PROVIDING A CUSTOMER MICROGRID AS A SERVICE – A REVIEW OF A PILOT INSTALLATION

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ABSTRACT

This paper describes some of the insights gained from a customer microgrid demonstration project located in the municipality of Askersund in Sweden. With this project it is intended to understand and create a better overall economy for investments in renewable micro-generation of electricity, and EV-charging through the use of battery storage and intelligent control systems.

From a business model point of view, we find that for this type of customer (large commercial or institutional buildings), an energy storage brings the highest value as a peak shaving unit (peak shaving becoming more valuable in the coming years with the growth of electric vehicle numbers in Sweden). However, one has to note that each market has its specificity and that generic control algorithms proposed as of today will not provide optimal results, especially for customers tending to be of in-between size (higher consumption than a single home, but smaller than of an industry).

From an installation point of view, it is worth observing that each customer installation is unique and that a standardized solution that fits everyone needs is probably not achievable. Instead, one should focus on developing a method to handle the specificity of each customer, by for example developing modular solutions or working with a broad range of products and suppliers that are compatible with one another. Finally, regulatory and safety aspects, mostly related to the battery, are hard to grasp since they are not yet well defined in Sweden.

INTRODUCTION

Askersund, a small city of 4000 inhabitants and municipality of about 12,000 inhabitants, has a strong sustainable strategy in mind. Their new municipal cultural centre is designed to be the flagship for their sustainable thinking and a place where school, culture and renewable technology meet. This is why they want this building to produce its own renewable energy while at the same time provide its visitors with electrical vehicle (EV) charging possibility. A customer microgrid can offer such opportunities.

Designing a microgrid requires expertise within the energy sector that the municipality lacks. Indeed, in order to maximize both economic and environmental benefits, the battery storage and the photovoltaic solution have to be dimensioned, designed, procured, installed and maintained adequately. Furthermore, photovoltaics (PV) and electrical vehicles (EV) chargers can cause new power quality problems onto the local grid, which if not taken into consideration from the beginning might have economic repercussions (through e.g. grid tariff) for the customer. Finally, regulatory and safety aspects, mostly related to the battery, are hard to grasp since they are not yet well defined in Sweden.

PARTNERSHIP AND BUSINESS MODEL FOR PILOT

The pilot installation is part of a demonstration project intending to understand and create a better overall economy for investments in renewable micro-generation of electricity and EV-charging through the use of battery storage and intelligent control systems, specifically for larger premises such as public or commercial buildings.
This two years demonstration project is a collaboration between Sustainable Innovation, Vattenfall and the municipality of Askersund. The goals of the pilot projects are to assess the current market conditions in terms of price of supplies, technical capacities of control systems as well as knowledge and readiness of sub-contractors in order to understand how to best propose microgrid solutions to this type of customer.

Parties involved in the project
Parties involved in this demonstration and research project are as follows:

- Vattenfall, is one of Europe's major retailers of electricity and heat and one of the largest producers of electricity and heat. In this demonstration project, Vattenfall provides field expertise for procuring and designing the microgrid as a service solution.
- Sustainable Innovation, is a non-profit organisation owned by the Association for Energy Efficiency. Sustainable Innovation leads this demonstration project.
- Askersund Municipality, is a municipality of about 11,000 inhabitants in Örebro County in central Sweden. The municipal building of Askersund is the location and the customer of the microgrid as a service solution.

This demonstration project is also co-financed by the Swedish Energy Agency.

Business model – Customer microgrid as a service
The microgrid solution is proposed to the customer as a long term service contract. Besides the provision and installation of the necessary equipment for a well-

functioning microgrid, the contract also consists of support and maintenance, which means a total care free and always fully efficient installation for the customer. Through a partnership with Vattenfall, the municipality of Askersund gets access to Vattenfall's field expertise that it otherwise lacks. The microgrid is first dimensioned through simulations, aiming at maximizing the customer's revenue (using both current and potential tariffs in Sweden) and minimizing environmental impacts. More importantly, by getting the solution as a service instead of buying it, the municipality is able speed up its sustainable strategy while at the same time reduce the investment risks. For Vattenfall, this kind of long term relationships means new business opportunities, especially worth exploring through a pilot installation.

Customer engagement

The municipality of Askersund has been helping Vattenfall with development projects since 2011 where new technologies to use the city's streetlight network for EV chargers were studied [1]. It is very important for technological research projects to have engaged and interested customers such as Askersund. Whenever possible, the municipality is involved so that not only the project needs are met but also that it can bring added values to the municipality of Askersund. An example can be adding interactive visualisation of the customer microgrid inside the building so that its users (e.g. the school pupils) can learn about the project and drive internal engagement.

CUSTOMER MICROGRID

The municipality of Askersund wants their new municipal building to produce its own energy and provide its visitors with the possibility to charge their electrical vehicles. They are also keen on maximizing their own consumption through the use of a battery. Figure 1 shows a simplified schematics of what has been installed at the site: the solar panels and the battery are connected together through a DC network while the rest of the building, including both the two slow EV chargers and the fast EV charger are connected through an AC network.

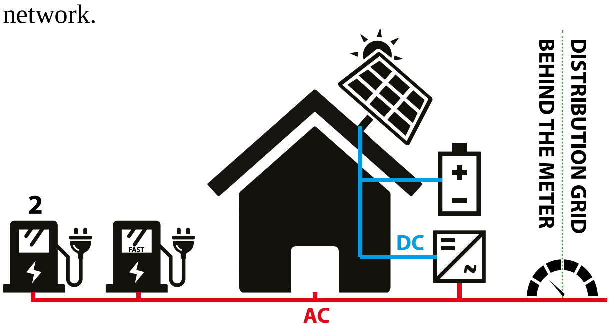

Figure 1: A simplified schematics over the microgrid installation at Askersund.

Dimensioning of the microgrid

In order to dimension the customer microgrid, the following aspects are considered during simulations:

- Energy prices,
- Network tariffs,
- Price of PV (OPEX and CAPEX),
- Price of energy storage (OPEX and CAPEX),
- Historical electricity usage (hourly granularity),
- Weather data (for simulation of PV production),
- Statistical EV charging data (for simulation of EV charging usage to be added to the historical electricity usage).

Energy prices in Sweden are decided on a day-ahead basis at the Nordic Electricity market, Nordpool (the municipality of Askersund is located in the SE3 area). Network tariffs in Sweden are divided into different categories as described in Table 1 [2]

Table 1: Network power and energy tariffs in Sweden

Monthly Power Fee (consumption)	SEK/kW, month
Transmission fee (consumption)	SEK/kWh
Feed-in compensation (production)	SEK/kWh

The prices for each network tariff component vary during the year, with higher values during the peak period (November to March)

Dimension of the system is decided by optimizing an objective function. For Askersund, three cases are studied:

- Maximizing the return on investment,
- Maximizing self-consumption of PVs,
- Maximizing return on investment with given self-consumption target as a constraint.

Installation

For the electrical design and installation of the customer microgrid, the following criteria are considered:

Photovoltaics life span and maintenance cost

Since this installation is at a customer site, we want the installation to require a minimum of technical intervention. This means that the solar panels should have a long lifespan and require low maintenance. In Sweden, this even means that solar panels should have a way to get rid of the snow that will otherwise build up and prevent any production during some parts of the fall, winter and spring. For that reason, etched glass solar cells are preferred over the coated film ones.

Impact on the building

It is important that the installation does not require a lot of unnecessary construction work as it is a public building. This puts requirements on how to install the solar panels on the roofs (where there might already be other equipment), where to place the inverters and battery (might be very heavy), the choice of voltage level (to minimize the size of the cables).

Safety

Since this is a public building, requirements regarding safety should be very high. Some factors to be considered are:

Fire safety

In case of a fire, the PV strings should not be live so that they are not a hazard for the firemen. Also, battery chemistry should prioritize safety over other factors such as cost, lifespan and performance. In that perspective, lithium-iron-phosphate seems preferable.

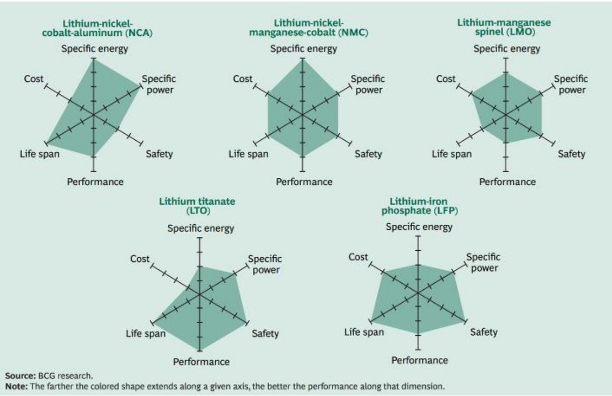

Figure 2: Overview of characteristics of several lithium-ion battery technologies[3]

Electrical safety

The installation should be remote controllable in order for workers or firemen to work in safe conditions. Moreover, all electrical equipment should be appropriately labelled and out of reach for children.

Commissioning

The inauguration was a success, as both the municipality and Vattenfall were able to showcase how their shared interest and work can lead forward to a more sustainable future. The installation was completed during the summer of 2017 and inaugurated in the fall of 2017.

Analytics

A data analytics platform is also developed, allowing Vattenfall to follow up and evaluate the effectiveness and efficiency of the different microgrid control strategies provided by the supplier, thereby giving Vattenfall the opportunity to propose improvements to the municipality. The data acquisition platform also enables Vattenfall to use the building as a test bed for studying new improved algorithm (and thereby improved the services provided).

INSIGHTS

Business model development

The type of customer chosen for this demonstration project, i.e. public or commercial building, have a consumption pattern that is very correlated to the PV production pattern. Indeed, these tend to have daily activities, meaning a battery is not needed to achieve that self-consumption of solar energy. The decision to install the battery was therefore solely based on the potential learnings that could be gained from such a pilot project.

What we find is that an energy storage brings the highest value as a peak shaving unit (reducing the highest hourly peak of every month). However, for the current market prices, the cost reduction is not consequent enough to motivate installing a battery. It is worth mentioning that we foresee a greater need for peak shaving in the future, since the addition of electric vehicles in the energy system will without doubt add more stress to grid sometimes already at its limit. This kind of capacity tariff will reflect the increasing need for efficient power distribution over time, probably making this kind of control strategy more cost-effective. Another possible source of income could come by optimizing the consumption and production (shifting in time with the help of the battery), but the energy spot prices are currently not volatile enough for this strategy to be profitable (one has to remember that the difference in price between feed in compensation (production) and transmission fee (consumption) network tariffs does not encourage this strategy).

Data monitoring provides a good understanding of the energy usage in the building and allows Vattenfall to quickly propose the municipality with changes. For example, one can get quick feedback whether the pricing of the EV chargers is optimal.

Installation

A DC network was chosen due to some of its advantages:

- Fewer and smaller cables (high voltage DC network means lower current and thinner cables, thereby a lesser impact on the building and faster installation work)
- Fewer components, only one common inverter for the whole PV/battery system.
- Battery and PV on the same DC network induce smaller losses in case PV energy directly stored in the battery.

An added technology for this pilot installation is adaptive current equalization [4] which reduces imbalances between AC phases. For examples, large single phase loads such as EV chargers can be used without needed to upgrade phase fuses.

It was chosen to install the solar cell string optimizers inside the building for several reasons:

- Less bulky solar panels on the roof, meaning increased modularity
- Easier overview and maintenance of the optimizer as they easy to access (compared with being placed under the solar cells)

Moreover, a main switch was installed so that firemen can remotely turn off the solar cells thus making it possible for them to intervene without risking electrocution.

The choice of battery chemistry was based on two main parameters: safety and weight. Indeed, it was initially intended to place the battery near the PV installation, near the roof. For these reasons, lithium-ion phosphate was preferred. However, due to unclear local safety regulations, the battery was finally installed outside of the building in a container.

Finally, it is worth observing that each customer installation is unique and that a standardized solution that fits everyone needs is probably not achievable. Instead, one should focus on developing a method to handle the specificity of each customer, by for example developing modular solutions or working with a broad range of products and suppliers that are compatible with one another.

Control

The control strategy we find to have the optimal business value (for the Swedish market) during simulations doesn't seem to be an off-the-shelf control algorithm in what our suppliers propose. One has therefore to note that each market has its specificity and that generic algorithm proposed as of today will not provide optimal results, especially for customers tending to be of in-between size (higher consumption than a single home, but smaller than of an industry).

Another point worth noting is that most of the customers of this type will generally already have a building energy management system and are very keen to integrate the microgrid management system to their existing system.

Measurements

Power quality measurements are done for the duration of the whole project in order to measure power quality deviations in the local grid. Parameters of interest are total harmonic distortion, sag and swells, flickers as well as supra harmonics. Power measurements are set up at the energy meter, where the municipal building directly interfaces with the local grid, at the power converter for solar and battery and finally next to the EV-charging equipment.

The outcome of the power quality measurement does not show so far (8 months) any major deviations, but there will be more detailed investigations further on. Distortions in the current due to the specific loads in the facility are observed, but they were already observed prior to the installation of the solar/battery power converter. Still, the solar/battery power converter appears to deliver a distorted current to the microgrid, but due to a very strong local grid in the vicinity of the facility no major changes are observed in the voltage quality compared with or without the power converter for solar and battery.

Even though we cannot observe any problem at this facility so far it is very important to reduce the current distortions from the power converter to prevent potential problems installations in weaker grid.

Regulatory and safety aspects

As the local authorities were unsure whether it was safe to install the battery inside a building containing a school, it was decided for precautionary reasons for the battery system to be installed outside of the building. Vattenfall has in the meantime initiated a discussion with several fire safety agencies in Sweden in order to study and clarify the safety requirements as well as the location and labelling of battery installations. This will hopefully lead to clear battery safety guidelines or even regulations on a national level.

FUTURE

Thanks to the high engagement from the municipality of Askersund, this pilot installation provides remarkable opportunities to test both new technologies and regulatory aspects. Future tests will, among others, involve islanding possibilities for emergency backup, using hydrogen storage for storing energy for longer period of times, connecting the EV charging points directly to the DC grid and testing the control system with new tariff structures.

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