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Forecasts applied to EV charging optimization on energy market: results of a 1-year real deployment

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Summary

In this paper, practical results of company sites with electric vehicles charging are presented where forecasting tools were combined with a pre-existing smart charging algorithm in order to further improve the optimization of electric vehicles charging based on energy prices. The interest and limits of forecasting are shown on a real practical case and discussed in the context of a Time-of-Use approach.

Keywords: electric vehicles, smart charging, mass market, optimization

1 Introduction

Smart charging is related to a possible control of the charging sequences to respect some constraints and/or try to achieve some objectives [1],[2].

The needs for smart charging are of different orders. It is commonly admitted that smart charging will be necessary to face the growing deployment of EVs, namely for the local grid operators [3]. Moreover, from the user point of view, smart charging can be seen as an additional motivation for the choice of an EV instead of a conventional car, if e.g. lower electricity tariffs are proposed for charging flexibility [4],[5].

Most commercial solutions today are based on real-time and/or pre-programmed charging profiles. This might not be the most efficient solution when dynamic realities are to be considered: variable charging needs, variable other local consumptions, variable local energy production. Static or real-time based decisions to delay or modulate EV charging cycles might lead to negative effects in the future, if unforeseen events are to happen.

In the case of grid services or Time-of-Use approach, non-optimal choices might lead to a direct financial impact.

In this paper, a real implementation is presented where a forecast is used of electric vehicles energy needs in order to be an actor on the energy market and optimize the charging costs.

2 Forecasts applied to smart charging

Smart charging induces an action on the charging session power curve, inducing among other things a delay in the end of the charging session, compared to charging in nominal, uncontrolled conditions. Without an adequate anticipation, delaying the charge might lead to unexpected results (e.g. the cars are not charged as the user would expect) or congestion problems (if some user needs have to be specifically fulfilled). A good optimization should therefore include the forecast of EV charging needs. Several technical options exist, that have been addressed in the literature [6].

The charging infrastructure is often part of a wider electrical installation, including other variable loads. Some of them can be controlled as part of a global energy management system, while others cannot and are then an additional dynamic constraint of the global installation. Being able to anticipate those last ones by using an appropriate forecast of site consumption leads to better possible optimization of the EV charging.

Next to the EV and site consumption forecasts, forecast of local energy production can also be considered.

In this paper, concrete results are presented based on the forecast of electric vehicle needs integrated into the smart charging solution of ENGIE.

3 Process explanation: optimisation based on energy market price

The authors have been developing an advanced smart charging solution for several years. It was deployed on many locations worldwide, including small and large sites. Various charging optimization objectives were implemented, among which energy price optimisation. Forecasting functionalities were developed and implemented in this last scenario.

The controller modulates the charge in order to respect the following criteria:

1) Ensure that the site electrical constraints are always respected
2) Ensure that each user's energy and time requests are optimally encountered
3) Ensure that the two previous criteria are met while minimizing the charging energy cost.

To take benefit from the energy price market, the expected energy profile must be engaged in the electricity market the day before, in order to organize the day ahead hourly balance between offer and demand [7]. For this purpose, the smart charging algorithm integrates the day-ahead forecast of electric vehicles' needs.

Once a day (D-1), the smart charging algorithm, so-called SMATCH, and GEM, ENGIE's global energy management entity, working as an aggregator, are interacting as follows:

- SMATCH iterates with the aggregator to provide him the best expected charging profiles for the next day (D), based on a forecast of the EV charges to come, the predefined constraints and objectives of the site and different energy price forecast scenarios (see example on Figure 1);

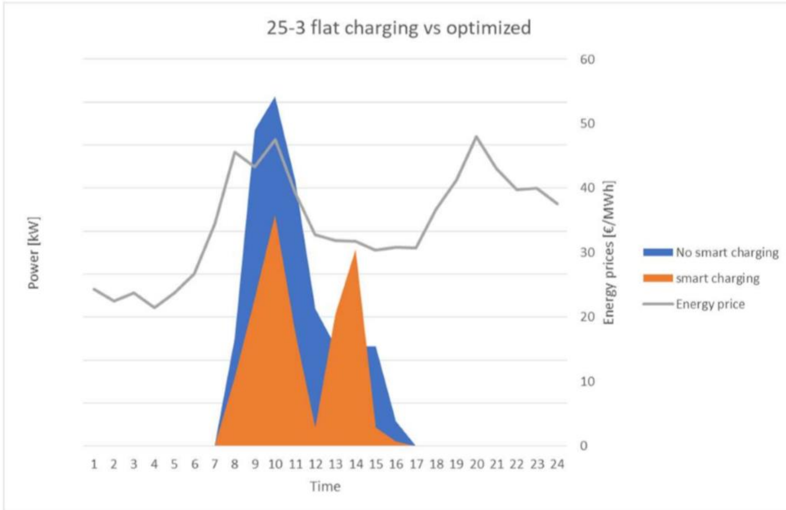

Figure 1: Smart Charging optimisation based on energy prices

- On day D-1, the aggregator selects the best charging profile, maximizing the reward/risk fraction and communicates it to SMATCH, and on day D, the selected charging profile is applied as a complementary objective during the real-time EV charging control on the site (see example on Figure 2).

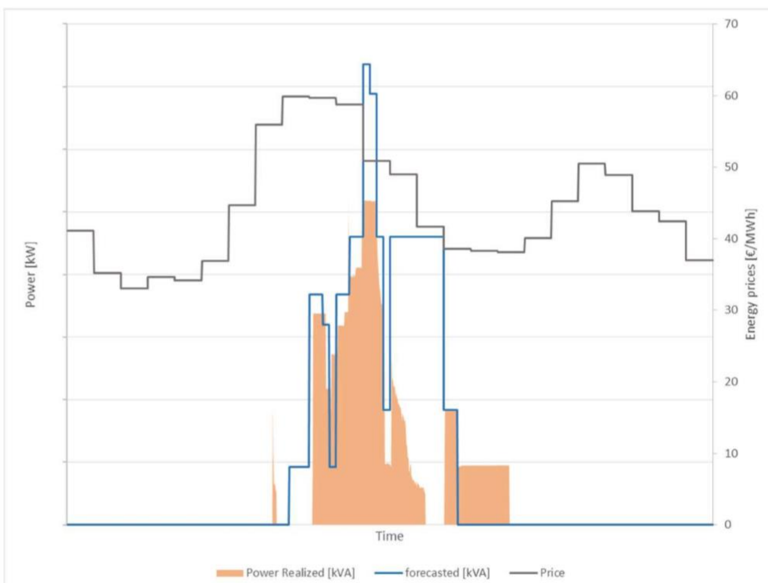

Figure 2: Realized power on day D vs day D-1 forecasted power

4 Implementation of the solution

The process has been tested throughout 2019 on multiple sites aggregating a total of 16 charging points, 22 kW maximum each (three phases, 32 Amps per phase) for a global maximum power of 352 kW.

The aggregation of the charging points enables to extract more charging flexibility which was offered for energy market optimisations. On site perspectives, the smart charging was always set to respect the local constraints and had for first objective to fulfil the needs of the electric vehicles drivers: charge the amount of energy necessary within the time requested.

The test sites were located in business area, therefore the EVs were available to charge mainly during the working hours in the day.

During the entire test period, the controller optimised the charging sessions based on multiple price scenarios representative of the market, as illustrated by Figure 3 below. On a daily base, he prices are globally higher in the morning between 7 and 10 o'clock while it is typically the connection time of electric vehicles on business sites.

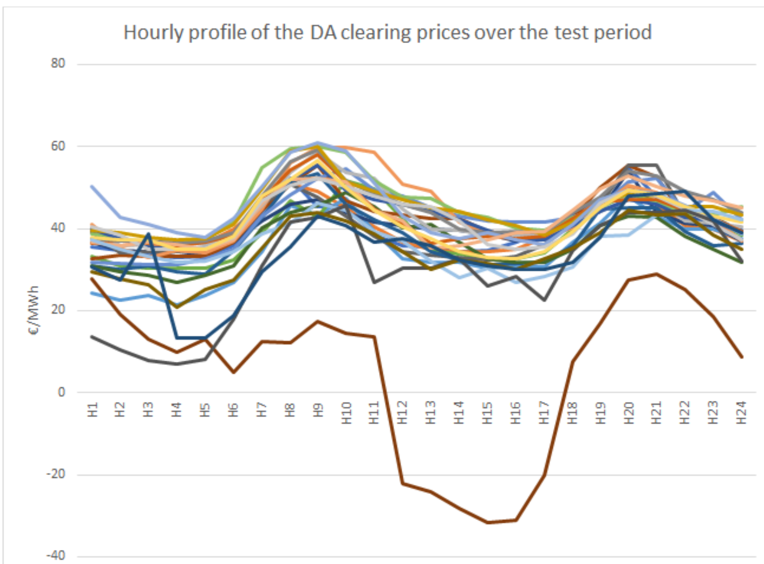

Figure 3: Energy price scenarios

5 Results and analysis

5.1 Smart charging optimisation based on the forecast

The smart charging solution can only predict the ideal charging plan for tomorrow if it has the knowledge of the needs of tomorrow in terms of energy consumption and time. Thanks to the forecaster developed, the future electric vehicles needs are known by the controller and it can optimise their charging plan in function of each price scenario. The optimised charging plans calculated by the controller are gathered on Figure 4.

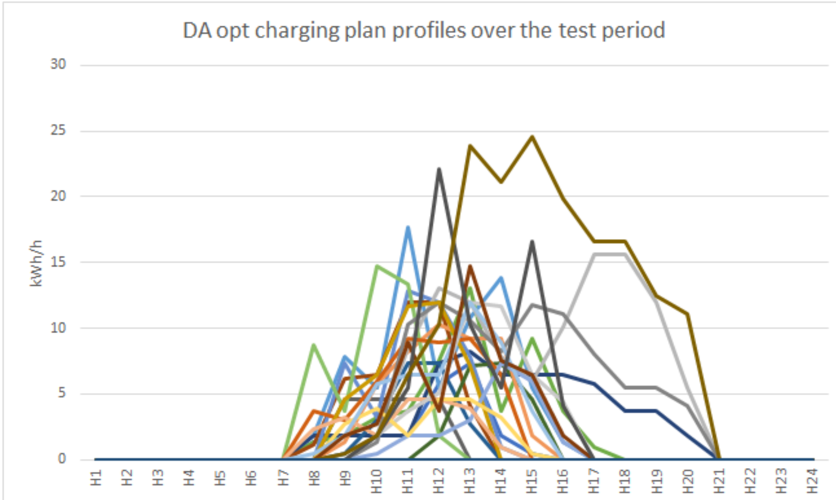

Figure 4: Smart charging outputs in function of price scenarios

All those charging plans resulting from the energy price optimisations are summed on Figure 5 and compared to what would happen without the price optimisation. There is a clear evolution of the charging power: it is generally delayed to the afternoon when the energy is cheaper compared to the morning peaks.

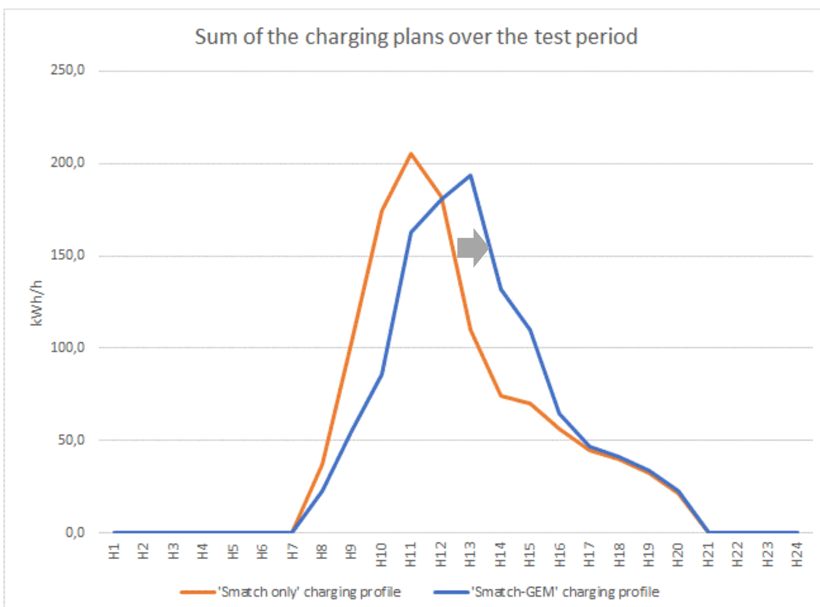

Figure 5: General effect of the smart charging optimisation based on energy prices

Further analysis has been made in order to better understand the flexibility extracted from the electric vehicles charging. As can be seen on the Figure 5, not the entire energy consumed can be moved at the moment the energy is the cheapest, this is mainly due to the respect of the site constraints and the electric vehicle drivers needs.

For those reasons, the flexibility extracted can vary from day to day and the financial added value depends of this flexibility extracted and of the price variation of the day. A closer look is made on Figure 6.

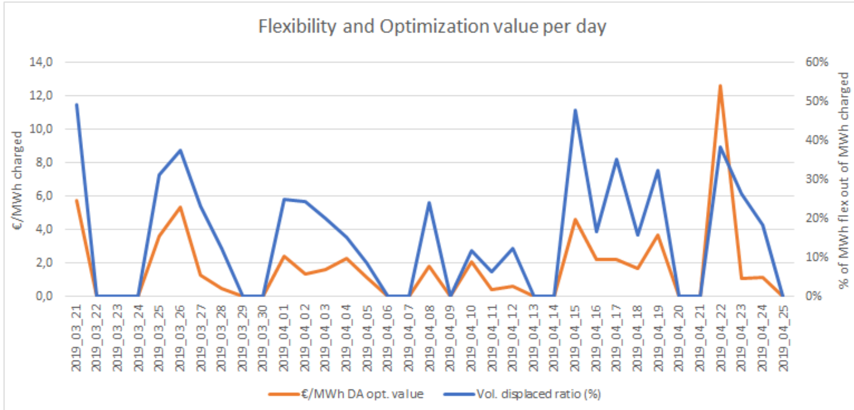

Figure 6: Flexibility and financial added value extracted

The flexibility extracted from the forecast of electric vehicles needs and site constraints went up to 51% with an average of 21% for the entire test period. On financial perspectives, the value captured by the optimisation is on average 2.3€/MWh and represents 6% of the wholesale charging costs over that period.

5.2 Application of the charging plan in real time

When the ideal charging plan is defined on day D-1, on day D the controller must align the real charging sessions of the sites in real-time with the charging plan defined the day before.

The success of the application of the charging plan is directly correlated with the forecast accuracy: it is only possible to fit with this charging plan if the real needs on day D are the same as the one forecasted on day D-1.

When the forecast was correct, the charging plan can be realized by the smart charging controller such as represented on the left of the Figure 7. On the other hand, if the forecast is wrong in terms of energy needs and EV availability, the controller cannot follow the charging plan defined. This is illustrated on the right chart of the Figure 7 where the energy needs were overestimated by the forecaster.

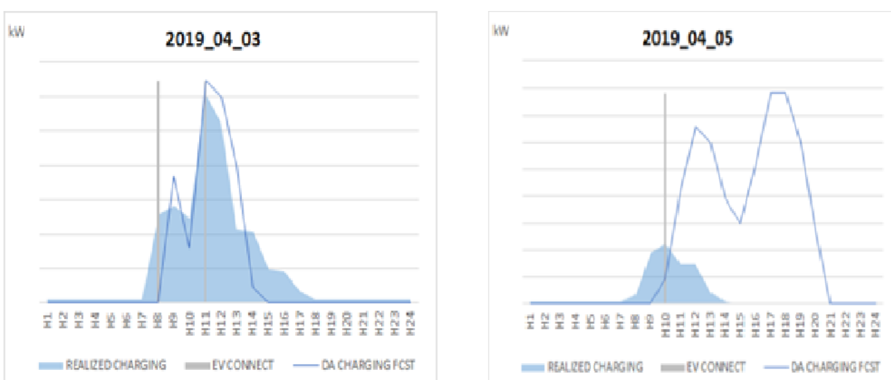

Figure 7: Real time application of the charging plan

The accuracy of the forecaster varies a lot in function of the days. The average error on the amount of energy charged between the forecast and the reality was -25 kWh and its median (P50) was -15kWh.

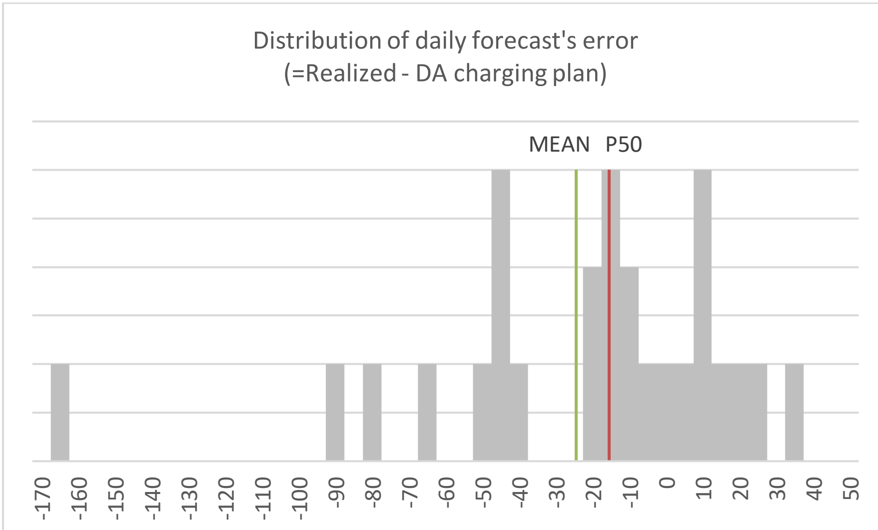

Figure 8: Forecast accuracy

Next to the inherently hard to predict human behaviour, the variability is high because the tests were carried on small sites. Therefore, a change of one driver's behaviour may have a strong impact on the total. The increase of EV aggregated will enable to reach a more global trend less sensitive to individual changes and will improve the forecast accuracy. This will be done by aggregating more sites controlled by the smart charging solution.

6 Conclusion and next steps

This report presents a case where, next to the optimization of local objectives while respecting the local constraints, the smart charging algorithm is also aimed at following a day-ahead defined global power curve.

The solution was first deployed on an aggregation of 16 charging poles from different business sitesIt was used during several months in real conditions, in order to quantify the efficiency of the forecast, and the real feasibility and result quality of the Time-of-Use approach, when combined to the smart charging algorithm.

Despite the small amount of chargers and cars in the considered case, leading to possibly important variability in the daily behaviours, the results show that the smart charging algorithm in combination with the charging forecast manages the day-ahead objective in a quite efficient way. It was possible to displace in average 21% of the amount of energy charged to serve energy market optimisation. This flexibility can also serve other purposes such as grid services. By releasing some site constraints, simulations showed that this flexibility can be increased up to 50%, and practical implementation is on the run.

In the next steps, the amount of EV charging aggregated will be increased to reach the minimum volume conditions of the day-ahead aggregation market; this will lead to more forecast accuracy, more flexibility extracted and more financial added value.

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