THE ROLE OF FAST CHARGING STATIONS FOR ELECTRIC VEHICLES IN THE INTEGRATION AND OPTIMIZATION OF DISTRIBUTION GRID WITH RENEWABLE ENERGY SOURCES.

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ABSTRACT

In the next 20 years the number of electric vehicles (EV) will exponentially increase. That will be mostly due to governments and car manufacturers which are coordinating the effort to reduce urban pollution and greenhouse gas emission. The energy required for charging EV usually recovering in private parking places for many hours, will be mainly provided through smart charging boxes ("wall box") managed by the (smart) grid control system of the LV network. In all other cases, EVs will be charged in fast charging stations or battery swap stations connected to the MV network. Such charging stations require high power during the day, especially when the network could be overloaded, hence there is the need to model the impact on the grid. This paper investigates the possibility to use storages to shave peak power demand due to FC stations and the possibility to use these storages to provide additional network services, included the optimization of intermittent-not-programmable energy sources, such as renewable energy.

INTRODUCTION

Fast charging (FC) will be referring in this document to charging stations with nominal power equal or higher than 50 kW. FC will be normally DC charging; although there are plans to build DC fast chargers able to offer the choice of AC quick charge (up to 43kW) to EVs featuring this option. At this time, limited availability of FC makes the evaluation of this option among customers somewhat incomplete. Today, most drivers still rely on normal home charging at night as the primary source of charging their vehicles. Considering the breakthrough in Li-Ion batteries which allows most EV to reach a range of approximately 170 km and the average size of traction batteries for EV up to approximately 20 – 30 kWh, FC will offer the convenience of charging EV traction batteries at 80% in below 30 minutes. Several demo projects of such FC stations do exist and a lot more are planned for the future. While today a charging rate of up to 50 kW for DC charging (e.g. specified by the CHAdeMO Consortium) is feasible without sacrificing battery performance and life time, some European OEMs expect a charging rate of up to 100-120 kW for a typical EV battery as a realistic target for DC fast charging in year 2020. At present DC fast chargers are extremely expensive; as the cost will come down and the networks of charging stations will increase, also customers will expand the way they use their vehicles and boost electric mobility.

POWER DEMAND OF FAST CHARGING STATIONS

For estimating power demand of a FC station, it is necessary to make an assumption on the number of EVs that need to be charged in each station at any time of the day. Considering the Italian case and data available from the census made by ISTAT (see [1-3]), that people owning a private parking place shall be more inclined to buy EVs and to charge their vehicle during the night (car not used and cheaper energy rate), makes possible to estimate that in Italy at the most 64% of the energy for charging EV circulating in 2030 would be allocated during the night and that at least 36% would be allocated during the day [4]. Than we take the further assumption that 6% of EV will charge (during the day) connected to a LV network and a 30% will use a FC stations connected to the MV network. Moreover, taking into account the daily average journey of a present car (about 35 km) and the energy demand per kilometre (0.15 kWh/km), the daily average energy demand of each EV is expected to be around 5 kWh/day. With this figure and making the hypothesis that the daily average travel in 2030 will be the same as today, it's possible to calculate the daily demand of the whole Italian EV fleet, which in 2030, should be around 55 GWh/day. In metropolitan areas, for a number of reasons, penetration of EV will be higher; additionally, due to the limitation of space, traditional gas stations will become the most suited spots to place future fast DC chargers. This scenario was adapted to the metropolitan area of Milan (provincia di Milano). In this area there are about 1100 gas stations which, in our 2030 scenario, will have to become "hybrid", hence refuelling both ICE vehicle and providing FC for about 300.000 vehicles (that is between 120 and 150 vehicles fast charged everyday by each "hybrid" refuelling station). Hence the energy that should be provided by the average urban "hybrid" refuelling station of the city of Milan should be about 1.2 MWh per day. Additional considerations were made to identify the profile of the power demand to the network. The FC will be more requested when people are moving, especially when they go to work in the morning or they come back home in the late afternoon, therefore it will be proportional to the "mobility diagram" in Figure 1.

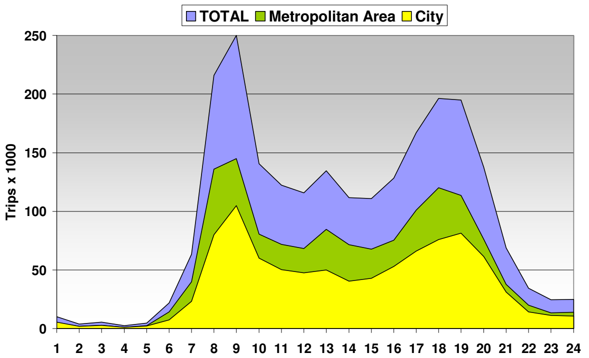

Figure 1 - Mobility diagram of the metropolitan area of Milan

Scaling FC requests to the electric demand of the average "hybrid" refuelling station in the metropolitan area of Milan, we find the average power request to the network as displayed in Figure 2.

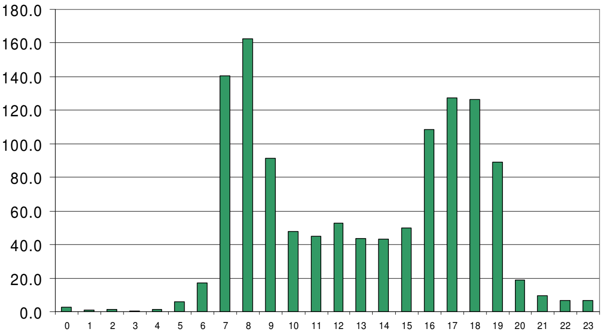

Figure 2 - Power request the network of the average "hybrid" refueling station of the metropolitan area of Milan

Direct connection of FC stations to an already congested grid, may result in inconvenience like feeders overloading and voltage drops. For that reasons, a cost benefit analysis may, in some cases, prove convenient the use of storages for shaving peak power demand and eventually to provide additional network services, included optimization of intermittent-not-programmable energy resources, such as renewable energy.

STORAGES TO SHAVE PEAK POWER DEMAND

Storages in FC stations allow accumulating the energy that has to be used for charging EV at high power. There are two main approaches for using storages. The first approach aims both at *optimizing the power request from the grid*, but also at limiting the capital investment in buying storages. The second approach aims at accumulating energy when tariffs are low (e.g. during the night) or to shave excess production from intermittent-not-programmable energy resources, such as renewable energy. This second case requires *high capacity storages* and gives also the capability to provide ancillary services: like injection of active and reactive power and voltage regulation.

Optimizing the power request from the grid

This approach aims at minimizing capital investments both in the connection of the charging station to the network and in the energy storage. The optimization applied to the average FC station of the metropolitan area of Milan shows the profile in Figure 2. It requires a 60 kW connection combined with a 210 kWh energy storage. Figure 3 displays the state of the average FC station. Green bars represents the energy in storages, blue bars represent the power that is requested from the electric network, yellow bar is the actual power that is requested to charge EV at any time of the day. Such figures shall be scaled for station smaller or bigger than the average. This means that bigger stations may require power and energy storages two or three times bigger, but also that for many FC stations (smaller than the average size) a LV connection and an even smaller storage may be enough to supply the requested service.

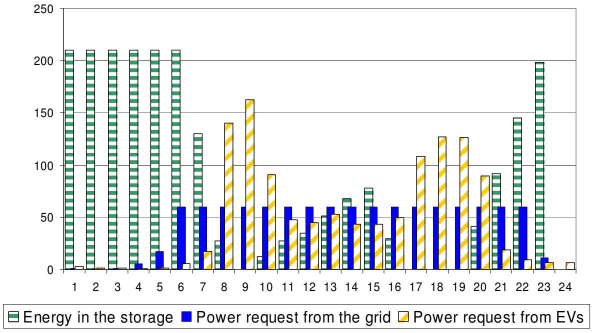

Figure 3 – Low capacity storage: Energy in the storage, power request from the grid and from the EV fleet

High Capacity Storages

This approach aims at accumulating all the energy that is required for charging EV when the price of energy is low or when there is an excess production from intermittent-not-programmable energy resources, such as renewable energy. Optimization of the investment brings to high capacity storages able to accumulate during night time all the energy that is requested during the day. Figure 4 represents the actual state of the storage (green bars), power that is requested from the electric network (blue bars) and power requested to charge EV (yellow bars) at any time of the day. The optimal size of the storage for this purpose is equal to the average energy that is needed to charge EVs during the day.

Unfortunately such system is very expensive. It may become convenient in case price of storages drops to 150

€/kWh as in the case shown in Figure 5, where a comparison between different plants' cost is displayed. Reducing the price of batteries, plants with storages becomes more convenient than plants without storages. The optimal storage capacity is for the same size of the energy that the FC station has to provide during the day.

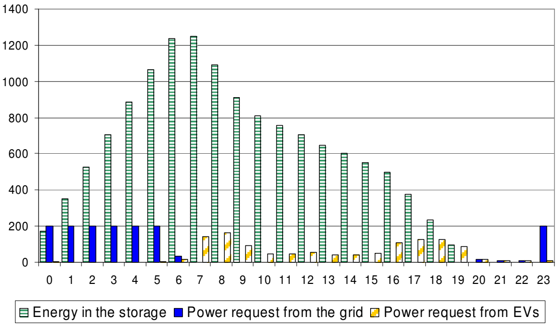

Figure 4 - High capacity storage: energy in the storage, power request from the grid and from the EV fleet

The costs benefits analysis was carried out with the following hypothesis: 12 years lifespan, 4500 cycles (one per day), 90% of efficiency (both in charge/discharge processes) and storage installation cost proportional to the size.

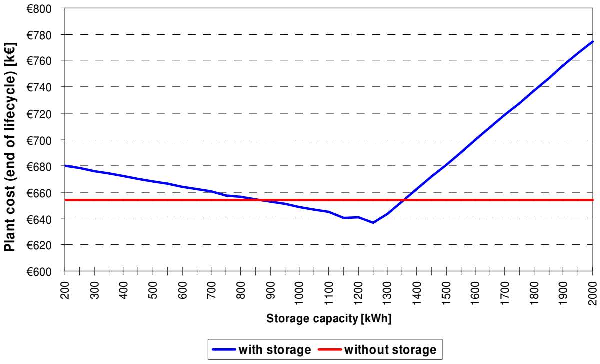

Figure 5 - Plants cost comparison

STORAGES AND ANCILLARY SERVICES

Charging stations with storages are intrinsically capable of providing services to distribution utilities. This is mainly due to the presence of a voltage source converter as the interfacing technology (converting AC into DC) and the presence of a storage system. The converter has the natural capability of de-coupled bidirectional control of the active and reactive powers as long as it is within its current capabilities. A storage of a fast charging station that provides (or draw) power to (from) the network is like a distributed generation applications capable of both drawing power and supplying it when required. The capability of the charging station to provide ancillary services to the distribution grid can be limited not only by the size and dynamics of the plant but also by the actual service that it has to guarantee for charging EVs. For this reason high capacity storages are more flexible to provide network services than low capacity storages.

Absorbing unpredictable production peaks from intermittent-not-programmable energy resources (for instance, photovoltaic plants have their production peak in middle hours of the day, when the energy demand is not at its maximum) can be achieve also by non-bidirectional system, like fast charging station with no implementation of auxiliary grid services. This task requires only the capability to control the power absorption to charge the storage systems. However to provide these service, the FC station shell be an active element in the smart grid and it needs a bi-directional communication with the smart grid control centre.

Voltage drops on MV lines

We considered the problem of voltage drop analysis and the effect of FC stations on it. Basic voltage profile along a MV line in Milan is shown in **Figure 6**. Adding a FC station in some of those nodes can represent a problem for the network, dropping local tension values. Storages systems avoid this issue providing energy to the grid and elevating the voltage level. Obviously this service must be integrated in a smart grid asset where a local voltage control is implemented.

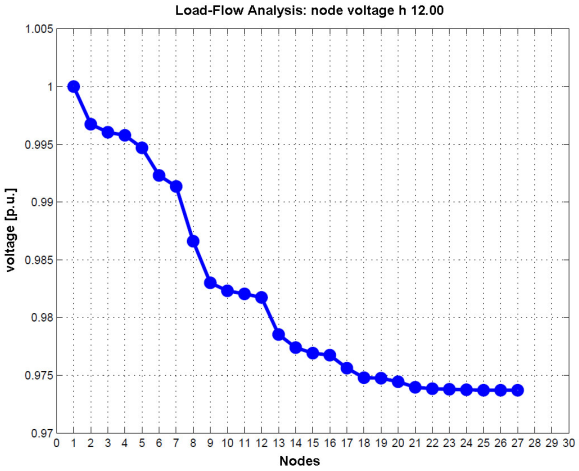

Figure 6 - Voltage dropping along a MV line

CONCLUSIONS

The impact of FC stations on the MV grid has been analyzed and exposed in this paper focusing on the hypothesis of putting storages in fast charging stations. It was highlighted that the power demand for electric mobility can be an issue for the electric grid, due to the fact that the typical electric power request has its peak just when there is a high energy request for recharging EVs. This can bring to an overloading problem or a tension dropping that can be controlled using storage and power electronics. FC stations can be used to store energy from intermittent-not-programmable energy resources, such as renewable energy for recharge EVs (green energy to green transport) or to give it back to the grid when it's requested. To provide such services a FC station requires a bi-directional communication to the smart grid control system.

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