A Chance-Constrained Approach for Electric Vehicle Aggregator Participation in the Reserve Market

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Introduction

Electric vehicles (EVs) can play an important role as long as they are supported by an electric power system, essentially made up of clean energy. The technology of these vehicles is continuously evolving and they are now able to compete with vehicles that use fossil fuels. Given the likelihood of high percentages of EVs penetration in the future, it is also imperative to study the impacts it may imply on the electric power system. The charging of EVs should be scheduled smartly to avoid grid overloading during peak hours and to benefit from off-peak hours charging. So, EV aggregators are new market players who have to compete with each other and have the capability to attract new consumers. The EV aggregator is responsible for gathering a set of information on the EVs' characteristics and on the users' characteristics. All this information is handled and from this point on the aggregator is available to interact with the different market agents.

Methodology

This work proposes an optimization model for solving the EV aggregator problem, considering the uncertainty and risk associated to the EVs usage for reserve provision. The proposed model includes penalties in the event of a failure in the provision of upward or downward reserve. Therefore, stochastic and chance-constrained programming are used to handle the uncertainty of a small fleet of EVs and the risk behavior of the EV aggregator. Chance-constrained optimization through the deterministic equivalent (including Big-M and McCormick relaxation methods) are applied in order to assess the risk of the EV aggregator decision. Equation 1 shows the chance-constrained application to one of the problem constraints.

$$Pr(\Delta SI_{(t,\omega)} Y_t = r^{DW}_{(t,\omega)} - r^{UP}_{(t,\omega)} + RLXD_{(t,\omega)} - RLXU_{(t,\omega)}, \forall t \in T; \forall \omega \in \Omega) \geq 1 - \varepsilon \qquad (1)$$

Furthermore, it was applied to another constraint and reformulated to obtain the deterministic equivalent problem, which was performed through the Big-M method or by bilinear reformulation.

Results

It is meant to analyse the expected profit under Big-M method applied to two different chance-constraints, namely the TSO balance and SOC constraints of the problem. These constraints refer to technical aspects, so they can be assessed by the decision maker on the risk they are willing to address. The results show that Big-M method applied to the balance between system needs and the availability of the aggregator to provide the contracted reserve has higher expected profits than when applied to the SOC equation.

McCormick method was also applied to the TSO constraint. In table 1 are compared the results between this method and the Big-M method. The results obtained are very similar, however the McCormick method presents a better performance, since there are more cases where it presents a higher expected profit and, in the cases where that happens this increase is much higher than the cases in which the Big-M method performs better.

The biggest differences are also found for the largest number of scenarios, which may indicate that the McCormick method may get better solutions than the Big-M for real dimension problems.

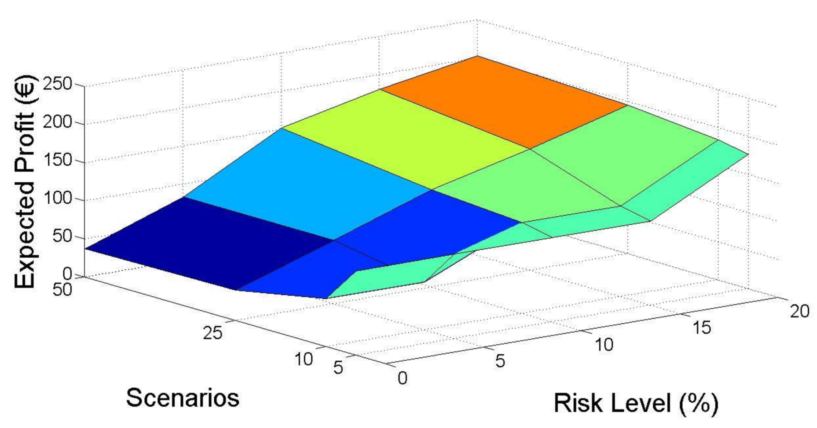

Figure 1 Expected profit by scenarios and risk level for the Big-M method applied to the TSO balance constraint.

Risk Level (ϵ)	TSO constraint			
	Scenarios (ω)			
	5	10	25	50
0%	0,0000	0,0000	0,0000	0,0000
5%	0,0000	0,0000	0,0000	-0,0149
10%	0,0000	0,0000	0,0001	0,1143
15%	0,0000	0,0000	0,0001	0,1018
20%	-0,0026	0,0000	0,0000	-0,0293

Table 1 Expected profit differences between Big-M and McCormick methods applied to the TSO balance constraint (%).

Another important issue for the aggregator is the timeline for submission of the offers. Thus, the tools should provide solutions within the limits for submission of the offers. More precisely, the aggregator must submit a offer even if it is not the optimal one within the time limits to ensure his participation in the market. This way, the computational effort was assessed and it is always possible to ensure a feasible solution to the problem.

Furthermore, risk assessment and its neglected costs analysis were also performed, so the aggregator can manage the risk and minimize it. It is important that the decision maker considers this trade-off between expected revenue and the potential costs of neglecting the worst case scenarios.

Conclusion

This work focuses on modeling the strategic offering of an EV aggregator, aiming to maximize aggregator's profit. To this end, a two-stage stochastic model with chance constrained programming was proposed to tackle the EV aggregator's problem. The proposed approach allows the aggregator to assess and submit their offers in the market under appropriate risk awareness.

The chance-constrained problem has been implemented following the deterministic equivalent way, which may require the use of relaxation methods. In this, the Big-M and the McCormick methods have been introduced, formulated and compared. The introduction of a binary variable and an M parameter allows the problem to be reformulated through the Big-M method. The McCormick method is used to derive the linear part of the mixed integer bilinear formulation.

The proposed methodology shows interesting results when analyzing the differences achieved under the Big-M and McCormick methods. In fact, the results present several similarities for most of the number of scenarios considered. For a low number of scenarios, the results are similar in both methods. However, when the number of scenarios increases, the differences start to become evident, which leads us to believe that for larger and real situations the proposed model under the McCormick relaxation method presents a better solution for the aggregator when it comes to the expected profit.

Lastly, this work contributes to optimizing the participation of EV aggregators in the reserve market. However, there is a different perspective that is analyzed using two different methods. This perspective aims to assess the risk that the aggregator should submit in the market, i.e. to give the aggregator the appropriate tools to reach the most appropriate decision. Thus, it is expected that it will be able to meet its primary objective - to maximize profits.