Ref. Ares(2020)7411408 - 07/12/2020

STORY

added value of STORage in distribution sYstems

Deliverable 5.2
Report Chapter on Neighborhood Network

Revision 1
Preparation date .. 2020-12-07(M67)
Due date 2020-10-31 (M66)
Lead contractor .... THNK
Dissemination level PU

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

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1. Publishable executive summary

The European project STORY demonstrates and evaluates innovative approaches for energy storage systems in the residential and industrial sectors. The overall objective of STORY is to show the benefit storage can bring for a flexible, secure and sustainable energy system. The project specifically focuses on the added value of energy storage in distribution systems.

The pilot on energy communities follows an earlier assessment of building level storage. Energy communities were integrated in the Clean Energy Package, which by the start of this pilot, started to become a well-delineated concept. As interest arose, the technical, business and societal aspects of energy communities gained attention. This pilot hence came at the right moment.

Replicability was a key design principle in setting up this pilot. Therefore, no overall neighbourhood platform is implemented due to the high cost of such and the dependency on the consent of end-consumers in the neighbourhood. The line data showed strong voltage variations, providing a good insight in the actual status of the line with regards to loads and generation. Point measurements of voltages were hence used as a simple control basis for the flexible loads on the line: the car chargers and the first Belgian neighbourhood battery.

The process towards the implementation of the neighbourhood battery was particularly time-consuming due to missing legal and regulatory frameworks as well as the communication gap between the different stakeholders engaged and specifically the challenge in explaining system-level thinking.

The neighbourhood battery implementation has resulted in a boost in RES installations in and around the pilot, installations in energy efficiency and an overall increase in energy awareness. At the larger scale, the pilot has resulted in an enabling framework which is now clear and is fully in line with a future-oriented view on grid-connected storage integration on low voltage lines: temporal set-ups to overcome a period until a grid-reinforcement can be executed are a potential business case. The grid line reinforcement is still the most economical solution for the DSO and hence with regards to the electricity tariff.

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2. Energy Community

2.1.1 Introduction

In this chapter the focus is on the process to deliver the BESS and the logic for both the BESS and charger controls. The effective operation of the BESS and its results are described in detail in the deliverable D6.1 of WP6. The operation of the chargers was prevented due to the COVID-19 lockdown.

2.1.2 Objectives

The objective of the energy community pilot is to show the added value of neighbourhood energy storage for the local grid, specifically in managing power quality related challenges. More specifically, the energy community demonstrator aims at:

- Increasing the capacity for renewable energy production through residential PV by lowering peak voltages and hence reducing curtailment;
- Using decisive loads in grid management;
- Reducing voltage swings and hence increasing the lifetime and operation of connected assets.

2.1.3 Partners engaged

THNK and ABB cooperated for the installation and operation of the BESS and the chargers. Data was stored at a subcontractor of ABB, Enervalis and closely followed up by THNK. Data were send to JR for further processing. VIES contributed in finalising the deliverable report.

2.1.4 Booklet chapter

The chapter is added as Annex 1.

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3. Acronyms and terms

BESS	Battery Energy Storage System
EV	Electric Vehicle
PV	Photovoltaic panels
UDP	User Datagram Protocol
SOC	State-Of-Charge

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4. Appendices

Annex 1: Report chapter on energy communities and grid balancing

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STORY D5.2 | Dec 2020

Report Chapter on on energy communities and grid balancing

System and implementation description

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1. Introduction

The Oud-Heverlee neighbourhood demonstration has been implemented in the second part of the STORY project. This demonstration focuses on the energy strategy to impact grid balancing and flexibility. The concept of neighbourhood energy operation assumes that energy communities assure balancing of the grid. This can be achieved by aggregation of flexible loads available in each household. However, limited residential loads are effectively both flexible and of a power demand that is relevant from a line-balance perspective. When it comes to home battery energy storage systems, their current prices and typical use for an increase of self-consumption do not offer a viable business case for a large scale roll-out of this technology. Also, the maturity of that techbology is not sufficiently demonstrated throughout the duration of STORY, nor were safety aspects adequately addressed through regulation and certification. Finally, also insurance and firefighters were unsure on the prevention and mitigation measures with regards to the various types of home battery energy storage systems. Therefore, a neighbourhood battery energy storage system (BESS) was proposed as a way to scale up and ensure adequate and well-orchestrated behaviour.

1.1 Objectives

The objective of this demonstration is to display the potential of an energy community to contribute to grid balancing and a flexible grid operation. Two main approaches are prepared: 1) the impact of EV charging following a specfically designed algorithm, and 2) the potential of the neighbourhood battery to react and solve grid issues and provide high power quality and flexibility to the system and mainly reduce curtailment.

2. The installation

The Oud-Heverlee demonstration site consists of 13 residential buildings that are located on the low voltage grid. The power quality of the local grid is non-optimal due to two factors: the neighbourhood being located at the end of an old distribution line and the high share of EVs by these households (7 EVs and HEV for 13 households). Voltage swings and undervoltages are hence a common challenges, overvoltages further prevent the full exploitation of the RES potential due to curtailment.

2.1 EV charging

Electric vehicle (EV) charging is a decisive load in this residential environment. A vehicle plugged into a residential charger requests between 3 kW and 7 kW power. When multiple chargers are installed on the same line, the local grid can become unbalanced. This results in a lower power quality, power interruptions or in extreme cases the interruption of a device's operation. The STORY demonstration in Oud-Heverlee has a high uptake of EVs , of which most are charged at home. In the specific case of a summy day and the EV owner working from home, the EV is mostly charged during the hours of PV electriciyty production. However, mostly end-consumers plug in the car when they arrive home from work. This implies a common timeframe and could imply voltage reduction mainly at the end of the line, due to the location of the chargers there. By aligning EV charging times on neighbourhood level, stress can be relieved from the local grid resulting in higher power quality.

2.1.1 Charging algorithm

The model that is to be developed for smart car charging should be as less disruptive as possible. Discussions with various stakeholders further showed that a form of "symmetric" curtailment could be meaningful, i.e. a curtailment to reduce the charging power or even cut it off in case of too low voltages on the line, as opposed to the curtailment of PV electricity in case of too high voltages.
Neighbourhood load balancing can be achieved by measuring the voltage on the grid and aligning this with the EV charger load. This implementation is based on household voltage measurements that directly influence the EV charger. This low-level implementation helps to balance the local grid in real-time by reducing the load of the chargers in the neighbourhood once a low voltage (< 230 V) is observed.
Important is to note that this version of the algorithm did not yet take into account the fair distribution of curtailment over the different chargers. A simple 3-phase powerline communication between the chargers was identified to address that matter.
User preferences need to be considered. The controlling algorithm cannot simply stop the charging process of an EV because the vehicle needs to be sufficiently charged when the EV user wants to leave his home. However, it is possible to slightly slow down the charging process without influencing user comfort. On average an EV charge takes about 2h each day while the EV is usually connected overnight. Users should have the option to choose for "fast charging" mode where full power is guaranteed in case of emergencies. This implementation requires the collection of user preferences which was not considered for the first prototype.

2.1.2 Communication and control

Voltage based load balancing requires voltage measurements and charging stations that can be remotely controlled. The Oud-Heverlee demonstration uses the ABB A43 energy monitor to collect energy data throughout the demonstration houses. This data includes voltage measurements on three phases. A custom gateway developed by Th!nk E allowed this data to be read out (over modbus protocol) with a time resolution of 1 measurement per second. They have a hardware-based connection. The gateway contains the load balancing logic and ensures measurement and processing happens within the resident's premises
Once data has been collected the gateway needs to be able to communicate with the charging infrastructure. In the Oud-Heverlee demonstration the ABB EVLUnic Pro (Figure 1) is installed. This charging station can be remotely programmed over UDP. It is possible to request status reports and push new setpoints to the charging station if the gateway and the charging station are connected to the same local network. One of these setpoints is the maximum allowed current. By regulating the maximum allowed current of the charging station, the gateway is able to control the requested power.

Figure 1: ABB home charger.

The time resolution of one voltage measurement (each second) allows for real-time load balancing of the local grid. The only transmission delays that can occur are between the KEBA charging solution and the gateway, no external data transfer is necessary. This is important, given the challenging data communication from within to outside of the residential buildings as experienced before.

The first prototype has been developed in the living lab at Oud-Heverlee. The gateway was successful in controlling the charge profile of one electric vehicle. The prototype was in the process of being tested in the other buildings before the COVID-19 pandemic forced the country into lockdown and cars were only exceptionally used.

The users were open to the control as the algorithm would never completely interrupt the charging process, only limit the power supply. Their previous experience with interruptions in charging due to black outs, was that the chargers would not automatically restart and hence the vehicles were not charged as planned. This concern was confirmed as valid based on previous experiences of VITO, where complete interruption of the charging process required a manual intervention at the level of the charger or the vehicle. Consequently, their pilot participants dropped out due to inconvenience of non-charged cars.

2.2 Neighbourhood battery

The concept of the neighbourhood battery has been discussed and analysed from a technical and economic perspective over the past few years. However, this installation represents the first installed neighbourhood battery in Belgium. The neighbourhood battery is a Lithium polimer ABB battery of 90 kWh and 90 kW capacity.

2.2.1 From idea to understanding

While a neighbourhood battery as such is no new technology and its added value in an old and overused grid is obvious, it is not easily made understood. Even before any procedure is launched with regards to permitting and environmental registration, stakeholders have to be aware of what the relevance of such device might be, what the safety risks are and which potential economic benefit the organisers could receive that would prevent it from being considered a societally relevant test case. The start in such procedure is the local government. The municipality of Oud-Heverlee has just above 11 000 inhabitants. While it is close to Leuven, it has its own team of civil servants on building regulation evaluation. The team is understaffed and an uncommon question as the planning regulation for a BESS is not an easy to solve challenge. A local lawyer was engaged to prepare the discussion and assess the regulation with regards to the implementation of the BESS. As such regulation was missing, one could argue to there was hence nothing that would prevent it being implemented. Or, one could argue that there was no legal basis for its implementation.

The Flemish administration was angegad, including the person responsible for the integration of new and renewable energy technology in the urban landscape. According to this person, there was enough room in the current legislation to enable the installation on a private or public property.

2.2.2 Permitting

The exact location of the device in the street was a challenge. A piece of land was bought for this purpose as the available public land was unsuited (not accessible from a public road). The piece of land has a steep entrance and like for its neighbouring pieces, the intention was to create an entrance at street level with a width equal to the other entrances, being close to 8 metres. Therefore, an official permit for adapting the steep entrance was submitted in close cooperation with all stakdeholders so far engaged. A complaint from an unexpected entity was filed: the service of Nature & Forest protection (Natuur & Bos) filed an appeal to the provided permit, based on an article that allows them to prevent the destruction of a specific type of a steep entrance, namely a naturaly available steepness that prevents erosion. Although it was obviously a wrong classification, the action delayed the permitting process by nearly 6 months. For that reason, an alternative location, was chosen: a parking lot of a neighbour, which was big enough to accommodate the battery and the connection to the grid was easier due to the proximity of an electricity pole. An agreement was made to rent the parking lot for the duration of the project.
During the period until the appeal, workshops were organized with several stakeholders at municipal, provincial and Flemish level to further investigate the effective legal and regulatory aspecs of the integration of a neighbourhood battery in the urban landscape. It turned out that neighbourhood batteries do not need a building permit and that there are no restrictions with regards to the duration of the battery being on the site. In order to install the neighbourhood battery, a simply environmental notification was needed.

2.2.3 From permit to effective connection

Two remaining agreements were to be made: a contractual agreement with the DSO and a suppliers contract.
The DSO had been engaged since the start of the pilot. Still, as this was the first grid-connected BESS, several departments within the DSO were engaged all working on different aspects and at different speeds. The openness from the side of Th!nk E and ABB enabled a smooth development towards a more than relevant outcome: an addendum to the standard connection contract, useable for any future grid-connected BESS. The provisions in the contract emphasized the need for grid-support in the operation of the neighbourhood battery and restricting specific behaviour that would not align with this goal. More specifically, the contract stipulated to not allow injection at high voltages and not allow BESS charging during periods of low voltage.
To assure the safe functioning of the battery in the distribution network an additional safety relay and a high frequency power quality meter were to be installed on the side of the DSO.
Further on the EN 50160 Standard on Voltage Characteristics in Public Distribution Systems was followed to assure that the power quality of the distribution line is maintained using the neighbourhood battery.
Finally a contract with an energy supplier was needed. Also this turned out to be less straightforward. Large suppliers could not provide a contract proposal, as the concept of a BESS did not fit into any standard contracts. A small supplier was able to resolve the matter offering 2 contracts: a supply and an injection contract. The supply tariff includes the price for energy used, DSO and TSO grid

costs and all levies and taxes (including societal contributions). In contrary to this, the injection tariff includes only what the electricity supplier is willing to pay for the energy that is injected into the grid. In practice, this implies that around 28 cent are to be paid for every kWh that the battery takes from the grid, while only about 4 cent is received for every kWh injected back into the grid.

2.2.4 Communication and Control

To fix the issue of high voltage variation, Th!nk E turned again to a point-based control with voltage measurements. Voltage measurement at individual houses could have been used but would still require coordinated local load control to assure the power quality on the distribution line is assured for the whole neighbourhood.
Therefore, the neighbourhood battery was installed in the middle of the line, having 13 households on one side towards the end of the line and additional 27 before the connection to the substation. The voltage on all three phases is measured at the neighbourhood battery and a control algorithm is used, as will be explained below, to control voltage variation for this 230 V lines to be between +/- 5 % as is needed for normal operation.
At moments when too many loads are operational on the line and the voltage is dropping below this limit, the neighbourhood battery is used for discharging to balance the line. Likewise, in case of a high amount of injection, the battery charges to balance local demand and supply.
To assure these requirements are respected, the following control limits are implemented:

- No injection with high voltages
  - o 230 V + 7% or 246 V
- No consumption with low voltages
  - o 230 V – 7% or 214 V
- If approaching the limit of 93%-107% mean 10 minute rms values, the load is kept the same and not suddenly changed.
- When the values of voltage on the grid change, the load will be adapted slowly.

Figure 2 ABB Neighbourhood battery installation in Oud-Heverlee demonstration site

A model predictive control was developed to ensure the battery started its charging and discharging optimally (Figure 3).

3. Operational phase

Due to lengthy preparatory procedure, the conditions for the neighbourhood battery were only met at the end of 2019. The neighbourhood battery was installed and started operation mid February 2020, i.e. just 4 weeks before the country went in lock-down. The commissioning and control testing went smoothly. Operation continued during the lock-down, though resolving technical issues took a bit more time due to the new modus operandi.
The operation of the BESS suffered from minor technical hick-ups, but high-

frequency measurements as performed by the DSO indicated a high peak demand on several occasions. The DSO reported those end of May 2020 and it was soon clear that the demands of up to 100 Amp were related to the start of the HVAC. A soft-starter was added to resolve the issue and the BESS continued its operation with minor further technical issues.
Late September 2020, the battery manufacturer organized a replacement of the batteries themselves, which was postponed until the end of the pilot in order to do it at ABBs factory after the BESS had been returned there.

4. Results

While the monitoring results are discussed in the monitoring chapters, the demonstration showed to be highly relevant also with regards to the non-technical outcomes.
End-consumers showed a decisively higher willingness to invest in renewable energy. The battery served as a kind of visual trigger and out of the 13 houses, 4 already had PV, 4 additionally installed PV following the BESS integration and one more will as part of ongoing remodelling works.
Although the official opening of the BESS with the Flemish minister of energy was cancelled due to COVID-19, the BESS was widely covered in the media. As a consequence, a lot of questions came with regards to the business case. Though, an in-depth assessment in cooperation with the DSO and the regulator revealed that for Belgium in its current status of low integration of RES and being far from having reached maximum grid reinforcement or even costly grid reinforcement, a BESS is not the first choice. Today, a neighourhood battery should be considered as a temporal solution until grid reinforcement has been executed

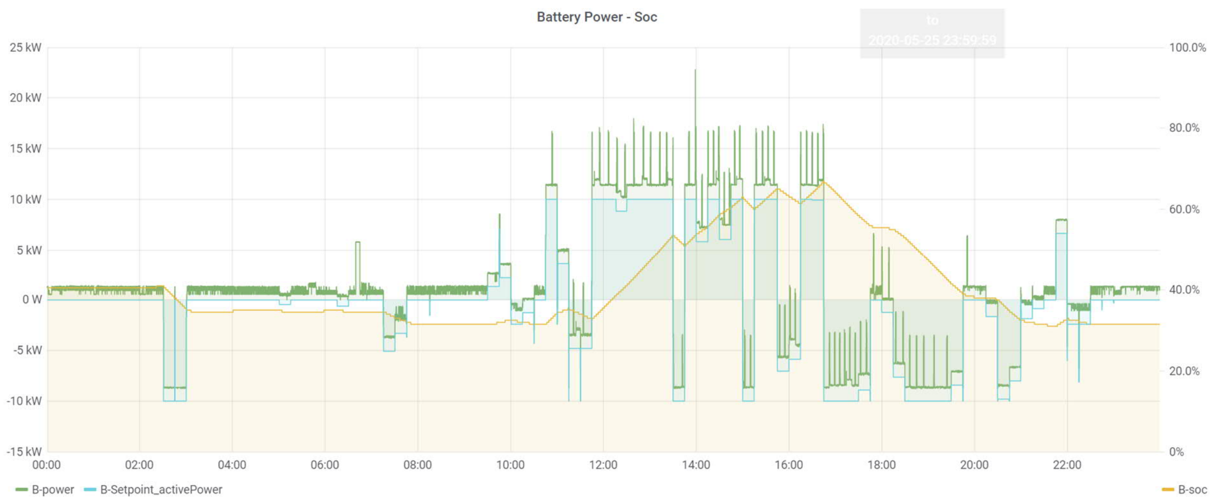

Figure 3: BESS control operation on 25/5/2020, showing grid exchange (left axis ranging form -15kW to +25 kW) and SoC (right axis, ranging from 0% to 100%