuation can be minimized so that the demand can be smoothed. This effect is shown in Figure 1. It shows a 3-day-period of solar power generation (blue curve), household energy demand (red curve) and the resulting energy demand that affects the utility company (yellow curve).

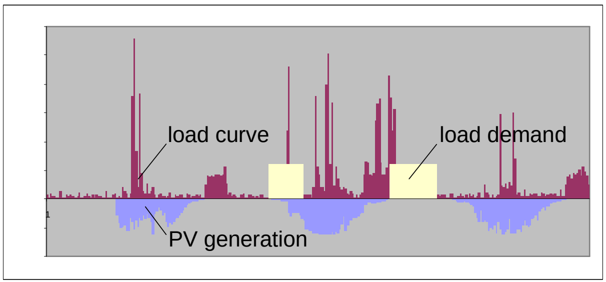

Fig. 1: Application of a plant storage system (PS) to a PV unit

Up to now the installation of storage plants to smooth the feeding is uneconomic. The main reason is based on the Act of Granting Priority of Renewable Energy Sources (EEG). This law assures operator of renewable energy generator fixed feed-in tariffs for energy supply into the power grid. The feed-in does not have to fit the current electrical demand. If the EEG would guarantee just a fixed feed-in tariff for generation which are applied a day before, renewable energy generators with energy storage systems may be established. Also feed-in tariffs which depend on the feeding-profile may lead to a market penetration of storage systems installed at distributed generators.

Experiment and simulation design

Figure 2 shows the developed design for the experiment of a grid oriented storage system. The loads are supplied with an AC-Bus which is separated to the grid: Any time when energy is needed, energy has to be converted from DC into AC and back. That is a disadvantage of the investigated system approach, but the technical feasibility is fundamentally given. In future optimizations of that system one should take this disadvantage into consideration to raise the system efficiency at all. To raise the functionality a simulation tool has been designed. It is a computer-based

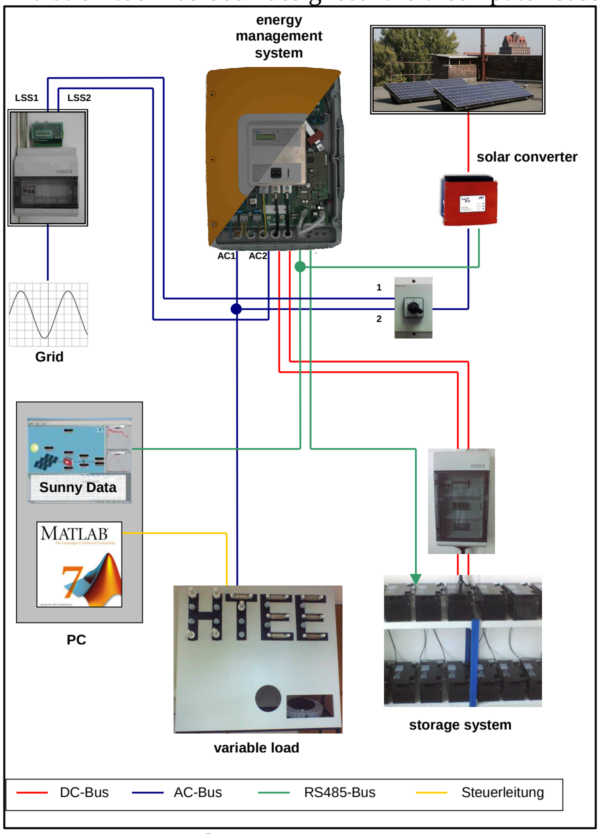

Fig. 2: Experimental energy storage system

and uses MatLab SimuLink for the visualisation of the systems behaviour. It is possible to try another set of input data without changing the hardware experiments design.

It is important to validate the simulation tools results before making any statements regarding system modifications. The result of the validation is shown in Figure 3 exemplarily. A three day testing period was used to adjust the simulations behaviour to the measured data. The interesting parameter of the storage system is the state of charge (SOC). With

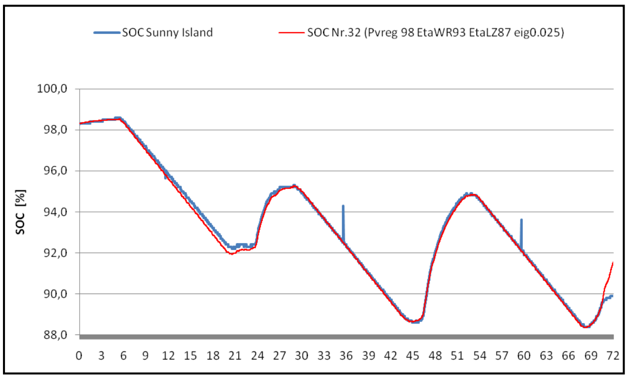

Fig. 3: Validation of simulation approach

modifications of the system efficiency and the energy demand of the storage system itself the simulation tool presents nearly the same results that have been measured in the experiment. This allows conclusions regarding to calculated storage systems that vary from the basis scenario. The simulation can only lead to feasible results for lead-acid battery systems.

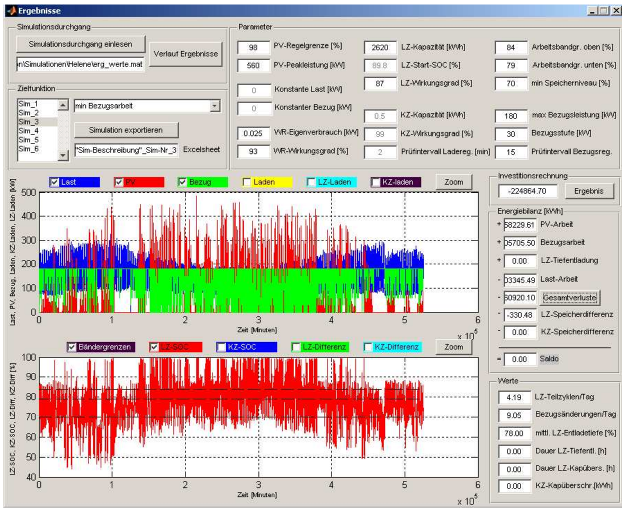

Fig. 4: Result screen of simulation tool

Figure 4 shows the result screen of the simulation tool. A long term scenario of a plant storage system for a low-voltage network district has been established to find out how the load flow can be affected. The original energy demand (blue) and the fluctuating power production of solar power plants (upper red) can be smoothened by using a storage system in a grid oriented way. The maximum load can be limited and variations in the value of the energy demand can be minimized.

But there are still some challenges to work on. The long term efficiency of this system approach is only about 67.5 %; the grid district will need one third of its energy demand supplying the storage system and someone has to pay for the additional energy. Future system approaches should be able to minimize the own consumption.

Another challenge is to minimize the number of cycles the storage system has to provide. A new calculation of life time should be established the take the number of cycles and the amount of energy stored during a cycle into account.

OUTLOOK AND SUMMERY

In the changing system of power production more storage systems will be needed in the future. The more renewable energy power plants with fluctuating supply of solar radiation or wind are connected with the grid, the more additional conventional power plants or storage systems are needed to guarantee a balancing of demand and supply of electricity every time.

It has been shown in this paper, that it is possible to build a storage system that helps to keep the negative influences of fluctuating power production away from the grid. The system efficiency could be figured out to only 67.5 %. Thus the energy demand of a household will grow by over a third to cover the system losses. This is not acceptable for a use in a wide-spread market that tries to raise efficiency and sustainability. A system modification has to be investigated that leads to variations in the chosen hardware, too. For example a different converter topology could permit a higher efficiency and lower costs.

A simulation tool helps to design the storage system for user-defined parameters of the individual case. One important result of this tool is the economy of the storage device.

Finally it can be pointed out, that it is more a question of economics, system operation and responsibility than of technical development when the next big storage devices will be installed.

LITERATURE

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