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Federal Department of the Environment, Transport, Energy and Communications DETEC

Swiss Federal Office of Energy SFOE
Energy Research and Cleantech Division

REEL Demo – Romande Energie ELectric network in local balance Demonstrator

Deliverable: 4b3 First Industrial Validation of Energy Management for Multiple Applications EMMA 2.0

Demo site: Chapelle

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1. Description of deliverable and goal

1.1. Executive summary

Within the collaboration of Romande Energie and Aurora's Grid, last June 2020 the latter provided two licenses of energy management system (EMS) for two Li-ions battery energy storages (BES) of 300 kWh-200 kW and 40kWh-20 kW respectively, manufactured be Eaton.

Within this framework Aurora's Grid:

- further validated the possibility of reducing the ageing of the BES;
- validated the capability to send optimal setpoint to the BES by only exploiting net power measurement;
- tested for the first time the possibility of making two services with the same BES (peak-shaving coupled with renewable self-consumption);
- delivered for the first time a peak-shaving algorithm customized for PV injection into the medium voltage (MV) grid.

1.2. Research question

1) Is it possible to install and deploy a BES into existing grid without any additional cost associated to a further need of observability of the grid?

2) Is there a chance of increasing the profitability of BES by making multiple services?

1.3. Novelty of the proposed solutions compared to the state-of-art

The totality of the BESs installations word wide is dedicated to single usage, namely single BES for peak-shaving, single BES for renewable self-consumption or for any other ancillary service. Of course, this approach does not involve a revenue stream

capable to reach a profitability of the system within 5-7 years (which is the time horizon required for any sound-interesting ROI project analysis).
Moreover, the installation of BES and its management are strictly related to the EMS, that sometimes, for being operated, require additional measurements and sensors. This increases the complexity and the cost of the whole system by extending once again the time horizon for a positive ROI.

Description for peak-shaving BES (300 kWh-200 kW)

As already introduced, a 300 kWh-200 kW NMC graphite battery manufactured by Eaton has been installed in Chapelle sur Moudon.
The main purpose of this BES is to reduce the injection of photovoltaic rooftop plant coming from the low-voltage (LV) community towards the medium voltage (MV) grid. In fact, since the majority of the building in this community are residential ones, their energy consumption during the day is limited and consequently the PV injection toward the MW grid could be relatively high. The total installed PV power is around 323 kW, while the nominal power of the LV-MV transformer is of 250 kVA, ergo, potentially this transformer can be overcharged of about 73 kVA.
Figure 1 illustrates the BES installations.

Figure 1: the two BESs located at Chapelle sur Moudon

The algorithm of peak-shaving has been integrated into the main Energy Management for Multiple Application (EMMA 2.0) provided by Aurora's Grid.

This algorithm can reduce the peak injection into the MV feeder by storing it into the BES and later on, during the evening self-consuming this renewable energy with an ageing-aware strategy.
The most original outcomes of this algorithm are:

1) Peak power injection reduced of 16%
2) Local renewable self- consumption increased of 16%;
3) Lifetime of the BES increases of 25 % since the discharge of the BES is made with an average current of 33% of the one deployed by the existing competitor solutions;
4) No need of extra measurement nor weather forecast.

The algorithm needed for reducing the charging and discharging profile involving an extended lifetime of the BES has been already developed and validated in another previous pilot project (ECOBATTEM 2018-2019). We should point out that it has been validated within an actual industrial environment instead of an academic environment.

Weather forecast issues

Concerning the peak-shaving algorithm, an ad hoc development has been required, since we had faced off with the following issues:

- avoiding weather forecast;
- avoiding installations of further devices such as solar irradiance sensor;
- avoiding the installation of additional power measurement devices to distinguish the two components of the existing measurement: PV injection and load energy consumption.

In order to avoid the above-mentioned issues, we have purchased online solar irradiance measurement for the targeted location with the aim of having a kind of threshold for each sampling time measurement and being capable to estimate the real-time PV production and extrapolate from the net measurement the load power consumption.

Accounting for seasonality

It is important to account that the need of peak shaving the PV injection depends on the seasonality. In fact, in "sunny" seasons the peak power from PV will be higher than the

one in “cloudy” seasons, consequently the BES needs to have enough available SoC to store the renewable energy.

The proposed algorithm has been adapted in order to refer the PV production that is measured at each sample during the day with the reference value that the PV production should have for the specific day of the year (via purchasement of historical solar irradiance data); namely the impact of the seasonality of the solar irradiance allows the scaling of PV production value.

Maximizing renewable self-consumption

Once the seasonality of the PV peak production has been accounted for, it has been necessary to increase, as much as possible, the renewable self-consumption. In fact, any too conservative algorithm involves enough possibility to store renewable energy but on the other hand there is the risk that the BES will not be fully charged due to associated loss of revenue (and renewable energy self-consumption). Moreover, any “inattentive” algorithm involves the possibility of maximizing the renewable self-consumption since the BES will be fully charged but it cannot allow enough capacity for the BES to store the renewable energy during the peak production.

Of course, the two above issues, maximization of self-consumption along with the seasonality of the PV peak production are both depending on each other and thus a solution of a strongly nonlinear optimization problem is needed. A classic method for solving this problem from a mathematical point of view requires computation time that is not allowed by industrial controller deployed into BESs. Consequently, Aurora’s Grid team developed a novel approach described above.

Proposed solution

Figure 2 illustrates, schematically the multidimension and nonlinear problem that has been fixed by Aurora’s Grid with their innovative EMMA 2.0.

In this figure it is possible to detect three main axes corresponding to:

- the weather class pattern classification (x), i.e., sunny, mixed, cloudy;
- deployed power with the BES (y) i.e., Very High (VH), High (H), Medium (M), Low (L), Very Low (VL);
- duration of the day, from sunrise to sunset.

The algorithm proposed and tested by Aurora's Grid is capable to dynamically classify the PV production in the targeted site and consequently adapt the expected peak PV injection, whereas by accounting the time elapsed during the day is capable to adapt the deployed power to charge the BES without losing the possibility to fully charge it.

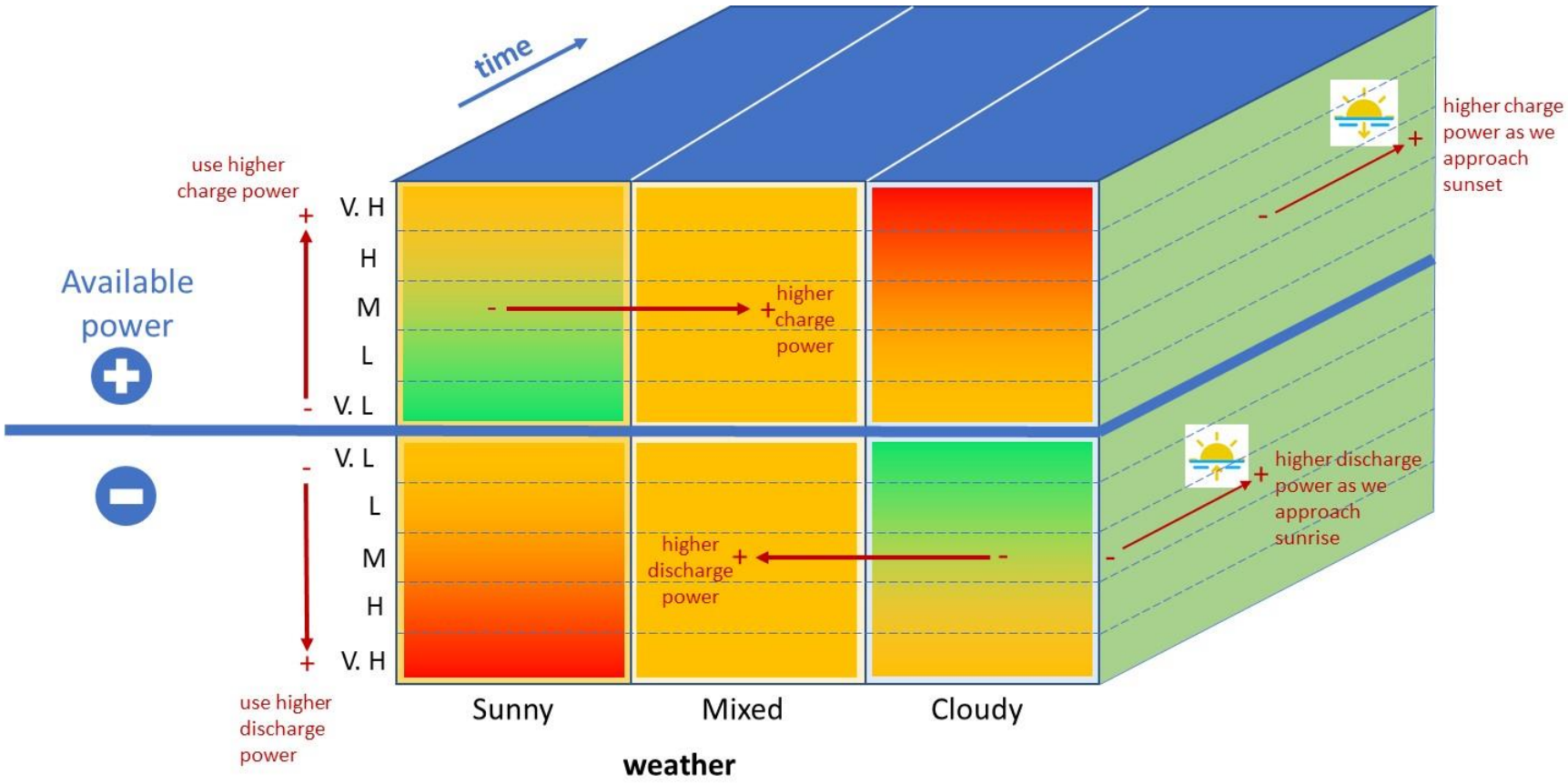

Figure 2: schematization of dynamic peak-shaving approach.

Figure 3 illustrates as example some day during summer 2020 where EMMA 2.0 algorithm was capable to cut the PV injection toward the MV grid. In particular we can observe that, as explaining into the algorithm chapter, the shaved peak change dynamically every day.

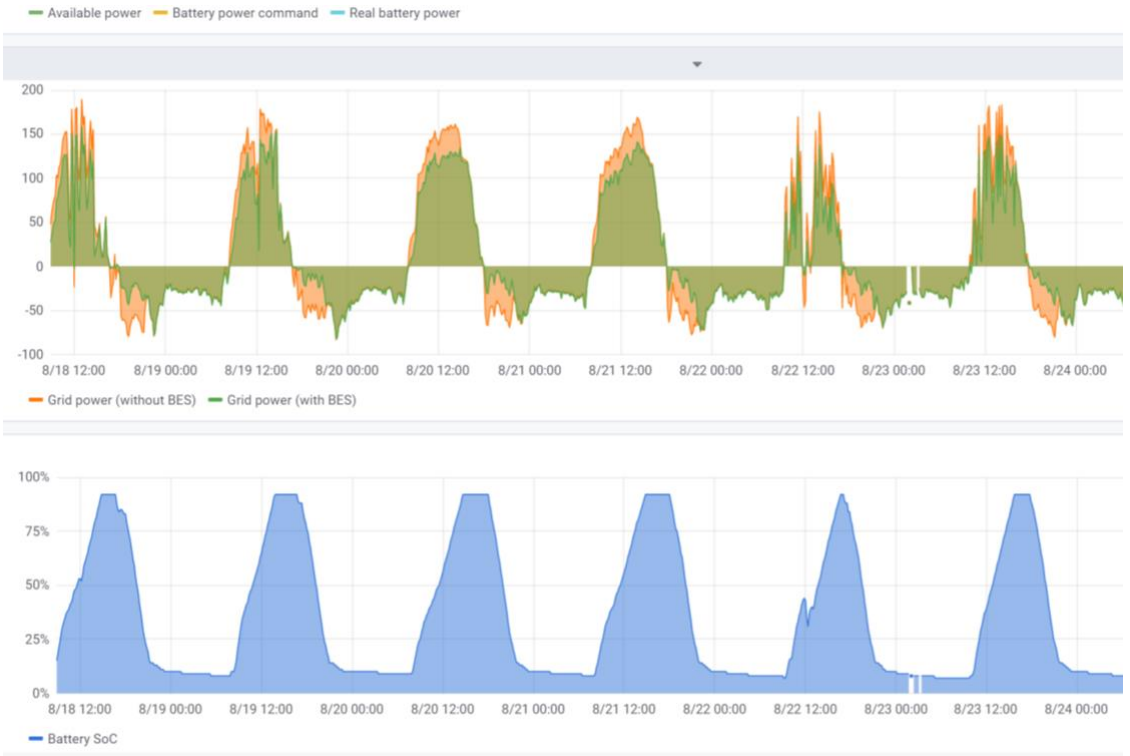

Figure 3: example of peak-shaving PV injection provided by EMMA 2.0

Description for self-consumption BES (40 kWh-20 kW)

The algorithm implemented in the lowest size BES is partially based on what has been developed for the 300 kWh BES and on the previous pilot project ECOBATTEM funded by SFOE in 2018.

Figure 4 illustrates a clear example of EMMA 2.0 capable of reducing the deployed power both for charging and discharging the BES while the self-consumption has been made before 10 p.m until the evening, namely in the timeframe with the highest retail tariff and therefor the highest benefit for the end-client.

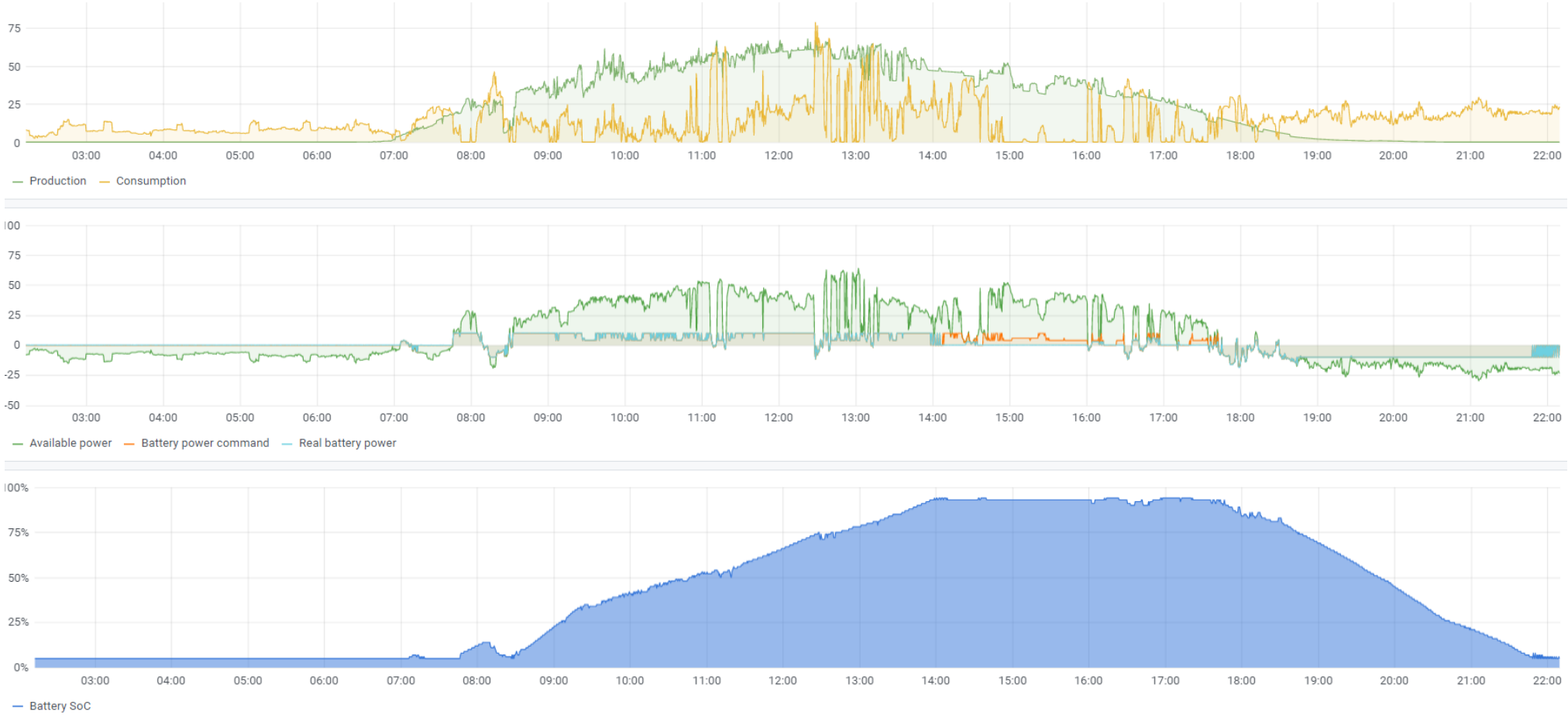

Figure 4: example of renewable self-consumption with BES ageing-aware strategy provided by EMMA

Summary of the results

Table I summarizes the main results obtained with both BESs, with a comparison of the existing EMS that are not ageing-aware.

More specifically, concerning the self-consumption BES (40 kWh-20 kW) we have made the computation of the equivalent cycles would be performed with existing EMS without any ageing-aware strategy. Based on our measurements and computations, we are capable to reduce the average C-rate both in charge and discharge phase, and this involves a 33 % less of performed equivalent cycles (less of ageing).

The same computation has been made for the peak-shaving BES (300 kWh-200 kW). The ageing reduction here is more mitigated since the delivering of pulsed power required for the peak-shaving involves a faster ageing process of the BES. The ageing mitigation of this BES relies only on the self-consumption that is performed during the evening.

It is important to highlight that the ageing reduction achieved with these two installations has 3 main benefits:

1) extending lifetime, postpone the need from the client to replace and purchase once again the BES;
2) extending the lifetime, increase the associated revenues since the BES can be operated for longer time;
3) extending the lifetime, decrease the C02 footprint of the BES. In fact, one kWh of Li-NMC BES involves around 311 kg of C02 emissions. Of course, an higher number of equivalent cycles involves a lower amount of C02 per kWh per cycle.

Table I: summary of main performance of EMMA 2.0

	Self-consumption	Ageing reduction	Peak shaving
BES 40 kWh-20 kW	16%	33%	-
BES 300 kWh-50 kW	16%	25%	16%

1.4. Regulatory and legal barriers for implementation

For the BES of 40 kWh-20 kW it has been relevant to add layer software protection avoiding the possibility of charging the BES with nonrenewable energy.

2. Achievement of deliverable:

2.1. Date

December 2020

2.2. Demonstration of the deliverable

Through the following link, it is possible to observe the operating of the two BESs in the "June-December 2020" timeframe.

https://grafana.aurorasgrid.com/d/MFW367WMz/chappele_moudon-peak-shaving?orgId=1&from=now-7d&to=now&refresh=30s

3. Impact

Aurora's Grid collaborates with Depsys, since we have deployed their measurement device grideye.

Aurora's Gris has strengthened its collaboration with Romande Energie and further started one with Eaton Group.

Aurora's Grid will deploy the two BESs for a current project funded by Innosuisse about online monitoring and diagnostic of BESs.