



# A robust optimization method for optimizing day-ahead operation of the electric vehicles aggregator

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## ABSTRACT

Due to consistently growing electric vehicles (EVs), penetration energy demand of the power grids is increasing all over the world. In near future a proper coordination of several EVs with the main grid is necessary to be developed. This system will mainly deal with the uncertain charging and discharging patterns of each associated EV to stabilize the grid. By deploying a vehicle to grid (V2G) framework excess energy stored in the EV battery could be supplied back to the grid. Every controlled EV owner, in order to motivate EV owners to take part in the V2G operation this paper proposes a profit enhancing EV-aggregation system which contributes to the Real Time and Day-ahead (DA) energy markets to minimize the energy consumption cost while enhancing the profits of both EV owners and energy suppliers. This framework determines the technical characteristics and uncertain driving patterns of each associated EV. A multi-stage hierarchical optimization model is proposed to regulate the decision-making process for EVs aggregation. The upper stage optimizes the profit maximizing aggregation decision by smoothing the EVs charging and discharging operation, while a sequence of lower stage constraints such as EVs dependencies (i.e., worst EVs State of Charge (SOC)) and reduced energy trading with the market are imposed. In last, these two layers are conjointly transformed into a mixed-integer linear-programming model which provides a completely uni-modular characteristic of the lower stage problem matrix which convexifies. In last, we have extensively analyzed the performance of the proposed hierarchical method with the pre-established stochastic and optimization models as well as comparison with the state-of-the-art techniques proves its effectiveness.

## 0. Nomenclature

The detail of notations used in this paper is given below, please note the superscripts  $u$  and  $v$  denote the projected and determined values respectively.

Indicators and Sets	
$T$	Number of time slots considered by $u$ .
$N$	Number of EVs determined by $v$ .
Parameters	
$C_u$	Overall charging power of $u$ in kW.
$D_u$	Overall discharging power of $u$ in kW.
$C_u^b$	Maximal charging power of an EV battery in kW.
$D_u^b$	Maximal discharging power of an EV battery in kW.
$E_u$	Maximal amount of energy stored in an EV battery in kWh.
$E_u^b$	Minimal amount of energy stored in an EV battery in kWh.
$A_u$	Minimal amount of hourly time slots in which an EV $u$ should be available during the desired time horizon.
$N_u$	Total time horizons in which optimization is possible.

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$P^g$	Overall Capacity of the grid in kWh.
$C_u^{p2}$	Cost of penalty \$/kWh.
$\alpha$	Linear approximation slopes of the EV battery life as a function of charging/discharging cycles.
$\delta_{u,v}$	Maximal availability time of an EV $u$ during the time horizon $v$ .
$\delta_{u,v}^b$	Minimal availability time of an EV $u$ during the time horizon $v$ .
$\eta_u$	Overall efficiency of an EV $u$ .
$\hat{E}_u$	Anticipated amount of energy, required daily for driving an EV $u$ .
List of variables	
$\alpha_u, \beta_u$	Rated Charging and Discharging power which can be supplied by an EV $u$ during time horizon $v$ .
$\alpha_u^b$	Total cost of degradation of an EV $u$ battery with respect to its charging or discharging cycles during the time horizon $v$ .
$\alpha_u^c$	Present SOC in kWh of an EV $u$ battery during the time horizon $v$ .
$P_u$	Total amount of power exchanged by an aggregator during the time horizon $v$ .
$\alpha_u^d$	

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