FAKULTA MECHATRONIKY,
INFORMATIKY A MEZIOBOROVÝCH
STUDIÍ TUL

SKFM 2023
STUDENTSKÁ KONFERENCE FM

Set of Economic Model Predictive Controls with Different Complexity for Smart Hybrid PV-Battery Microgrid

Pavel Vedel <pavel.vedel@tul.cz>, Lukáš Hubka

ABSTRACT

Nowadays, different Battery Energy Storage Systems (BESS) are of profound interest due to the need to balance energy in the grid and maximize the utilization of Renewable Energy Sources (RES) [1]. However, Li-Ion batteries are high-price consumable materials, and special inverters and converters are necessary to connect them to RES, load, and grid.

Predicative algorithms are usually used for such tasks. Algorithm model can be described by different complexity. A complex algorithm model should provide more accurate results, but at the same time, it takes more time to calculate it.

This work defines several algorithms and tests it on a virtual smart grid. Additionally, the work shows that it is necessary to find a compromise between the complexity and speed of the algorithms.

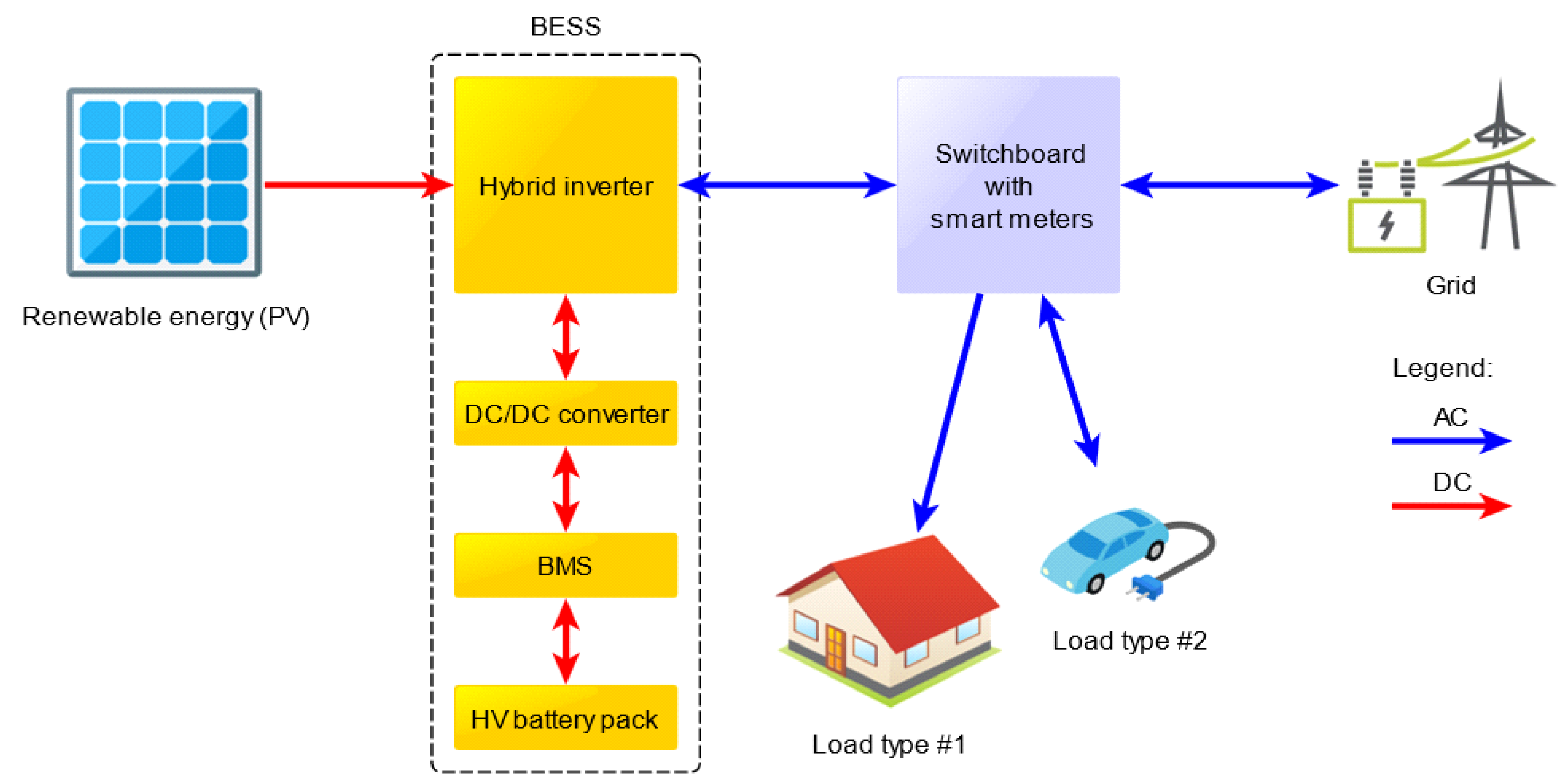
WORKFLOW

1. Specify system of smart hybrid PV-battery microgrid
2. Specify predictive controller and different complexity variants
3. Run the set of protective controllers in parallel on the virtual model
4. Compare controllers work

SYSTEM OVERVIEW

This paper considers a system consisting of RES, BESS (hybrid high voltage inverter, converters, and battery), load, and connection to the main grid.

Electricity prices are not flat and are based on the local electricity market (day-ahead market).



BESS
Hybrid inverter
DC/DC converter
BMS
HV battery pack
Renewable energy (PV)
Switchboard with smart meters
Grid
Legend:
AC
DC
Load type #1
Load type #2

CONTROLLER STRUCTURE

Economic Model Predictive Control (EMPC) can be used for a system that includes BESS [2], [3]. The basic idea behind this combination is to minimize total electrification expenses by transferring energy from one time to another. It can be used for load pick shaving in a system with renewable energy or a system with a non-flat price program.

In extended representation, EMPC equations for system with BESS is represented by (1-4).

$$\min\left\{\sum_{i=1}^{H} MOF_i + BUC_i\right\} \tag{1}$$

$$MC \tag{2}$$

$$SOC_i = SOC_0 + \frac{1}{Q^A}\cdot\sum_{k=1}^{i}\Delta t_k\cdot\left(I_k^C - \frac{I_k^D}{\eta^{CE}}\right),\ \forall i \tag{3}$$

$$0 \le SOC_i \le 1,\ \forall i$$

$$I_i^{bat} = I_i^D - I_i^C,\ I_i^C \ge 0,\ I_i^D \ge 0,\ \forall i \tag{4}$$

$$\left(I_i^C > 0\right) \wedge \left(I_i^D > 0\right) = 0,\ \forall i$$

$$BUC_i = \frac{Price^B\cdot\Delta t_i}{1-EOL}\cdot\frac{dSOH}{dt}_i \tag{5}$$

COMPLEXITY VARIANTS

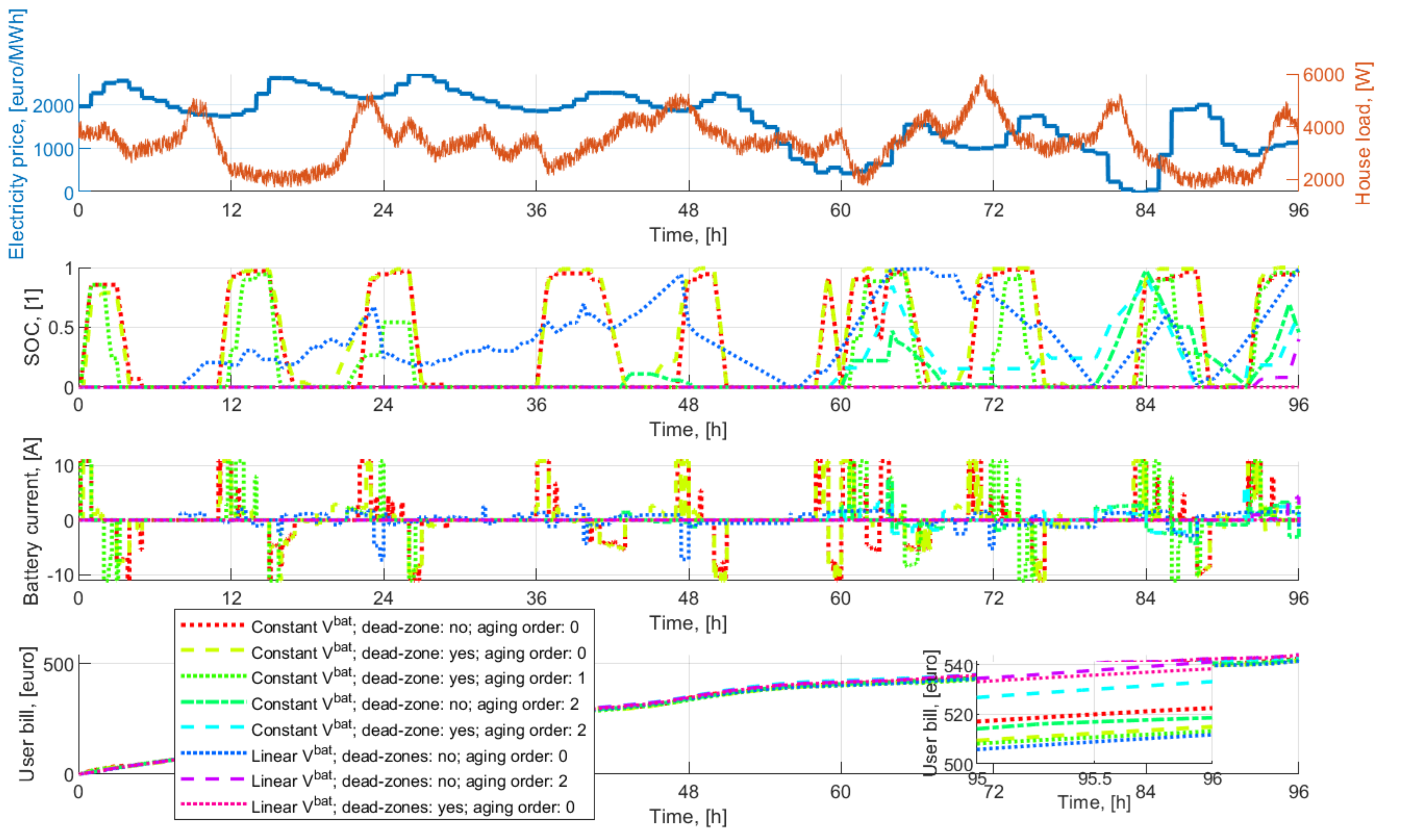
It can be possible to highlight 3 components which can have different representation. They are listed in below:

TYPE	EQUATIONS	ORDER
	Battery voltage	
Constant	$V_i^{bat} = V_i^{bat,mean}$	0
Linear	$V_i^{bat} = k\cdot SOC_i + b$	1
	Converter dead zones	
No	$P_i^{out} = P_i^{in}$	0 or 1
Yes	$P_i^{out} = \begin{cases}\eta\cdot P_i^{in}, & P_i^{in} > \alpha\\ \frac{P_i^{in}}{\eta}, & P_i^{in} < -\frac{\alpha}{\eta}\\ 0, & otherwise\end{cases}$	0 or 1 + binary variables
	Battery aging	
No	$\frac{dSOH}{dt}_i = 0$	0
1-st order	$\frac{dSOH}{dt}_i = f_i\left(I_i^C, I_i^D, SOC_i, SOH\right)$	1
2-nd order	$\frac{dSOH}{dt}_i = f_i\left(I_i^C, I_i^D, SOC_i, SOH\right)$	2

RESULTS AND DISCUSSION

The virtual smart grid model is the model of the considered system. Figure below shows the day-ahead electricity price, load, SOC, battery current, and final cost for different controllers.

It is seen that the most complex controller, which includes linear battery voltage, converter dead-zones, and 2nd-order battery aging function, cannot reach minimal cost for 4 operation days. One of the reasons, it is because solving such a controller takes a significant amount of time.



REFERENCES

[1] K. C. Divya and J. Østergaard, “Battery energy storage technology for power systems—An overview,” *Electric Power Systems Research*, vol. 79, no. 4, pp. 511–520, Apr. 2009, doi: 10.1016/j.epsr.2008.09.017.

[2] A. Cabrera-Tobar, A. M. Pavan, N. Blasuttigh, G. Petrone, and G. Spagnuolo, “Real time Energy Management System of a photovoltaic based e-vehicle charging station using Explicit Model Predictive Control accounting for uncertainties,” *Sustainable Energy, Grids and Networks*, vol. 31, p. 100769, Sep. 2022, doi: 10.1016/j.segan.2022.100769.

[3] P. Kou, D. Liang, and L. Gao, “Distributed EMPC of multiple microgrids for coordinated stochastic energy management,” *Applied Energy*, vol. 185, pp. 939–952, Jan. 2017, doi: 10.1016/j.apenergy.2016.09.092.

[4] P. Vedel and L. Hubka, “Linear Regression Model of Li-Ion Battery Capacity Losing Rate Based on Equivalent Circuit Model Parameters and Operation Modes,” in *2022 International Conference on Smart Systems and Technologies (SST)*, Oct. 2022, pp. 243–248. doi: 10.1109/SST55530.2022.9954715.

Tato práce byla podpořena z projektu Studentské grantové soutěže (SGS) na Technické univerzitě v Liberci v roce 2023.