Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

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: 2b2 Successful response of the entire feeder with the use of COMMELEC agents

Demo site: Aigle

Developed by
Plouton Grammatikos and Prof. Dr. Mario Paolone
Distributed Electrical Systems Laboratory, EPFL

[Lausanne, 20.03.2021]

1. Description of deliverable and goal

1.1. Executive summary

The goal of this activity is to demonstrate the successful deployment of a COMMELEC framework for the real-time control of a battery energy storage system (BESS) to follow a dispatch plan computed day ahead. COMMELEC is a control framework proposed in the literature [1][2] that computes optimal active and reactive power setpoints using a hierarchy of agents. While COMMELEC has already been tested in a test-bed microgrid [3], this is the first demonstration on a utility-scale distribution grid. In particular, experiments were run on a 12kV/20MVA MV distribution network in Aigle, Switzerland using a 1.5 MW/2.5 MWh BESS. The performance of COMMELEC is evaluated on its ability to track the day ahead dispatch plan computed by the method described in deliverables D1.3.4 and D1.4.4c.

1.2. Research question

How can we control the power grid in real-time when we have limited information on the grid resources?

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

Compared to past demonstrations of COMMELEC there are two main novelties:

- The framework is tested for the first time on a MV grid in the MVA scale
- A new method is used to compute the weights of the various objectives optimized by COMMELEC. The benefit of the method, which is described in detail in deliverable D.1.2.3c, is that it translates the weights into auxiliary quantities that can be chosen intuitively by the user. This minimizes the time and effort needed to configure the parameters of the control algorithm and provides a priori a general idea of how the control will perform.

1.4. Description

The deployed framework consists of two layers of control. The first one is responsible for computing a dispatch plan day-ahead, while the second one employs COMMELEC to track the dispatch plan in real-time. The two layers are described in deliverables D1.3.4 and D1.2.3c respectively. In this deliverable we evaluate the performance of COMMELEC.

The cost functions optimized by the grid agent (GA) require certain parameters to be configured. The values chosen for this experiment are:

- Target battery state of charge (SoC): $SoC_t = 50\%$
- Maximum allowed grid's nodal voltage deviation: $\beta = 0.05pu$
- Maximum deviation from the dispatch plan: $|P_s - P_t|_{max} = 100kW$

The weights of the various objectives were chosen according to our new method. Also, the battery setpoints are updated every 10s.

Performance evaluation

The experiments were performed in a medium voltage (MV) distribution grid located in the municipality of Aigle, Vaud, Switzerland, which is operated by the local distribution grid operator Romande-Energie. It has a nominal voltage and power level of 21 kV and 20 MVA respectively.

An example of validation of the COMMELEC framework was carried out on Friday the 19th of March 2021. Figure 1 shows the dispatch plan and the measured slack power with the BESS control contribution, as well as in the case where the COMMELEC-based BESS control would have not been activated. The measurements are averaged over a 1min period. In Figure 2, the BESS active power and the evolution of the SoC are shown. In both figures, positive power indicates production of power from the slack/battery, while negative power is consumption of power.

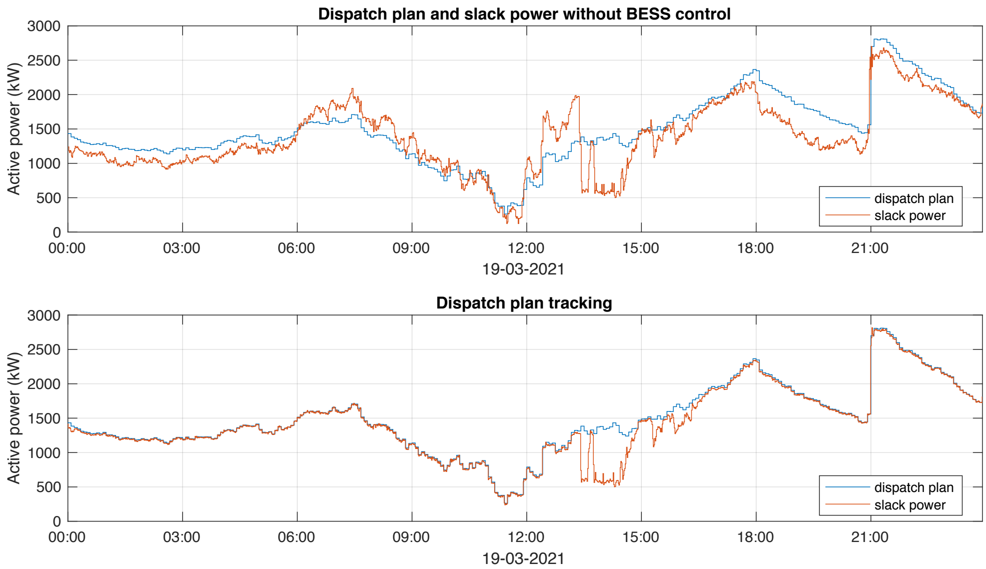

Figure 1. Dispatch plan and slack power without COMMELEC BESS control (upper plot) and with COMMELEC BESS control (lower plot).

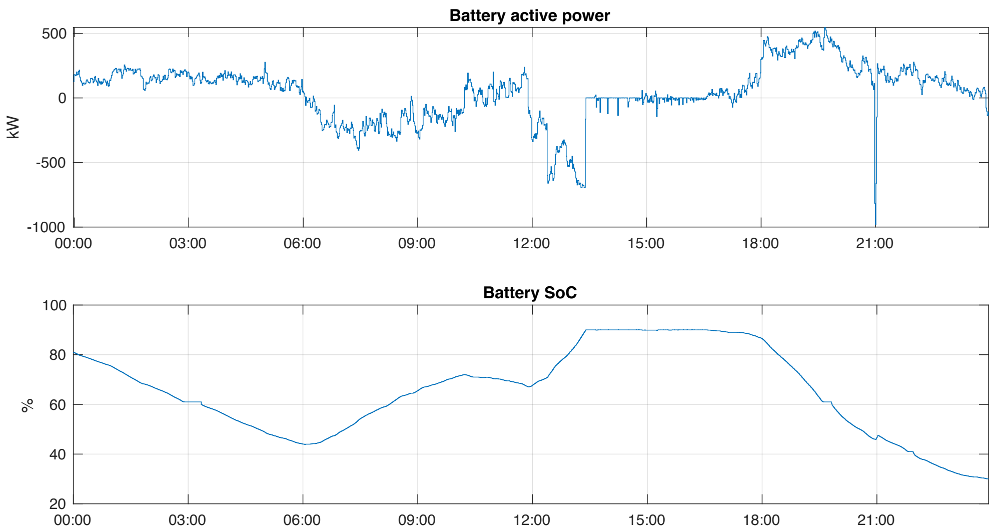

Figure 2. Measured active power and SoC of the battery in case of COMMELEC control.

It can be noticed that between 14:20 and 17:40 the tracking of the dispatch plan was missed because the SoC of the battery reached its upper limit of 90%, as shown by Figure 2. The dispatch plan required the slack to produce more power during this period, but the battery could not charge any further. As the maximum tracking difference $|P_s - P_t|_{max}$ is chosen to be 100kW, COMMELEC is expected to track the dispatch plan within this desired bound, assuming that the battery has enough controllability to do so. However, when SoC>90%, the battery is restricted from consuming power, so COMMELEC loses tracking.

To better visualize the performance of COMMELEC, Figure 3 compares the cumulative distribution function (CDF) of the absolute dispatch tracking error with and without BESS control. In order to have a fair evaluation of COMMELEC, the measurements corresponding to the time window where the SoC was outside its bounds were removed, as the saturation of SoC was caused by the inaccurate forecasts embedded into the computation of the dispatch plan. The graph justifies the choice of the slack cost function, as it can be seen that 95% of the measurements were below the 100kW limit, when the COMMELEC control was active.

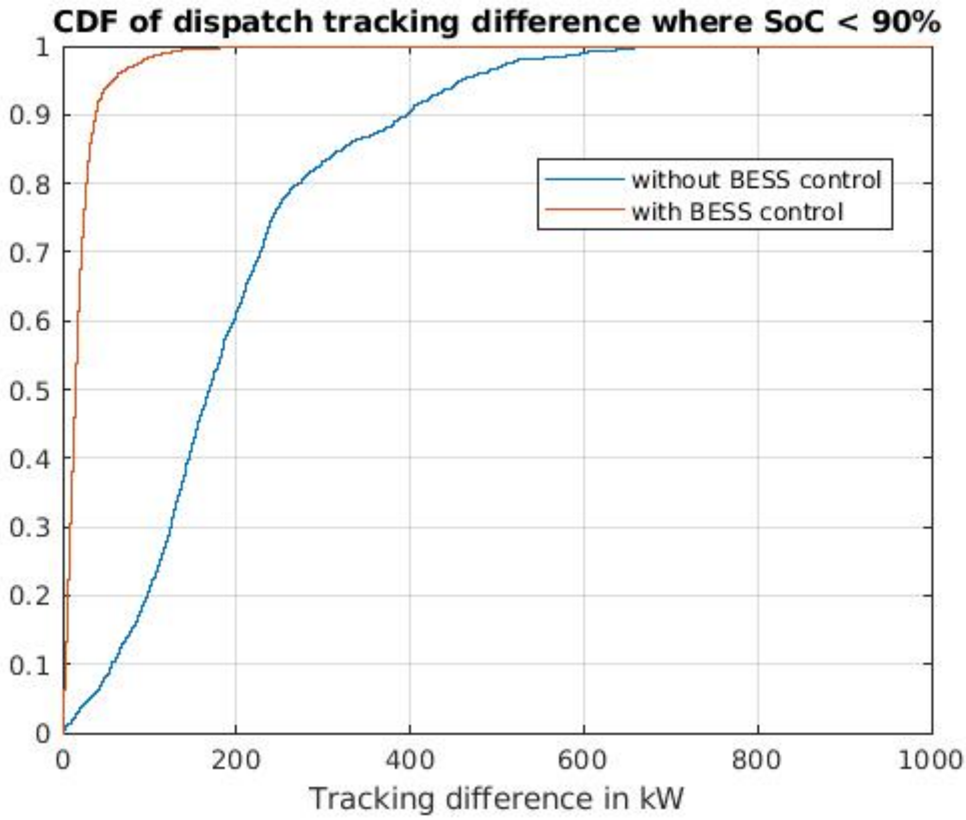

Figure 3. Absolute dispatch tracking difference with and without COMMELEC control, when the SoC is within the acceptable bounds

1.5. Regulatory and legal barriers for implementation

The revised electricity supply act provides the framework for the deployment of self-consumption communities in Switzerland. This will enable the utilization of the proposed solution in such cases. However, this does not include the energy communities without proximity among the members as a requirement. Such energy communities are not recognized yet, setting a barrier for the implementation of our proposed solution for the control of such distributed resources.

2. Achievement of deliverable:

2.1. Date

March 2021

2.2. Demonstration of the deliverable

This deliverable has been achieved through the validation of a COMMELEC-based control system that successfully tracks the dispatch in real-time within given tolerance, while ensuring a feasible state for the grid.

3. Impact

The performance of COMMELEC is evaluated on its ability to track the day ahead dispatch plan computed by the method described in deliverables D1.3.4 and D1.4.4c.
Those results enabled us to strengthen our collaboration with Romande Energie.
Indeed, a follow-up projects was defined and financed by SFOE in the frame of the European program, ERA-NET.

4. Scientific publications

[1] A. Bernstein, L. Reyes-Chamorro, J. Le Boudec, M. Paolone, "A composable method for real-time control of active distribution networks with explicit power setpoints. Part I: Framework", Electric Power Systems Research, vol. 125, 2015, pp 254-264, ISSN 0378-7796, doi: 10.1016/j.epsr.2015.03.023.

[2] L. Reyes-Chamorro, A. Bernstein, J. Le Boudec, M. Paolone, "A composable method for real-time control of active distribution networks with explicit power setpoints. Part II: Implementation and validation", Electric Power Systems Research, vol. 125, 2015, pp 265-280, ISSN 0378-7796, doi: 10.1016/j.epsr.2015.03.022.

[3] L. Reyes-Chamorro, A. Bernstein, N. Bouman, E. Scolari, A. Kettner, B. Cathiard, J. Le Boudec, M. Paolone, "Experimental Validation of an Explicit Power-Flow Primary Control in Microgrids," in IEEE Transactions on Industrial Informatics, vol. 14, no. 11, pp. 4779-4791, Nov. 2018, doi: 10.1109/TII.2018.2802907.