# Mobile Energy Resources in Grids of Electricity: the EU MERGE Project

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## I. Introduction

Electric power systems are facing a major new challenge (and hence opportunity): future massive integration in the electric grid of electric plug-in vehicles (EV). Since these vehicles will require the use of batteries with high energy storage capacity and possibilities of high electric load charging requirements, a large deployment of this concept will provoke considerable impacts in electric power system design and operation.

When parked and plugged into the electric grid, EV will absorb energy and store it, being also able to deliver electricity back to the grid. The latter is the distinctive feature of the V2G concept, allowing the provision of several ancillary services like peak power and spinning reserves.

It is important to understand that the existing power system infrastructure is capable of handling large scale integration of EV without the need of large grid and generation reinforcements, provided that a specific control solution is adopted. This will be made by controlling EV battery loading and thus avoiding the peak load conditions in the electrical grid and in the generation system.

A large deployment of EV will involve:

- Evaluation of the impacts that battery charging may have in system operation;
- Identification of adequate operational management and control strategies regarding batteriesôcharging periods;

- Identification of the best strategies to be adopted in order to use preferentially RES to charge EV;
- Assessment of the EV potential to participate in the provision of power systems services, including reserves provision and power delivery, within a V2G concept.

The EU MERGE project involves the development of a methodology consisting of two synergetic pathways:

- Development of a management and control concept that will facilitate the mobility shift regarding the power system operation ï the MERGE concept;
- Development of an evaluation suite that consists of methods and programs of modelling, analysis, and optimization of electric networks into which electric vehicles and their charging infrastructure is integrated.

In order to allow EV controllability and be able to provide flexibility to the electric power system, the MERGE concept requires that a two layer control approach should be developed, consisting of a local control installed on board of the vehicle, capable to respond to voltage and frequency changes and an upper level control structure to manage globally the provision of services by clusters of EVs. For this purpose, each EV must be equipped with:

- An electronic interface for grid connection, responding locally to the grid electrical variables variations to allow controlled electric energy exchanges, requiring a bidirectional communication interface to communicate with managing entities;
- A direct connection to a meter device (installed on board or outside the EV).

The upper level control involves a new entity - the supplier / aggregator, who will be in charge of managing at regional and national level large clusters of EVs.

In this paper preliminary results of the MERGE project and a conceptual description of the proposed management and control approach are provided.

## II. Identification of Traffic Patterns and Human Behaviours

The identification of traffic patterns and human behaviours is crucial to accurately evaluate the EV impacts in distribution networks and to implement efficient EV charging management strategies, as they will define the extra amount of power that EV will demand from electricity networks. Therefore, within the context of the MERGE Project, it was developed a survey with the objective, among others, of obtaining reliable data about current vehicle usage patterns of drivers from some European countries: Germany, United Kingdom, Spain, Greece, Portugal and

Ireland. The data analysed in this survey was collected using a targeted questionnaire that was filled in by a total of 1,621 people from a number of countries in Europe, from a range of backgrounds, providing a sound basis from which to draw conclusions and perform analysis [1].

The extra power demanded by EV, during one typical day, can be quantified based on knowledge about:

1. the hour EV connect to the grid for charging purposes;
2. the amount of power absorbed during the charging period.

Based on the answers received from the questionnaire and assuming a 10% penetration of EV in the total vehicle fleet, an average daily distance travelled of 40 km, a charge rate of 3 kW and that all vehicles are plugged in, and begin charging, immediately when they return from their last journey of the day, the total power demand for the above mentioned countries was computed. As an example, Figure 1 presents the impact on Greece's electricity demand of introducing a penetration of electric vehicles of 10% of its total vehicle fleet.

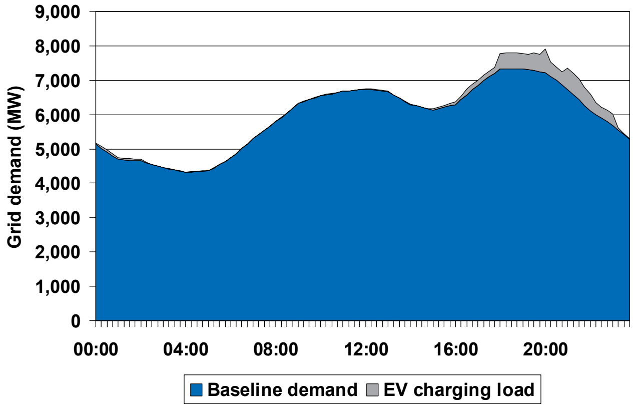

Figure 1 - Effect of dumb charging scenario on Greece's electricity demand [1]

It is important to stress that these results were obtained assuming a dumb charging scenario, meaning that all EV start charging as soon as they arrive home from their last journey of the day. The peak load of the baseline demand was 7,339 MW at 18:30. The peak EV demand was 687 MW at 20:00. The addition of the EV demand to the baseline demand created a new peak of 7,902 MW at 20:00 [1].

Nonetheless, the peak load increase obtained in the dumb charging scenario might be mitigated by means of adopting a smart charging approach. The smart charging scenario assumes that a control system can be put in place that can instruct specific chargers to begin or stop charging, or limit charge rate, so that the total demand for EV charging at a particular time can be dictated by the system. This scenario represents the ideal situation where the overall load on the grids is levelled, so that valleys of demand are filled and existing peaks are not increased.

According to the survey results a significant majority of responders would participate in smart control of charging (Figure 2), if multiple-tariff electricity rates were used to incentivise it. A number of studies were therefore performed to evaluate the impact of the smart charging approach in the above mentioned countriesôelectricity demand.

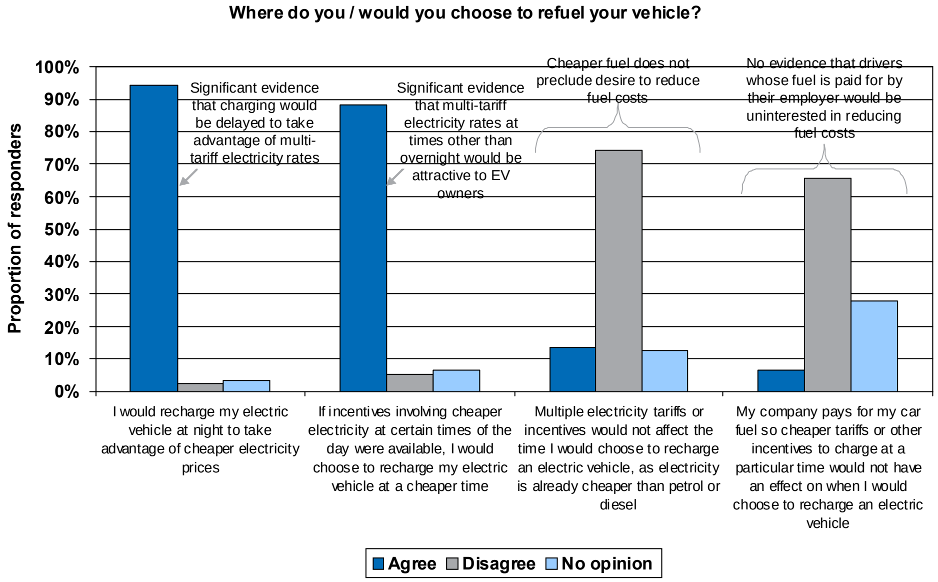

Figure 2 - Responses to questions regarding adaptability to alternative charging times to take advantage of variable tariffs [1]

In Figure 3 the impact of the smart charging approach in the Greeceôs power demand is presented, assuming that all charging is moved to the night-time valley periods, a 10% penetration of EV in the total vehicle fleet, an average daily distance travelled of 40 km and a charge rate of 3 kW.

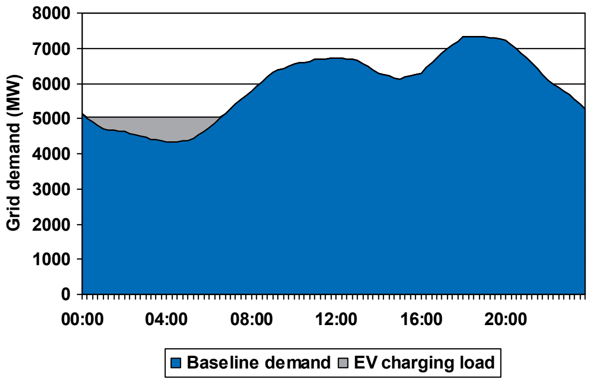

Figure 3 - Effect of smart charging scenario on Greeceôs electricity demand [1]

The peak load of the baseline demand was 7,339 MW at 18:00, which was not altered by the addition of the EV charging load. The peak EV demand was 727 MW at 04:00, up 6% from the peak EV demand for the dumb charging scenario 687 MW at 20:00 [1].

## III. Communications

In order to implement the smart charging strategies referred earlier, it is necessary to account for a reliable communications system capable of handling the information exchanged between the involved parties. Furthermore, the integration of EV in the smart grids context will make the communication systems an even more crucial element, since it will ensure the required information flows between all the parties involved [2]. Taking this into account, an Information and Communications Technology (ICT) model was developed in the MERGE Project, in order to enable the implementation of smart charging schemes and smart metering procedures. This ICT model, proposed as part of the EV interface with the grid, is described in the next subsection.

### *Information and Communications Technology*

The ICT model presented in Figure 4 identifies the involved parties and the associated information flows from technical and market perspectives. It accounts for the exchanged data between the different actors regardless of the location of the charging point (public or private) and the type of access (public or private) **Error! Reference source not found.**.

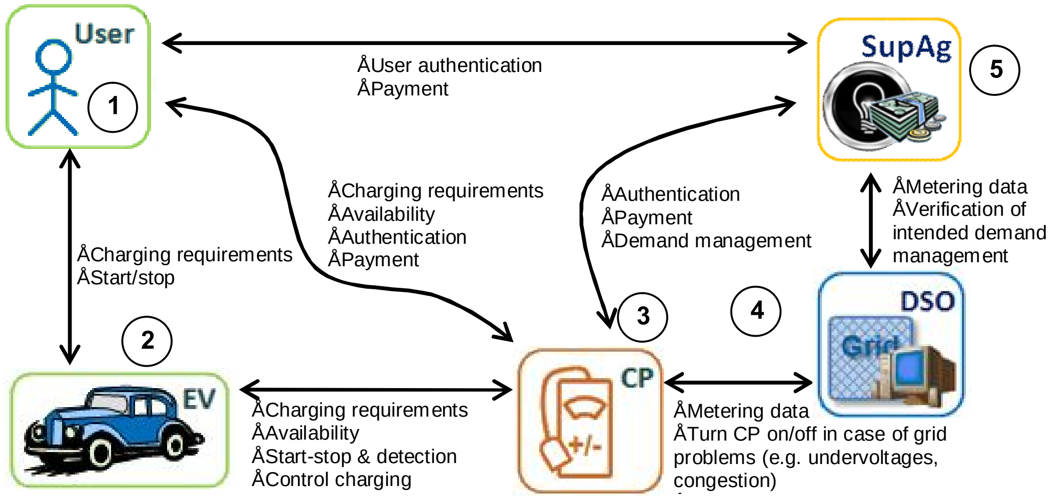

Figure 4 - Overview of different information flows

The charging point is associated with a Smart Meter (SM) which will be responsible for the management of the EV. The SM will also interact with Distribution System Operator (DSO) and the service provider, which can be either a supplier or an aggregator (SupAg). The SM is thus responsible for delivering functionalities that allow large scale deployment of EV and enable more ambitious Demand Side Management (DSM) solutions.

### *Smart Metering*

Under the smart grids context, concepts such as advanced metering infrastructure and SM have gained considerable attention. In the MERGE Project the definition of SM unifies concepts such as advanced meter reading, automatic meter management and advanced metering infrastructure, providing a single and universal entity to address the EV integration under different scenarios.

The expected functionalities introduced by SM along with suitable communication systems, will allow a more detailed characterization of consumers and enhanced control strategies of the distribution network. These functionalities will have to deal with the electric mobility introduced by EV taking advantage of the identified traffic patterns and human behaviors. The SM can be regarded as a gateway for the exchange of services between consumers and service providers [3], being also responsible for the local management of the EV, establishing the necessary communications with it through the charging point and with the electric grid. In a public environment the SM will provide the necessary interaction of EV users with market agents (SupAg) and technical agents (DSO), as depicted in Figure 5, [4].

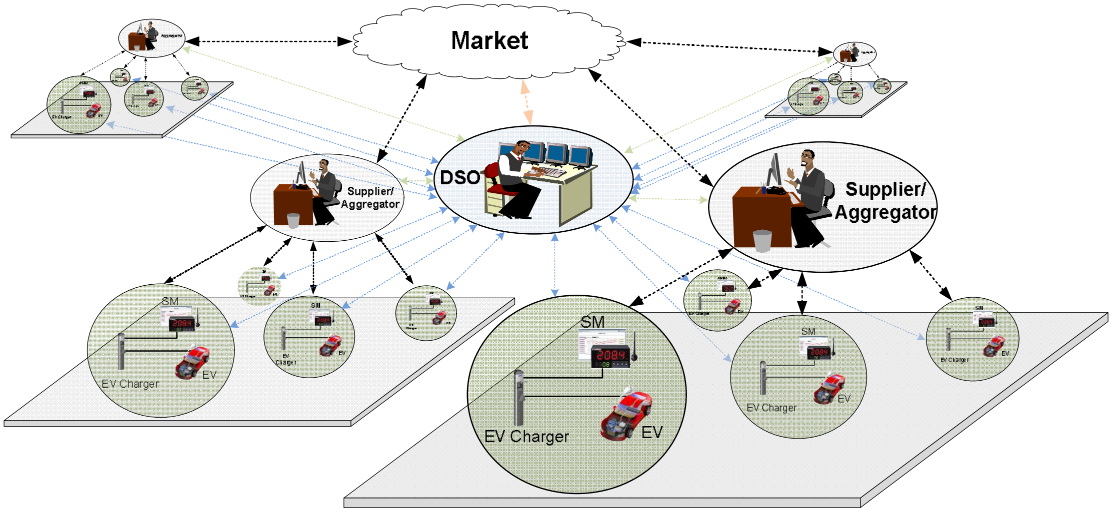

Figure 5 - Framework for EV charging management and control

In a domestic environment, besides the interaction described in the public environment, the SM will also have the capability of establishing a home area network which might manage local loads, available microgeneration and EV.

## IV. Control and Management Architecture

The simple use of a local control installed on board smart EV grid interfacing device does not solve all the problems arising from EV integration in distribution networks. These smart interfaces can be rather effective when dealing with voltage drops originated by EV charging, by locally decreasing charging rates through a voltage droop control approach [5], but fail when addressing issues that require a higher control level, such as managing flow congestions or enabling EV to participate in the electricity markets. For these cases, coordinated control is required and therefore a hierarchical management and control structure responsible for the entire grid operation, including EV management, must be available.

The efficient operation of such a system depends on the combination of local and centralized control modes. When operating the grid in normal conditions, EV will be managed and controlled by a new entity ï the aggregator ï whose main functionality will be grouping EV, according to their ownersô willingness, to exploit business opportunities in the electricity markets.

However, due to high uncertainties related to when and where EV owners will charge their vehicles, the existence of a grid monitoring structure will be required, controlled by the DSO, with the capability of acting over EV charging in abnormal operating conditions, i.e. when the grid is operated near its technical limits, or in emergency operating modes, e.g. islanded operation. In these situations, EV might receive simultaneously two different set-points, one from the aggregator and other from the monitoring and management structure headed by the DSO. To avoid violation of grid operational restrictions, the DSO signals will override the supplier / aggregator ones.

The description of the control and management architecture, under a market framework, can be found in [6].

## V. Conclusions

The analysis showed that a 10% penetration of electric vehicles, with a dumb charging strategy, e.g. when all vehicles charging as soon as they return from their last journeys of the day, would cause increases in daily peak demand levels of between 6% and 12% compared to the baseline peak demand and that the peaks would occur at a time different to that of the baseline peak demand. The analysis further showed that, with a ñsmartò charging strategy with all EV charging load moved to the night-time valley periods, would cause no change to the baseline peak demand levels and would reduce the peak EV demand levels for most countries analysed. The daily variation from minimum to peak demand was shown to increase significantly for the dumb charging scenario and reduce significantly for the smart charging scenario [1].

The communication systems in electric grids provide the necessary support for the implementation of smart charging strategies. The ICT model accounts for the data exchange among the different entities and the SM provides the necessary functionalities that will allow EV users to actively participate in energy services exchange. Both the electric grid and consumers benefit from more detailed up-to-date information, regarding energy usage, allowing more ambitious DSM solutions.

Finally, the original Microgrid centralized control hierarchy concepts need to be adapted to include EV as active participants in the markets and system operation during normal but also abnormal and emergency modes of operation.

## VI. References

[1] Downing N., Ferdowsi, M., Deliverable D1.1, "Identification of Traffic Patterns and Human Behaviours," April, 2010. http://www.ev-merge.eu/

[2] Tomsovic, K., D. E. Bakken, et al. (2005). "Designing the Next Generation of Real-Time Control, Communication, and Computations for Large Power Systems." Proceedings of the IEEE 93(5): 965-979.

[3] Peças Lopes, J. P., Rua, D., Issicaba, D., Soares, F. J., Almeida, P. M. R., Rei, R. J., ñAdvanced Metering Infrastructure Functionalities for Electric Mobilityò, to be presented at ISGT Europe, Gothenburg, Sweden, Oct. 2010.

[4] MERGE Project. Deliverable D1.1. ñSpecify Smart Metering for EVò, Aug. 2010, http://www.ev-merge.eu/

[5] Peças Lopes, J. A., Silvan A. Polenz, Moreira, C. L., Rachid Cherkaoui, "Identification of control and management strategies for LV unbalanced microgrids with plugged-in electric vehicles." Electric Power Systems Research, Vol.80, Issue 8, pp. 898-906, August, 2010.

[6] Soares, F. J., Rocha Almeida, P. M., Peças Lopes, J. A., Luís Seca, Moreira, C. L., ñA Technical Management and Market Operation Framework for Electric Vehicles Integration into Electric Power Systemsò, Proceeding of the Smart Grids and Mobility Conference, Brussels, October, 2010.

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