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MODEL PREDICTIVE CONTROL OF GRID-CONNECTED BATTERY SYSTEMS TO AVOID PV-INDUCED OVERVOLTAGE

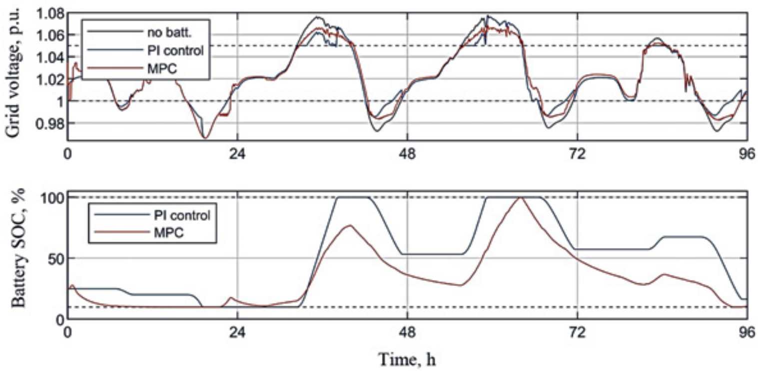
Harald KIRCHSTEIGER[1*], Sarah LANDL[2]

[1, 2] *University of Applied Sciences Upper Austria, ASIC Energy Research, A-4600 Wels, Austria*

[*] ***Corresponding author.*** *E-mail address: harald.kirchsteiger@fh-wels.at*

Abstract – Photovoltaic (PV) power plants are currently built at a high rate, both small ones for single family houses and large-scale plants with a power output in the MW range. This development accelerated even more since the beginning of the energy crisis in 2021. Due to intermittent energy production, large voltage swings may result in the electrical grid, which are challenging for grid and operators. We are considering the problem of overvoltage in times of excessive PV production, which is well documented in the literature. To avoid overvoltage, without PV-curtailment or grid expansion, grid-connected battery systems are proposed. The research focus is on advanced control strategies for such systems which charge and discharge at appropriate times to reduce the overvoltage in the grid while simultaneously minimizing the required battery capacity. The work presented extends a previous contribution of the authors. The analysis was done in a simulation environment (MATLAB/Simulink). The case-study shown considers a 5 MW PV plant connected to the 10 kV grid level, where load profiles of residential areas and commercial areas were analyzed. A mathematical model of the grid behaviour was estimated from regular grid operation data using system identification methods. The model predicts grid voltage from solar irradiation and grid load. A model predictive controller (MPC) was designed with the aim to keep the averaged grid voltage magnitude on all lines in-between upper V^U_{Grid} and lower V^U_{Grid} bounds. The MPC makes use of load and irradiation predictions, enabling a proactive charging and discharging of the battery to avoid large voltage peaks. A graphical result is shown below, where 4 days of simulation were compared with 3 different setups: 1) no battery in the system, 2) a battery controlled with a standard PID-type controller, and 3) the advanced MPC control. The 10kV (nominal) grid voltage is shown in the top panel, the state of charge of the 5 MWh battery in the lower panel. While the PID controller is able to reduce the voltage swings, the MPC can improve the performance further, since it has knowledge of future load and irradiation and can anticipate the overvoltage occurring, for example, between time 50–60 h and discharge the battery prior. Using the integrated squared deviation from V^U_{Grid} as performance criterion, we obtain 18.75 (no battery), 9.08 (PID control), and 7.07 (MPC).

Keywords – Power grid; photovoltaic; resilience



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