E-CAR AND ECONOMIC IMPACT: ENHANCING THE SMART GRIDS II

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ABSTRACT

The future penetration of electrical vehicles and the related increase of electrical energy demand may impose new requirements on the power system and affect network operation. However, the flexibility of the vehicles' charge turns out to be suitable for the deployment of control and demand response strategies.
Both EV demand aggregators and the procedures used currently at transmission networks might help maintain suitable power quality and reliability standards in distribution networks even under a massive penetration scenario of electrical vehicles.

INTRODUCTION

This paper presents the final conclusions of a research work developed with the scope of exploring ways to reduce the electrical vehicle (EV) impact on distribution networks, while optimizing economic benefits for load aggregators. The research was carried out in the frame of the Spanish R&D project VERDE led by SEAT and partial results were already presented in CIRED 2012 [1].
The role that information and communication technologies (ICT) will play in future distribution networks opens broad operation and control capabilities, allowing for the efficient integration of EVs and distributed energy resources, including demand response (DR) strategies, which should result in an efficiency improvement and in an environmental impact reduction of the electrical system.
Two SIEMENS commercial software applications were used to simulate the proposed methodology: DEMS and PSS/E. The reference scenario was built upon real network data provided by IBERDROLA and related to the area of the Spanish city of Vitoria.
First, a distribution network operation procedure will be proposed based on that deployed currently for transmission networks in relation with the electricity market rules. Next, the work methodology used for the analysis will be explained and some of the results of the simulation will be shown. Finally, the main conclusions of the research will be presented.
Nowadays, the demand aggregator is not a common actor in European networks. This is a role played today by energy suppliers, but in the future it could also be played by new agents such as the Recharge Manager, a figure defined by the Spanish regulation able to sell electricity only for the charge of EVs. Throughout this paper the term demand aggregator will be used to refer to all agents able to execute electricity supply contracts for EV charge.

DISTRIBUTION NETWORKS OPERATION PROPOSAL

The increase of distribution network controllability is necessary to face both generation and demand variability by means of flexibility. However, it requires setting up and defining procedures able to guarantee optimum power quality and reliability levels. For this purpose, the operation procedures of the transmission network were taken as starting point to design the operation of distribution networks.
One of the main roles of TSOs in the definition process of daily electricity generation programmes is the technical restriction detection and solution [2]. For this purpose, the TSO runs a simulation of the network system considering the expected values of demand and generation for each of the periods in the following day (operation base programme). By means of a load flow analysis, the TSO is able of detecting the locations in the transmission network where parameters may result out of adequate operation margins. Then, the TSO requests the modification of the programme to guarantee the security and stability of the system and the provisional viable programme is issued as result.
The proposed methodology extrapolates partially the previous two steps to the distribution network level. The DSO would then fulfil the analysis currently performed by the TSO and would interact with demand and generation aggregators in order to keep distribution network characteristics under suitable levels.
The deployed methodology considered that the only controllable load was that of the EVs, while conventional demand and distributed generation were considered not flexible for simplicity purposes.
Several EV demand aggregators were taken into account. They were responsible for supplying electricity to their clients (EV users) and they were thought to be able to manage their customers' demand and offer demand response services to the DSOs through contractual relationships.
The main steps taken in the analysis are described below more in detail.

Demand aggregator's load forecast

Making use of demand forecast and optimization tools, the aggregators would send daily their EV related demand programme to the DSO/s in charge of the distribution networks their clients are connected to, for each of the defined nodes and market time periods.
The difference with the transmission network procedure is that, in this case, the network area is considered in the programme due to the fact that loads are mobile.

Distribution System Operator (DSO) validation

The DSO carries out the technical validation of the network operation. The EV demand forecast received from the aggregators is added to the conventional demand estimation (residential, commercial and industrial) in each of the distribution network nodes. Then, the available distributed generation information would be considered and load flows would be run for every time step of the following day. Load flows would permit to identify the nodes of the network in which power quality parameters would result out of the required range addressing, for instance, saturated line/cable segments, saturated distribution transformers, voltage out of margins, etc.

Feasible daily programme

EV demand aggregator companies would modify their operation programmes based on the technical restrictions identified by DSOs (load flow results). Load supply adjustments should be realized by the aggregators taking care of the contractual relationships existing between them and each of their customer EVs.

METHODOLOGY

An algorithm was developed with the scope of integrating both softwares deployed in the analysis: on the one side, the demand aggregators' planning and optimization tool (DEMS software) and, on the other, the DSO off-line network analysis tool (PSS/E software).

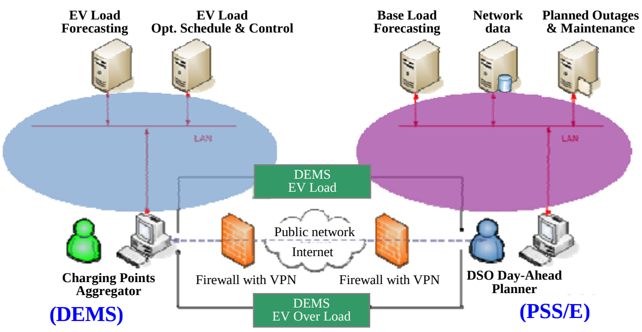

Figure 1: Integration of DEMS and PSS/E SW applications for distribution network operation.

The virtual power plant (VPP) concept lies on the basis of the DEMS software. It permits the planning and operation of a group of loads, generation sources and storage. In this case, the planning functionality of the application was deployed. Quarter-hourly periods were defined for the next operation day and an economic optimization of the system was run for each time step, considering forecast data of demand, weather and the electricity market price. This optimization defined the operation programme for EV supply for the next day taking into account aspects such as the periods of the day with higher levels of renewable generation, the price of electricity and the demand expected for EVs along the whole day.
Regarding the technical restriction analysis, real network data was extracted from the DSO's power control system and used to perform simulations with the PSS/E software. The economic optimization is, therefore, validated technically by running power flows on this network considering hourly time steps.

SIMULATION RESULTS

Based on the distribution network operation proposal and on the methodology described above an implementation was carried out on a defined used case.
An area of Iberdrola's distribution network was selected in the city of Vitoria (Spain), ALI substation's transformer no. 4 and downstream MV feeders and distribution transformers, to be precise.

Figure 2: 25kV distribution network supplied by ALI substation transformer no.4

2020 time limit and an EV penetration of the 6%, with respect to the total number of vehicles in the Spanish market in 2008, were considered. Figure 3 shows a scheme of the VPP managed by the aggregator.

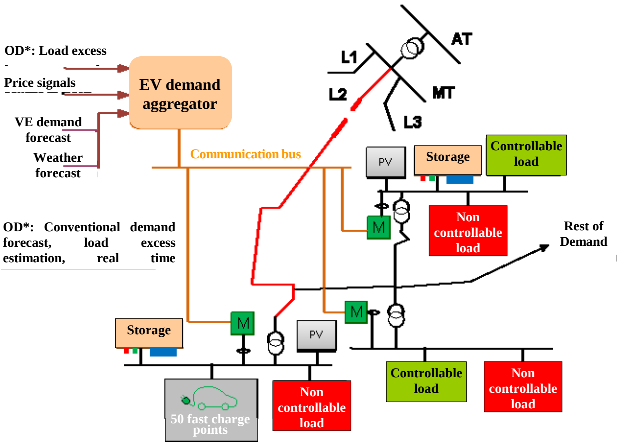

Figure 3: VPP managed by the aggregator

Three cases were analysed.

Saturation at substation level

The technical restriction process, after the optimization by the aggregator, resulted in the necessity of re-planning the EV demand supply, due to the saturation of the transformer at the substation.

The following two figures show the total load curves at transformer no.4 before and after the technical constraint analysis and DSO programme validation.

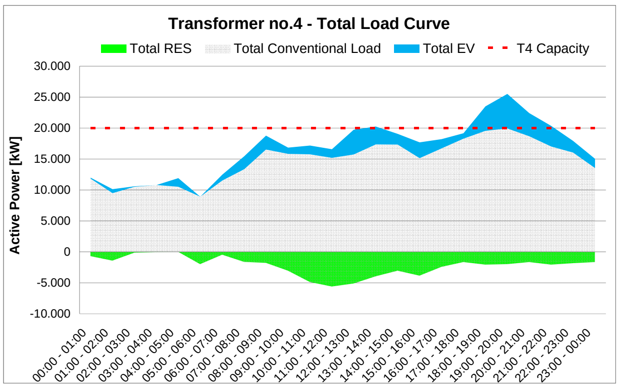

Figure 4: EV demand curve forecast as result of the aggregators' economic optimization. Substation.

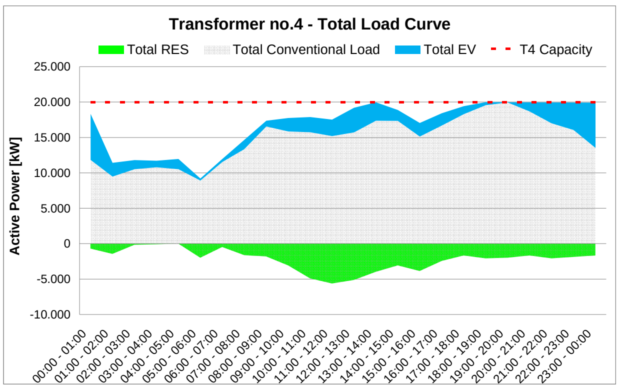

Figure 5: EV demand curve programme as result of the DSO's technical validation. Substation.

However, even if the saturation problem was resolved at the substation transformer, some feeders supplied by it remained overloaded. Therefore, the restriction solution analysis was performed at MV circuit level.

Saturation at MV feeders

It was considered that the EV demand affecting the saturated MV feeder was contractually related to different aggregators. These agents would optimize the electricity supply programme from an economical point of view, considering both contractual agreements with their customers and technical restrictions addressed by the DSO. The next figures show, as in the previous case, that after the restrictions solution process the saturation of the feeder is avoided for all time steps in the day.

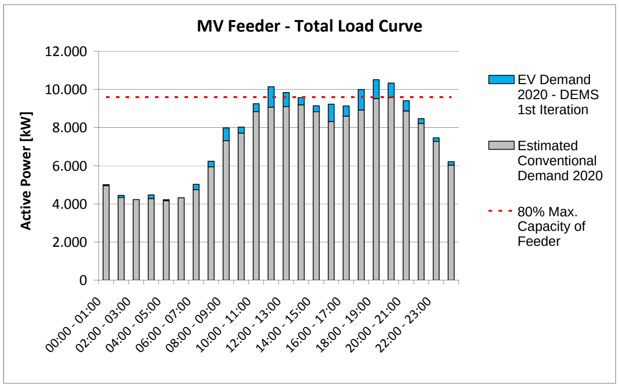

Figure 6: EV demand curve forecast as result of the aggregators' economic optimization. MV feeder.

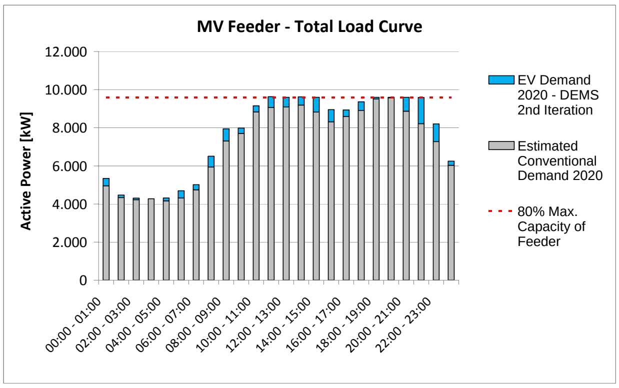

Figure 7: EV demand curve programme as result of the DSO's technical validation. MV feeder.

The following step focused on eliminating the saturation at distribution transformer level within the feeders.

Saturation at distribution transformers

A similar procedure was applied in this case at distribution transformer level and results are similar.

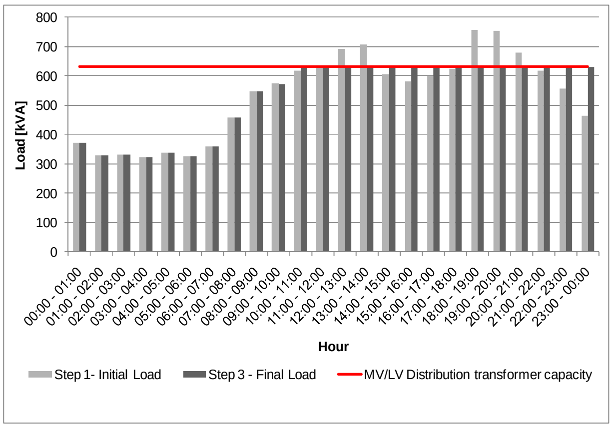

Figure 8: EV demand curve programme as result of the DSO's technical validation. Distribution transformer.

CONCLUSIONS

As result of the research work described throughout the present paper the following main conclusions were obtained:

1) In the short term, it is expected that the EV integration will not pose significant problems to transmission and distribution networks. Additionally, electrical vehicles present the advantage of behaving as controllable loads, therefore, the deployment of demand response strategies in EV context may contribute to enhance the efficiency of the electrical system.

2) In the case of a massive penetration of EVs connected to distribution networks, system upgrades leading to new investments might be necessary. The deployment of control procedures at distribution network level might reduce the saturation of network assets and the investments associated to refurbishing needs.

3) The deployment of some of the procedures used at the transmission level, such as the solution of technical restrictions, proves to offer positive results for the planning and operation of distribution networks. The implementation of these procedures can be carried out by means of commercial software applications for the analysis and operation of electrical networks.

4) The introduction of new operation procedures at the distribution networks to deal with electrical vehicles makes essential an active participation of EV demand aggregators. Regulatory changes might be required depending on the country.

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