# Options for an autarkic operation of a communal power grid using a battery and renewable energies

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*Abstract* —With a growing share of renewable energy, the structure of the electrical power grid structure should reflect their distributed nature. A cellular grid structure would meet this demand. In case of global blackout each cell would even be able to operate autarkic. Then, still a minimum level of supply would be possible. An innovative community in the north of Germany aims to pursue such a concept. The local energy provider, Versorgungsbetriebe Bordesholm, is planning to install a large battery (12 MWh / +/-8 MW) to provide control power during daily operation. In case of a global blackout it should supply the community in combination with available energy sources. However, the supply consisting of two biogas generators with 800 kW each and several photovoltaic systems are not sufficient for an infinite autarkic supply. Therefore, this publication investigates the possible operation time for such an autarkic operation. Typical self-supply times for this community range from 3 to 20 hours.

## 1 Introduction

With a growing share of renewable energy, the structure of the electrical power grid structure should reflect their distributed nature. The approach of a cellular grid divides the grid in cells, which can operate autarkic [1]. The basic principle is to balance supply and demand deviations on the lowest grid level as possible. In case of global blackout certain cells would be able to operate autarkic. By synchronizing these cells the transmission grid structure can be recovered quickly. Commonly, distributed generators are shut down to prevent uncoordinated islanding grids. However, distributed system operators (DSO) are able to coordinate isolated micro grids.

There are already various initiatives to apply and analyse the capability and applicability of isolated emergency operations of grid-tied micro grids. The Bavarian communities Wilpoldried and Niederschönenfeld want to apply this system. Wilpoldsried has a supply surplus by up to 500% of its load. The power is supplied by 6 MWp photovoltaic, 1 MW biogas, and 12 MW wind power. Within the project IREN2, the communal micro grid wants to apply switching to an isolated and grid tied operation without interruption [2].

The power supply in Niederschönenfeld includes a big hydro power plant. Primarily, in project LINDA an isolated emergency operation will installed including blackstart with this leading power plant. Within the communal micro grid supply is supported by biogas and photovoltaic power plants. By means of field tests with a load bank or consumers the impact and control of load steps is analyzed [3].

The initiative Micro grid Brooklyn investigates the emergency operation of Brooklyn, New York. Primarily, critical infrastructure will be supplied, followed by the supply of residential buildings. An isolated operation is provided by photovoltaic systems and batteries and load management. Combined heat and power plants can blackstart the micro grid. In daily grid tied operation power within the grid is traded by block-chain method [4].

As one of various local pioneers within the integrated European network, the communal power grid operator Versorgungsbetriebe Bordesholm wants to enable an isolated emergency operation. A big battery storage will supply the town without interruption as supervisory control [5]. First switching and isolated operation tests will be done in summer of 2019.

However, Bordesholm is not in excess equipped with decentralized generators. It turned out that it cannot supply itself for unlimited time without restrictions. In this paper it is analysed, how long a self-sufficient islanding operation would be possible. For this purpose, feed-in profiles of the available generators and load profiles of the existing loads are compared taking the battery storage into account. With these data it is calculated for each hour of the year, how long an autarkic operation would be possible, if an islanding event would occur at that point of time. Details about the used algorithms can be found in [6].

Finally, it is analysed, how an existing biogas plant would have to be extended to allow an unlimited autarkic operation.

## 2 Communal power grid

The communal power grid consist of three medium voltage branches, which can be looped together (see Figure 1). Each square represents a low voltage transformer station. The current demand and supply structure is shown in Figure 2. Two biogas generators with 800 kW each (at Positions 1.1 and 1.2) provide the main power generation. Additionally, several distributed photovoltaic (PV) systems support generation within the power grid. Their installed power can be derived from Figure 2. The loads mainly consist of households with some distributed business consumer. The load is rather equally distributed and there are no single power consumers dominating the demand. Even the street lighting has no significant contribution, because it was converted to LED recently.

Figure 2 shows the max. current demand of consumers and the installed power of generators in every branch and substation. The demand data is obtained from drag pointer measurements in the low voltage transformer stations and therefore indicates the worst load case. The total demand of the communal grid is about 10 kA respectively 7 MW, the total supply is about 3.5 MW.

The following time dependent simulations are based on measured profiles for the year 2015. The biogas power plants operate nearly constantly with smaller changes of the power level for longer periods. Profiles of nine of the larger PV systems are measured. The profiles of the further smaller PV systems are derived from one of these profiles by scaling it to their installed power. Furthermore, load profiles of 47 large consumers are measured. These are besides others: street lighting, water supply, waste water treatment station, town hall, offices, hotels, schools. It turned out that the peaks of the load profiles relate reasonably to the peak power values shown in Figure 2.

In addition, the total residual power flow at the transmission grid connection point is measured (see Figure 3). In most of the times the residual load is positive, which means that the consumption exceeds the available generation with renewable energy sources. Therefore, the autarkic operation time can be assumed as limited for the whole period.

By subtracting the feed-in profiles and the known load profiles from the residual load the resulting power profile can be attributed to the households in the community.

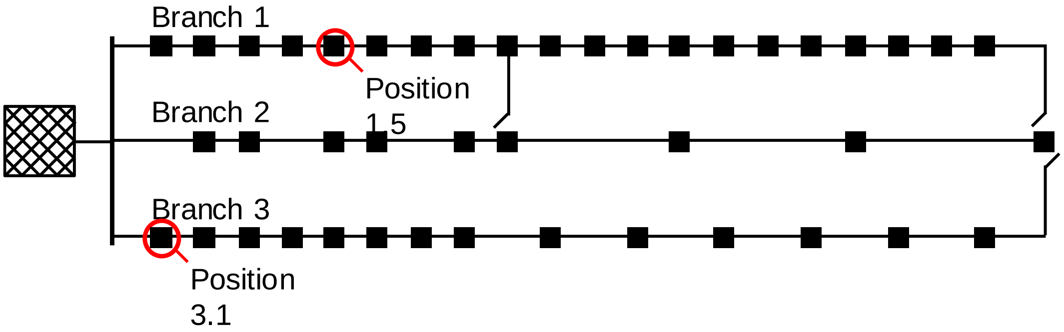

*Figure 1: Topology of the medium voltage part of the investigated power grid.*

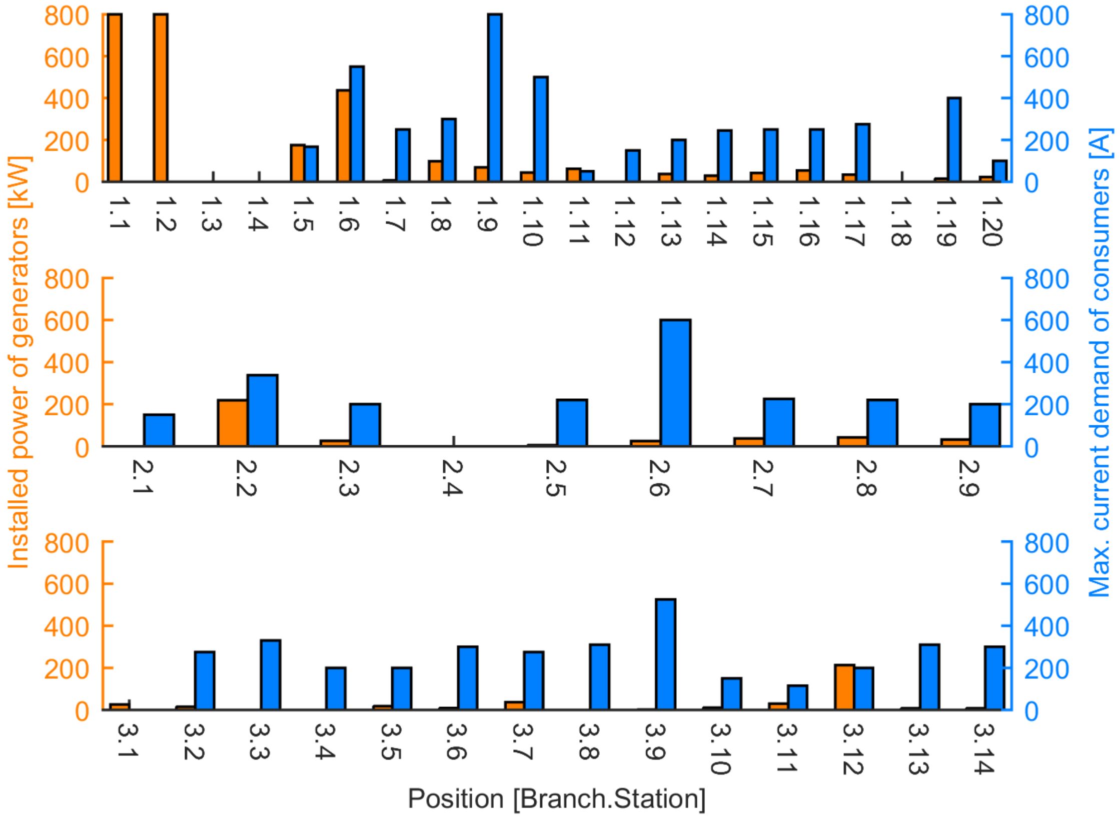

*Figure 2: Maximum power feed in and demand at the nodes in the three branches of the medium voltage part of the investigated power grid.*

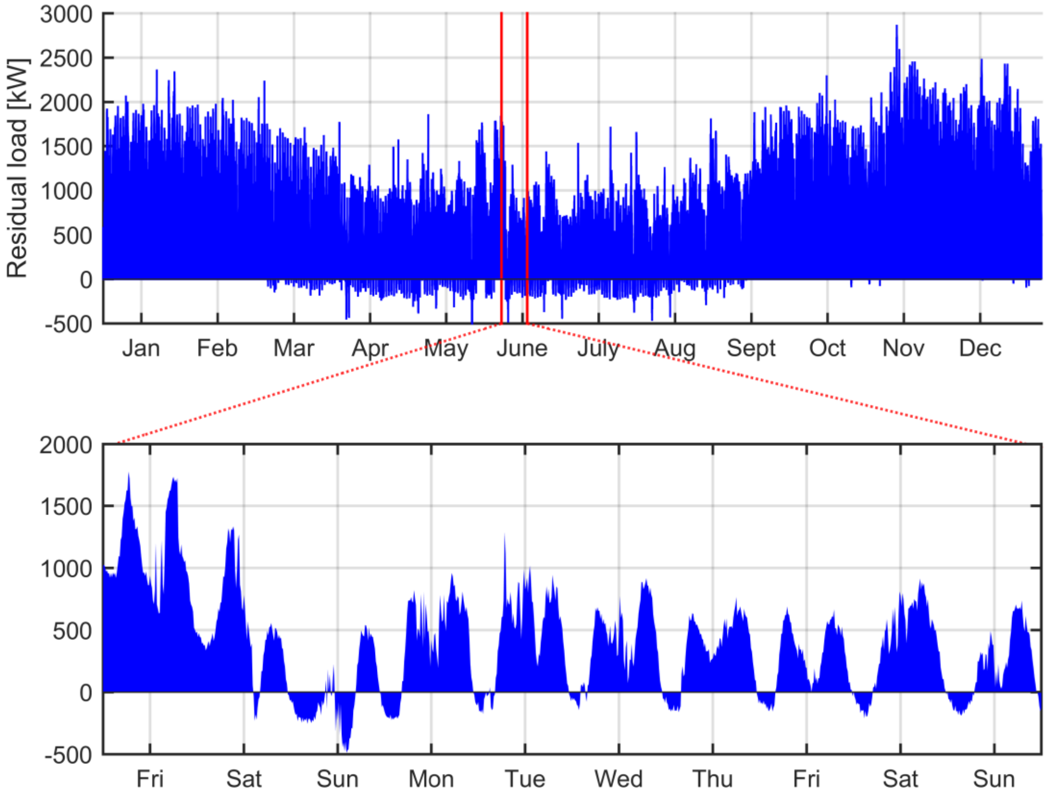

*Figure 3: Residual load measured at the point of common coupling.*

## 3 Self-sufficiency time

The self-sufficiency time is discussed with three storage scenarios:

1. No battery: self-sufficient operation by means of negative residual loads (supply surpluses)
2. 5 MW/ 5 MWh: initial plan of the communal grid operator
3. 8 MW/ 12 MWh: current intended construction plan.

For scenario 1 only times with negative residual load (feed-in excess) are considered. If the residual load becomes positive the self sufficient time is reached.

For scenarios 2 and 3 the battery is taken into account. During normal grid tied operation the battery is intended to provide primary reserve power. Therefore, an average state of charge (SoC) of 50% is assumed as the initial SOC for the calculation of the self sufficient time. During islanding operation, the battery takes over any residual load or excess power. If a maximum SoC of 90% is reached, it is assumed that feed-in sources are cut, but operation continues. If the SoC is below 10% the system is assumed to shut down and the self sufficient time is reached. In this publication no controllable loads are considered.

This way, for every point of time it was calculated, how long the community could supply itself. The results are shown in Figure 4 as time dependence and in Figure 5 as a sorted distribution.

As the time dependence of the self-sufficient time shows (Figure 4) it is difficult to predict, when a long self-sufficient time is possible. In general, the probability for long times increases in summer due to the larger contribution of PV systems.

A more general statement can be made from the sorted distribution in Figure 5: Without a battery, only during a small time of maximum 20 days per year, an autarkic operation is possible anyhow (see grey part in Figure 5). Therefore, for this community a battery is a precondition for any autarkic operation throughout the year.

Typical self-supply times range from 3 h to 20 h for the larger 12 MWh battery. On a few times in the year (in total less than 15 days) the self-sufficient time is longer than 20 h. These are e.g. sunny days with low load, as exemplarily shown in in the lower part of Figure 4.

As could be assumed a larger battery results in longer self-sufficient times. The battery capacity is relevant for this result, because for both batteries the maximum battery power was not needed at any time. The self-sufficient time seems more or less to scale linearly with the battery capacity. However, in detail it does not simply relate to a larger energy provision. In some cases, the larger energy provision can prevent falling into blackout by bridging times to a state, where again generation is available. Such an event happens early on Sat in Figure 4. At that time, the smaller battery (red) is not able to provide enough energy, while the larger battery (blue) can bride the supply until further energy sources are available.

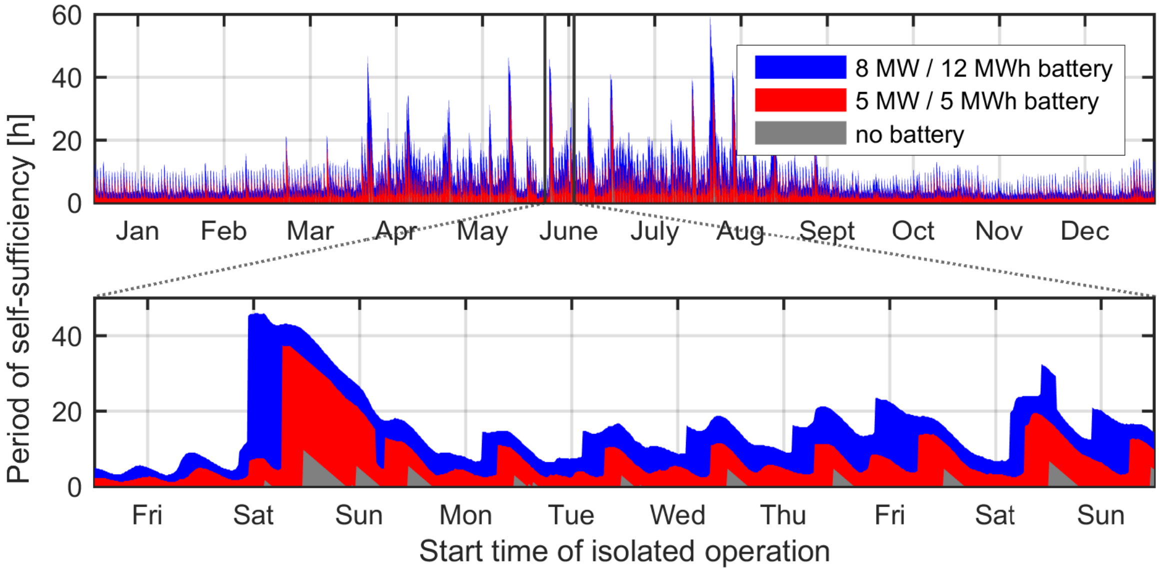

*Figure 4: Calculated period of self-sufficiency for every possible point of time in a year (2015).*

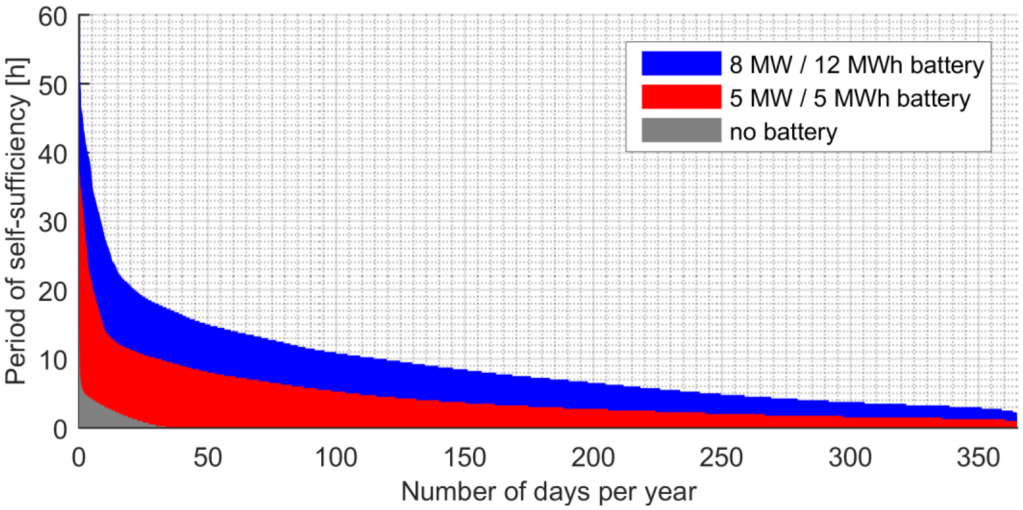

*Figure 5: Annual sorted period of self-sufficiency which can be attained (2015)*

To provide Bordesholm completely autarkic, the missing residual load needs to be covered by decentralized generation. This adds up to an energy of 21 GWh. To achieve this amount of energy, it would be an option to increase the biogas generator to a power of 2.4 MW including the related increased generation of biogas. If it operates constantly throughout the year, it could cover the missing energy. Simulations show that then the remaining residual load can be covered by the battery. Concluding a full autarkic operation can be achieved with an upgrade of the biogas generator to 2.4 MW including related biogas energy provision.

## 4 Conclusion

In most of the times the consumption exceeds the available generation with renewable energy sources, such that the autarkic operation time is limited in the investigated community Bordesholm. Without any battery, only on less than 20 days per year autarkic operation is possible for s short time.

Typical self-supply times range from 3 h to 20 h for the planned 12 MWh battery. On a few times in the year (in total less than 15 days) the self-sufficient time is longer than 20 h.

To provide Bordesholm completely autarkic, it would be an option to increase the biogas generator to a power of 2.4 MW including the related increased generation of biogas.

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