Stochastic model predictive control of a set of electric vehicle charging stations for demand response service provision

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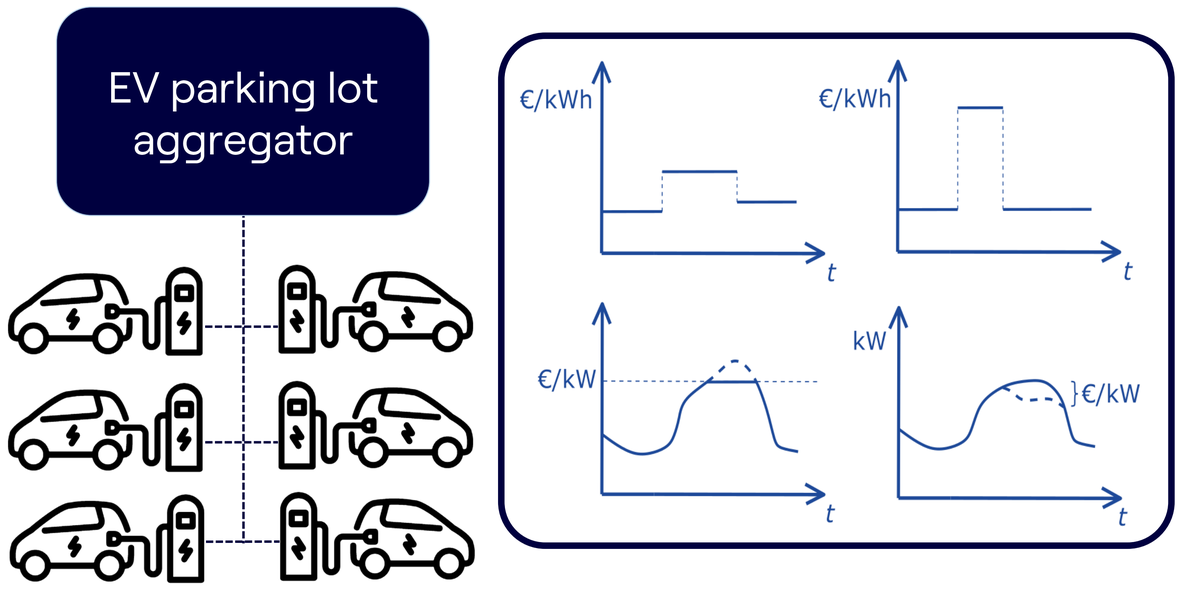
1. Introduction

Charging electric vehicles (EVs), whose number is increasing, is a great challenge for the power grid due to the charging load variability. Coordinated charging and schedule optimization with seized demand response opportunities are well-know conceptual solutions to that. Still, the main challenge is to adequately predict availability and parameters of electric vehicles which is crucial for determining the charging schedule and the demand response potential.

2. Problem description

It is required to predict future EV connected to the parking lot charging points of the aggregator and to optimize charging schedule that will provide economical benefits as the consequence of demand response.



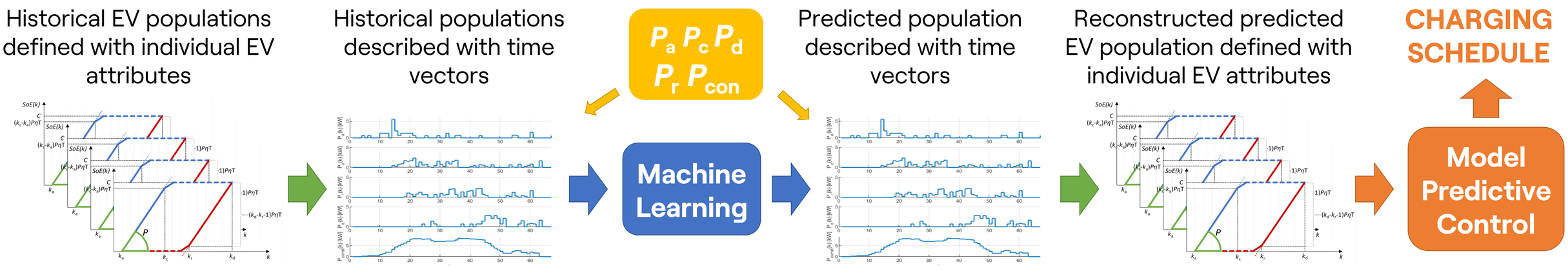
Conceptual scheme of EV aggregator and examples of different demand response tariffs: volatile energy prices, critical time pricing, peak power shaving, frequency control

3. Methodology

The proposed concept utilizes the innovative aggregated representation method (**green arrows**) that transforms historical individual on-arrival commitment data to five discrete-time vectors (**yellow**) related to envelopes of feasible charging powers and charging states for the EV population whereas these signals are suitable for quantification of demand response ability. The method has the following features:

- it captures population's flexibility to offer demand response;
- it can describe any EV population represented in discrete-time;
- it allows that every EV has a different nominal charging power, relative capacity and staying time.

Aggregated representation of historical EV data is fed to machine learning model to predict future EVs (**blue arrows**). The predicted data is basis to determine optimal charging schedule of all the EVs using stochastic predictive control (**orange arrows**).



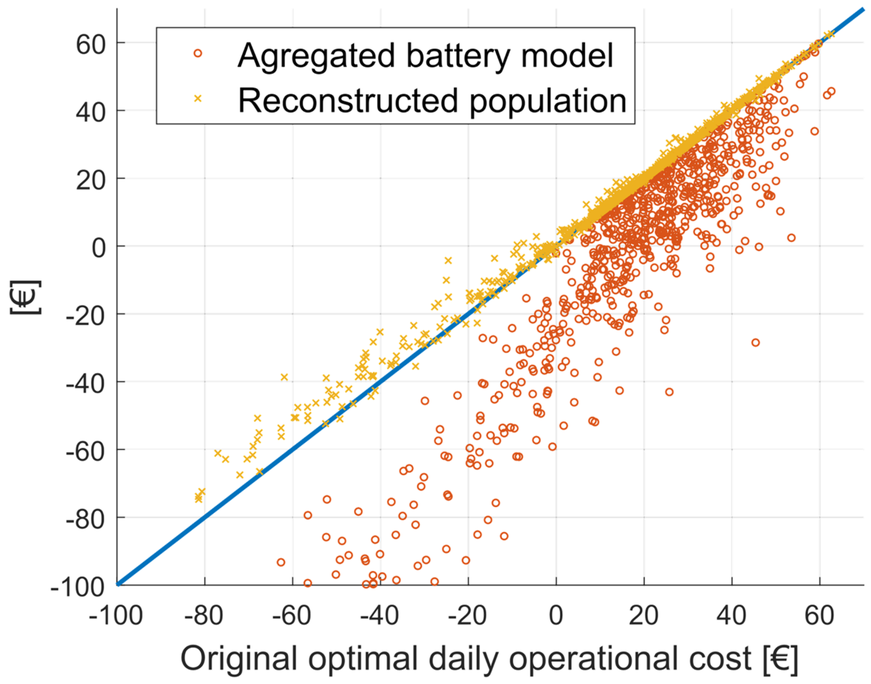
The proposed concept of aggregated population prediction using machine learning and charging scheduling of individual electric vehicles.

4. Results and conclusion

The proposed concept is tested every step separately. The innovative aggregated representation and the main hypothesis about its reversibility are tested by deterministically optimizing both the original and the reconstructed populations .

Prediction of future EVs is implemented using eXtreme Gradient Boosting (XGBoost) model which significally outperformed simple baseline of weekday average.

	Weekday avarage		Persistence		XGBoost	
	MAE /kW	RMSE /kW	MAE /kW	RMSE /kW	MAE /kW	RMSE /kW
P_a	1.375	2.197	1.120	2.785	1.021	1.983
P_c	1.318	1.955	1.021	2.365	0.765	1.586
P_d	1.336	2.113	1.160	2.774	0.723	1.613
P_r	1.344	1.912	1.063	2.316	0.917	1.648
P_{con}	6.503	8.983	0.809	1.953	0.807	1.557



Reversibility verification of aggregated representation

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