OPTIMIZING THE EV ELECTRICAL DEMAND IMPACT

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ABSTRACT

This paper addresses the subject matter of the electric vehicle (EV) impact on the electrical demand and distribution infrastructures. Although a lot of different projections on EV market penetration evolution are available, relying upon in the inevitability of EV, one thing will happen for sure in a near or a far future: each house will have a new electric device to plug-in, which alone represent a charge equivalent to a typical house. With characteristics of an off-peak charge, is seen as an opportunity to increase the efficiency of the entire electrical system, flatting the load diagram. Two setbacks present to this idyllic vision: the first is how to achieve an optimal EV distribution along the load diagram, filling off-peak gaps, and the second is how to flat the upstream load diagram not raising the gap in downstream load diagrams. The focus is on ways to regulate the impact of electrical vehicles in demand and on the role of smart metering in providing the required data to manage active distribution networks.

INTRODUCTION

Unlike most new tendencies that have been pointed out as sources of potential huge impacts in distribution network, like the distribution energy resources (DER) dissemination, EV will not need a fix address license. This implies that the plug-in of a 230 V – 15 A EV (3,45 kVA equivalent to a domestic user) will appear with no notification to the distribution network operator (DNO). This causes a problem to DN management.

Part of the problem is being addressed with the smart metering systems development. Not having the DNO means to impose a balanced dissemination of EV, a closer management of DN equipments assets is mandatory. This kind of management would be possible gathering the required data about the power demand in every network node, something beyond today's network where only the HV/MV nodes are under close supervision. Being the EV plug-in in the far end of distribution network, the metering systems must be smart enough to flag likelihood future problems (surcharges …) in the DN equipment, all the way from source to EV, so prompt mitigation measures will be put in place.

The other part of the problem is related with the demand curves. Adding the future EV charges to today MV/LV power transformer (PT) readings (acquired from the EDP new smart metering system INOVGRID), two cases will be presented showing that the EV could increase the gap between off-peak and peak hours, imposing the rerating of existing equipment and by this means lowering the equipment efficiency rating. Furthermore it is shown that considering today's incentives to consume in off-peak hours, those off-peak hours would be converted in peak hours, with more impact in distribution network than in the transport network and power generation mix.

Following this analysis two important outcomes are brought to consideration. The first is the need of a comprehensive off-peak schedule that postponed equipment rerating could increase the DN equipment efficiency rating, and the second is the reinforcement of the increasing importance of smart metering systems to both customer and DNO.

ADDING EV TO GENERATION DEMAND

Although a lot of different projections on EV market penetration evolution are available, all those projections rely upon the inevitability of EV, drived mostly by the higher efficiency demand in all humankind activities.

Consider then that today's 4.5 million combustion vehicles in Portugal will be one day plug-in electric vehicles. With an average annual mileage of 15,000 km/year, a consumption of 15kWh/100km, a 230V – 15A plug charge, a 6 hour charge time and an 85% efficiency battery energy cycle, those numbers result in an annual average of 100 charges, meaning that on average 25% of EV will be charge per day.

Assuming that consumers will start charging at the beginning of off-peak hours (at today's lowest price), overlapping this consumption to today´s upstream load diagram off-peak hours results in Figure 1.

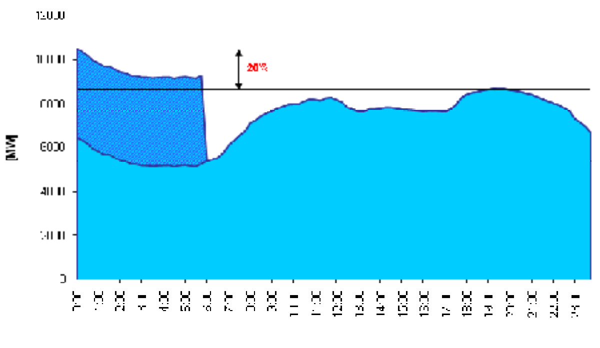

Figure 1. EV plug-in in today's power generation mix off-peak hours (January)

The first observation is that this will not happen just because in Figure 1 scenario the EV's would be charged in peak hours. With EV load the peak hour has been moved meaning that the lowest price would be shifted.

Considering that the consumers will be properly encouraged by the electricity tariff to have a perfect behavior in a comprehensive off-peak schedule, it is observed that the EV load fits in the upstream load diagram, Figure 2.

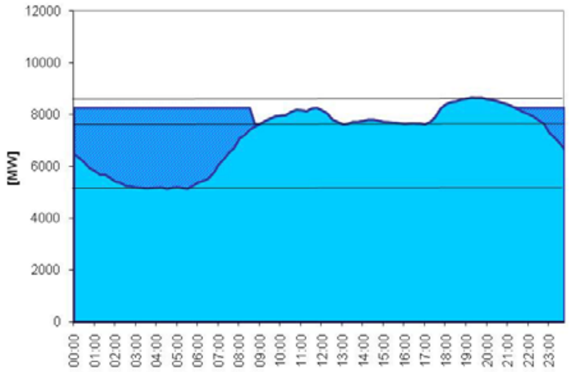

Figure 2. EV optimal plug-in in today's power generation mix off-peak hours (January)

Although not surpassing the peak power in Figure 2, it appears to be space to move some EV charges to the middle of day off-peak. This fact is more significant when observing Spring or Summer load diagrams, Figure 3, where EV charge in today's off-peak will means a new peak.

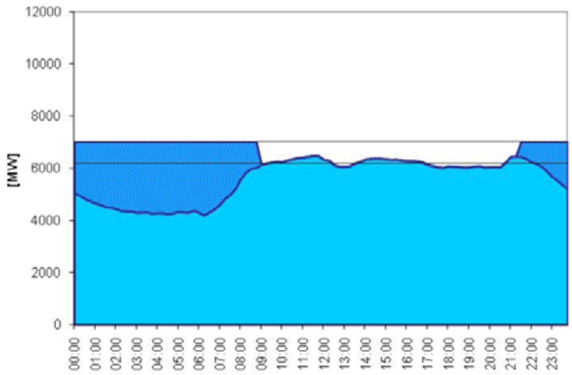

Figure 3. EV optimal plug-in in today's power generation mix off-peak hours (May)

Trusting that the right signs will be given to the consumers encouraging the fill of the future off-peak hours, EV load seems an optimal vehicle to raise the efficiency of power generation mix and electricity transport infrastructure.

ADDING EV TO LV NETWORK

First Case

For the EV impact as shown in the upstream load diagram, how could one expect the downstream load diagrams to behave? Thanks to EDP new smart metering system INOVGRID real load diagrams were available to analysis. Considering a 250 kVA power transformer (PT) feeding a suburban residential area of 240 low consumption LV loads, Figure 4, one EV per load and the considerations about EV charging made above, overlapping to daily diagram the charge of 60 EV at the beginning of off-peak hours results in Figure 5.

Figure 4. 250 kVA PT feeders in a low consumption suburban residential area

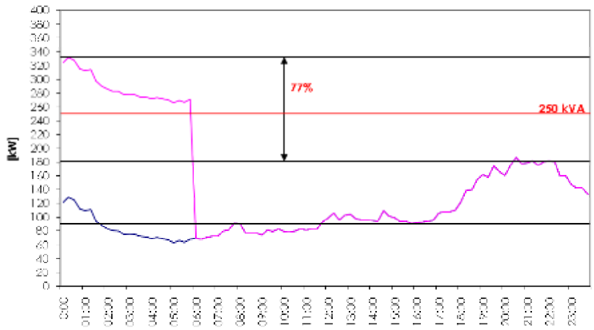

Figure 5. EV plug-in in today's low consumption residential area PT off-peak hours (January)

While the EV load increases the peak in 20% in Figure 1, here a 77% increase is observed, even surpassing the installed power.

Considering, as in Figure 2, that the consumers will be properly encouraged by the electricity tariff to have a perfect behavior in a comprehensive off-peak schedule, overlapping EV load result in Figure 6.

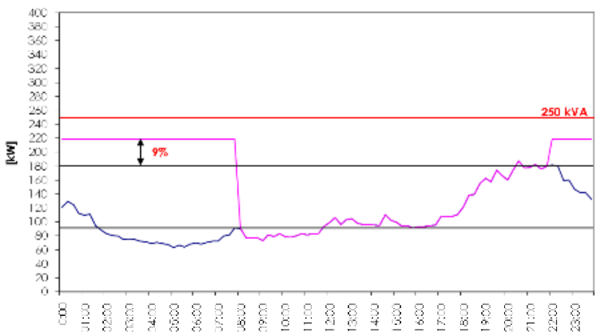

Figure 6. EV optimal plug-in in today's low consumption residential area PT off-peak hours (January)

Although still 12% away from installed power a 9% peak increase would be observed. Two main differences may be found between Figure 6 and Figure 3 results. The first is the strict limit imposed by the PT installed power that when surpassed implies a investment in a new asset that will take longer to achieve the replaced asset utilization factor (distribution assets rerating are made in steps, being a 250 kVA PT probably replaced by a 400 kVA), while production mix and transport infrastructure will be glad to receive loads that will reduce the seasonal peak differences. The second is the fact that the 9 to 5 consumption gap will always exist in downstream load diagram just because there are not much demand in these residential areas at those hours.

Second Case

Analyzing a 400 kVA power transformer (PT) feeding a suburban residential area of 100 high-consumption LV loads, Figure 7, one single EV per load under the charging conditions stated above, would overlap the charge of 25 EV at the beginning of off-peak hours. This results in the diagrams presented in Figure 8, and in Figure 9 for an optimal plug-in.

Figure 7. 400 kVA PT feeders in a high consumption suburban residential area

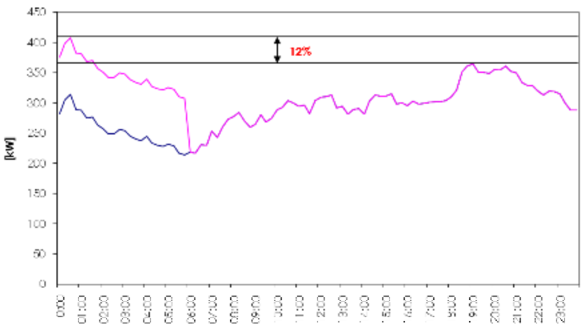

Figure 8. EV plug-in in today's high consumption residential area PT off-peak hours (January)

In this high consumption residential area case the installed power is slightly exceeded in Figure 8, but clearly away from peak in Figure 9.

Considerations

Even if considering that higher consumption areas will have higher EV penetration, resulting that Figure 9 will be more like Figure 10, where two EV by LV load were assumed, it seems that the challenges will be in today's low consumption areas. Shifting EV loads from those areas to their parking areas during the day, not only alleviates distribution assets, but also fills up the upstream load diagram mid-day off-peak.

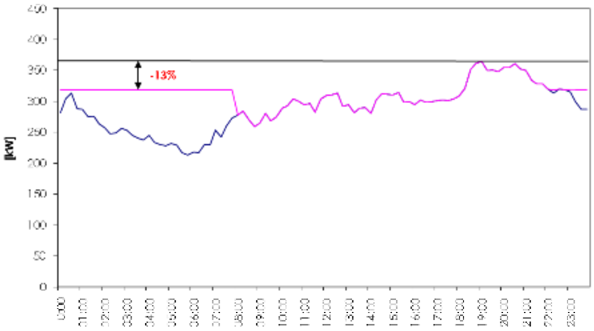

Figure 9. EV optimal plug-in in today's high consumption residential area PT off-peak hours (January)

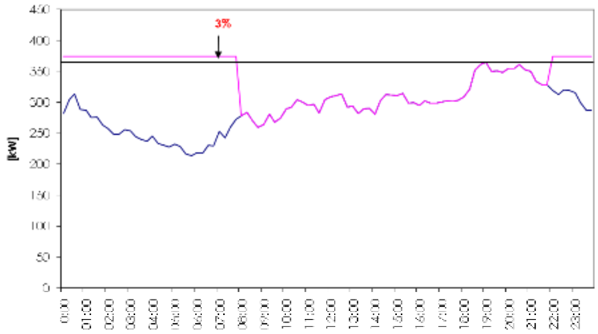

Figure 10. EV higher penetration optimal plug-in in today's high consumption residential area PT off-peak hours (January)

TODAY'S LV CUSTOMERS BEHAVIOUR

Being stated that, to achieve a higher efficiency level, consumers should be properly encouraged by the electricity tariff, it is interesting to observe how those consumers have reacted to existing incentives.

In Portugal the LV normal consumers could choose between a simple tariff, where electricity price is always the same, and a dual tariff, where peak and off-peak hours have a different electricity price. Observing the LV customers' distribution evolution since 1999, Figure 11, the customers' adherence to dual tariff has an almost perfect correlation with the new customers' entrance. Obviously, not all new customers adhere to dual tariff, but the number of customers doing some math to save in the electricity bill is proportional to the number of new customers. Considering that these incentives have the merit to at least lead the new customers to evaluate their choices, it seems that there is something missing for that already installed customers be able to do the same.

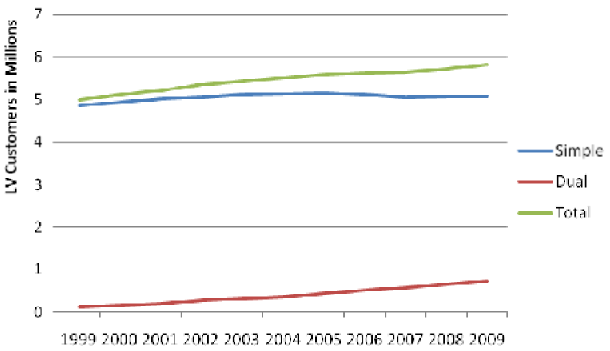

Figure 11. LV customers distribution evolution between simple and dual tariff

This fact is corroborated by our findings. There are consumers with an average consumption of 2.9 MWh, with a 3.45 kVA hired power, Figure 12, who found interesting adhering to dual tariff, but there are other customers with higher average consumptions that do not change from simple to dual tariff.

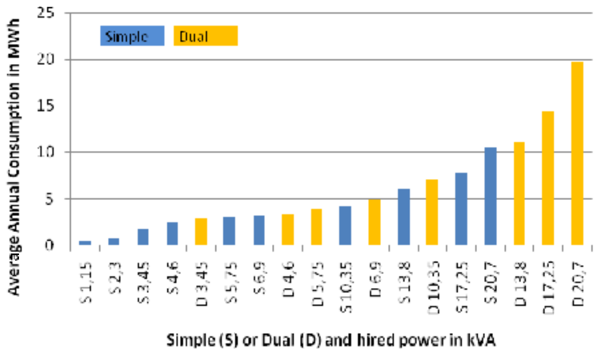

Figure 12. LV customers average consumption by hired power and simple and dual tariff

If moving the 1.8 million customers in the simple tariff with annual average consumptions higher than 3.0 MWh, Figure 13, to the dual tariff, then the shift of their consumptions to off-peak hours would lead to not only direct savings to those customers, but also savings to the system decreasing the load diagram peak-load in around 10%.

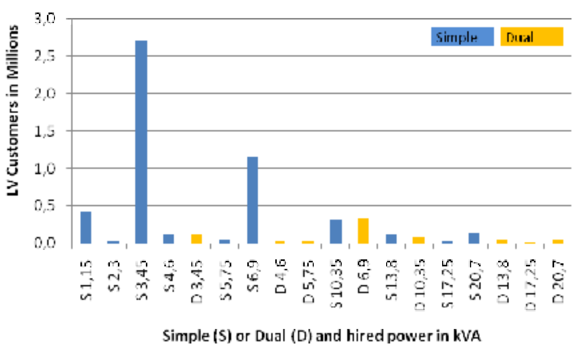

Figure 13. LV customers number by hired power and simple and dual tariff

Stated that the existing incentives have the merit to lead customers to evaluate their choices, what seems to miss is information. Information that will give power to the customer to evaluate his situation; information that the customer could easily use to look up to the solution that will best fit to his consumption. If this information is now important to achieve higher efficiency levels, then, with EV charging, it will be mandatory.

Expected in the smart grid development, Figure 14, the installation of sensors in the far end of the network is the key to give both customer and DNO the information needed to achieve the required efficiency level.

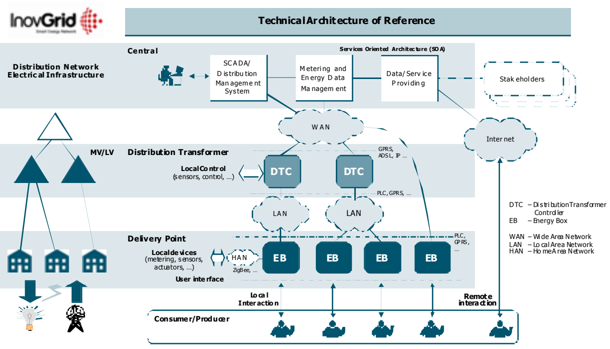

Figure 14. INOVGRID technical architecture of reference

CONCLUSIONS

Although the presented scenarios had shown that the EV is an opportunity to increase the electrical system efficiency, important considerations must be taken to achieve that goal. The first is the need of a comprehensive off-peak schedule that should drive to an optimal EV loads distribution, focusing in not only postponed distribution assets rerating, namely in low consumption areas, but also in taking advantage of the upstream load diagram middle of day off-peak hours. The second is the increasing importance of smart metering systems to both customers and DNO. Only with indispensable information given by their metering sensors will customers have the power to evaluate their consumption situation and easily use it to look up to the available tariff solution that will best fit them. Only with the indispensable information, all the way from source to EV, could the DNO put in place prompt mitigation actions to respond to those distribution network far end loads.