Minimizing the energy grid exchange in case of increased PV generation in a neighbourhood: First insights of STORY simulations

In the STORY project, a pilot in Belgium is investigating the smart control of flexible devices, including storage, in a residential neighbourhood. The STORY partner ACTILITY has developed several use cases within the pilot, including the minimization of the electricity exchange between the neighbourhood, supplied by a single low voltage (LV) distribution grid feeder, and the rest of the distribution grid. The use case intends to limit the required connection capacity of the neighbourhood with the grid due to better alignment of local variable renewable electricity generation (e.g. PV generation) with its consumption through smart consumption control. Such alignment would increase self-consumption of the prosumers and bring them tangible savings since they could reduce their grid connection capacity (as set by their main home fuse power).

By using Model Predictive Control (MPC) to schedule the consumption of flexible loads, e.g. heat pumps (HP) or batteries, during the periods of high PV production, the alignment can ensure that a neighbourhood with a high penetration of PV generation does not suffer grid stability issues. Namely, during the night, unaligned consumption of the heat pump to heat the building or produce domestic hot water can cause high peaks, while during sunny days, the PV installation injects a high amount of power on the distribution grid. The objective of the MPC controller is to optimally schedule the heating periods together with the PV production to minimize the maximum energy exchanged with the grid.

Scenario description

In order to assess the robustness of the control algorithm to a strong increase of local variable renewable generation on our optimization results, the varying amounts of PV production in the neighbourhood is analysed in three different scenarios, indicated in the table below:

Table 1 PV generation scenarios

Scenario	Description
PVx1	The initial level of PV production.
PVx2	The PV production is doubled.
PVx4a	The PV production is quadrupled.

When upscaling the PV production of the neighbourhood, the consumption needs to be adjusted as well to preserve the energy balance. Three elements are modulated in the simulations to investigate the PV generation scenarios:

- PV production - Power produced by the PV panels.
- Inflexible consumption - Power consumed by the houses without the flexible HPs.
- Flexible consumption - Power consumed by the HPs

For each scenario, three control strategies are investigated, as shown in Table 2.

Table 2 MPC control strategies investigated

Control strategies	Description
Reference	No optimization, only inflexible demand
Without battery	MPC optimization of flexible demand without batteries
With battery	MPC optimization of flexible demand, including batteries

The aim of the MPC control is to reduce the power as measured at the point of common coupling of the LV feeder with the medium voltage grid:

- the peak off-take power – the peak power consumed by the loads in the residential LV feeder;
- the peak injection power of the PV generation into the LV feeder.

The MPC therefore controls the operating schedules of flexible demand, considering the operating limits of the flexible loads and batteries, as well as the grid operating parameters, such as voltage limits and line capacity.

Simulation results

The following figures show the final result for the PVx4 scenario for all 3 control strategies. The results are shown separately for the decrease of the peak offtake power, Figure 1, and for the decrease of peak PV generation, Figure 2. The decrease of off-take and of PV power injection levels is shown for the MPC optimization with and without the batteries.

The results show that the MPC algorithm is able to optimally schedule the consumption of the HPs as well as the battery operation in order to minimize the peak exchange with the grid. The same holds true for the PVx1 and PVx2 scenarios.

Figure 1 Decrease of the peak off-take power

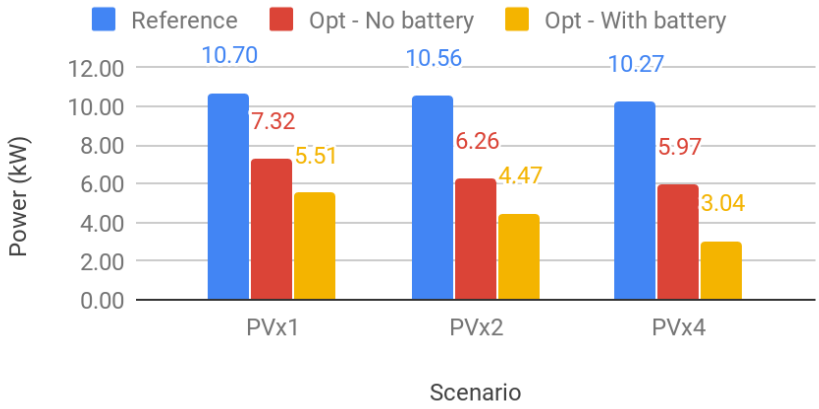
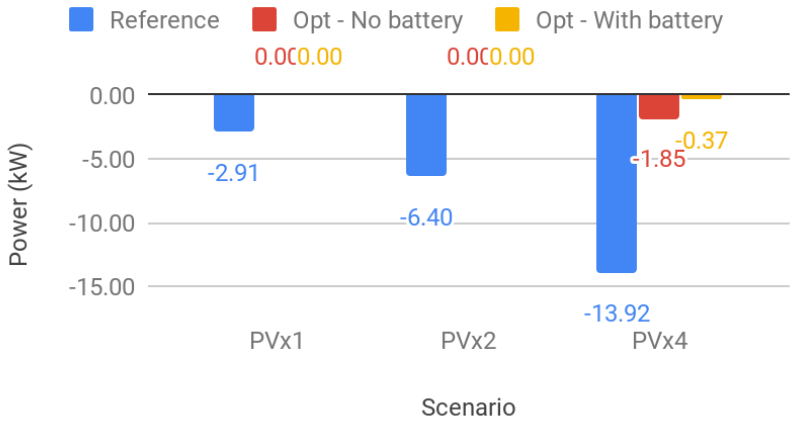


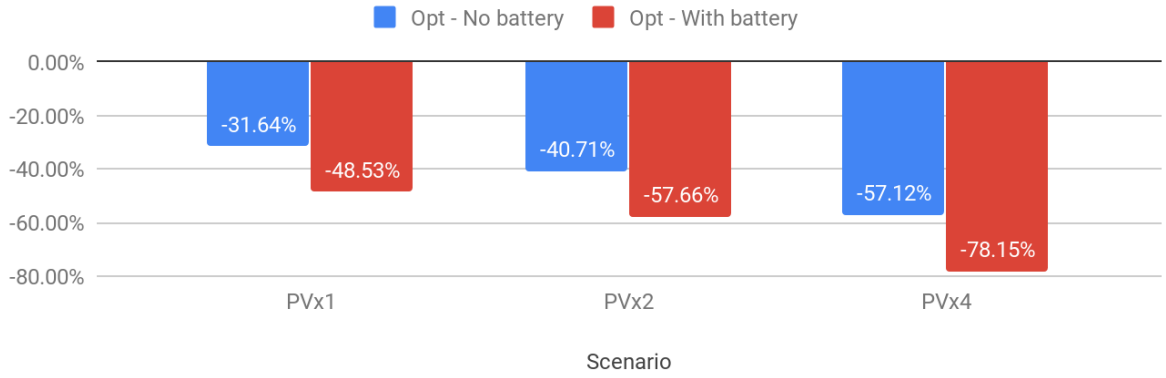
Figure 2 Decrease of the peak PV power injected into the grid



The results show that the STORY MPC for our residential demo in Belgium can greatly reduce the absolute impact of the residential LV feeder on the grid compared to the reference, even without the addition of a battery. However, while the addition of a battery does not greatly decrease the injection, it does significantly reduce the offtake peaks which remain the most important ones.

Figure 3 shows the relative reduction of the **resulting grid exchange which is defined as the maximum exchange of both the injection and offtake.**

Figure 3 Relative decrease of the peak grid exchange, with and without battery



The MPC algorithm clearly shows its flexibility in various PV scenarios by performing well for every control strategy. This flexibility is especially important as **not a single optimization parameter is changed to tune the algorithm between the different PV scenarios. The only difference among**

the scenarios is the amount of PV production. The MPC control methodology clearly shows excellent robustness with respect to the increase in local renewable production in the neighbourhood.