We achieve dispatchability and load leveling of a generic group of prosumers with a two-stage procedure[Load Leveling and Dispatchability of a Medium Voltage Active Feeder through Battery Energy Storage Systems: Formulation of the Control Problem and Experimental Validation]

* day-ahead: the aggregated consumption profile of the group of prosumers is forecasted using historical data and used to compute a leveled *dispatch plan* with a scenario- based robust optimization;
* Real-time: the mismatch between dispatch plan and ac- tual power consumption is compensated by controlling the BESS active power injection with model predictive control (MPC).

1. Battery model

It was found that the model with best performance (namely, with uncorrelated model residuals) for the considered experimental BESS is a three time constant model (n = 3) with structure as follows.

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Model parameters normally depend on the BESS SOC: in order to capture this dependence, a number of PRBS experimental sessions are performed when the BESS is in different SOC ranges (0-20%, 20-40%, 40-60%, 60-80%, 80-100%). The dependencies between model parameters and both C-rate and temperature are not modeled at this stage, and it will the objective of future investigations. Nevertheless, it is worth noting that the latter dependency is expected to play a minor role because the batteries are installed in a temperature controlled environment at 20 ◦ C. [Achieving the Dispatchability of Distribution Feeders Through Prosumers Data Driven Forecasting and Model Predictive Control of Electrochemical Storage]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SOC | 0-20% | 20-40% | 40-50% | 60-80% | 80-100% |
| E | 592.2 | 625 | 652.9 | 680.2 | 733.2 |
| Rs | 0.029 | 0.021 | 0.015 | 0.014 | 0.013 |
| R1 | 0.095 | 0.075 | 0.09 | 0.079 | 0.199 |
| C1 | 8930 | 9809 | 13996 | 9499 | 11234 |
| R2 | 0.04 | 0.009 | 0.009 | 0.009 | 0.01 |
| C2 | 909 | 2139 | 2482 | 2190 | 2505 |
| R3 | 2.50E-03 | 4.90E-05 | 2.40E-04 | 6.80E-04 | 6.00E-04 |
| C3 | 544.2 | 789 | 2959.7 | 100.2 | 6177.3 |

The BESS voltage model is formulated by using the continuous time stochastic state-space model:

The continuous time model is discretized at T = 10 seconds resolution. By simulation, the dynamic response of (R3 , C3 ) branch exerts little effect on the analysis. In order not to incur in numerical instabil ity, the quickest time constant given by the (R3 , C3 ) branch is dropped in favor of an algebraic state by using the matched DC gain method.

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The updated BESS voltage model is as follows:

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The discrete time state-space equations of the BESS equivalent circuit model is as follows:

2. Day-ahead:

In the day-ahead stage, the objective is to determine the *dispatch plan*, namely the power consumption profile that the group prosumers is willing to follow during real- time operation. The *dispatch plan* is built as the sum of the forecasted power consumption profile, obtained through data- driven forecasting, and an *offset profile*. [Load Leveling and Dispatchability of a Medium Voltage Active Feeder through Battery Energy Storage Systems: Formulation of the Control Problem and Experimental Validation]

The *dispatch plan* P is defined as the sequence of N = 96 (i.e., the number of 15-minute intervals in 24 hours) average power consumption values for the incoming day. The feeder *dispatch plan* is composed by the sum of the prosumers forecasted consumption profile **L** and the *offset profile* F:

The offset profile Fo = F1o,...,FNo is determined by a constrained optimization problem that minimizes the movement of the forecasted consumption sequence L1, . . . , LN around its average daily value Lavg. The optimization problem constraints are:

• the BESS apparent power injections should respect the BESS converter nominal power;

• the BESS state of energy (SOE) should be within its nominal limits.

s.t.

We performed a series of cycling experiments on the BESS in the SOE range from 10% to 90%, with power rates from -100 to 100 kW and depth of discharge (DOD) of ±5% and assessed values of efficency higher than 0.95 for all the operating conditions. We can assume therefore β = 1 without introducing a relevant error in a 24 hours horizon in order to preserve the convexity of the problem. [Load Leveling and Dispatchability of a Medium Voltage Active Feeder through Battery Energy Storage Systems: Formulation of the Control Problem and Experimental Validation]

3. Real time:

The intra-day operation consist in controlling the BESS active power injection in order to track the *dispatch plan*, namely compensating for deviations between the dispatch plan and actual consumption, which are likely to differ due to the offset profile and to forecasting errors. This is accomplished using MPC. [Load Leveling and Dispatchability of a Medium Voltage Active Feeder through Battery Energy Storage Systems: Formulation of the Control Problem and Experimental Validation]

The real-time tracking problem is implemented with a shrinking horizon MPC actuated with 10 s resolution. The main features of the adopted MPC are:

• it achieves a certain BESS energy throughput in a designed amount of time;

• it implements the BESS current on the DC side as decision variable, thus allowing to conveniently formulate operational BESS constraints in a linear fashion;

• it retains convexity, for an increased level of tractability and efficiency.