THE IMPACT OF EV'S FAST CHARGING STATIONS ON THE MV DISTRIBUTION GRIDS OF THE MILAN METROPOLITAN AREA

Giuseppe MAURI, RSE – Italy, Giuseppe.Mauri@rse-web.it
Danilo BERTINI, RSE – Italy, Danilo.Bertini@rse-web.it
Enrico FASCIOLO, A2A Reti Elettriche–Italy, Enrico.Fasciolo@a2a.eu
Stefano FRATTI, A2A Reti Elettriche–Italy, Stefano.Fratti@a2a.eu

ABSTRACT

In the next 20 years the number of electric vehicles (EV) will significantly increase and will reach more than 40 million in EU. The energy required for charging EV, usually recovering in private parking places for many hours, will be mainly provided through smart charging boxes connected to the LV network. In all other cases, EVs will be charged in fast charging stations (FC) 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 and analyze the impact on the grid. The paper describes the 2030 scenario for the metropolitan area of Milan, and explains how power demand due to Fast Charging stations for electric mobility can represent an issue for the electric grid, and how it is possible to face such problems using storages and power electronics.

INTRODUCTION

The spreading of EVs in the next years, thanks to decreasing purchasing prices and dedicated recharge tariffs, is expected to reach up to 10% of total number of vehicles.
In the present paper, the 2030 scenario includes the following hypoteses at the national level:
- total number or vehicles: 40 million;
- composition of the 2030 fleet: ¼ petrol, ¼ diesel, 1/10 gas (LPG or methane), the remaining as electric vehicles (full electric or hybrid).

The exact number of EVs in a given Province will depends on several factors, among them one can mention:
- average income (since EVs will be likely more expensive than traditional cars);
- total number of already existing vehicles (number of vehicles/1000 inhabitants);
- poor air quality, that can lead to the adoption of local policies supporting EV diffusion.

For the Milan metropolitan area, an estimation of 10 millions of EVs at 2030 could be considered as a reasonably figure, taking into account census information by the Italian Statistical Institute, ISTAT [1-2].

To make an assumption about the number of EVs that need to be charged at any time of the day, it's worth considering 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). This 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 [3].

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 EVs to reach a range of approximately 170 km and the average size of traction batteries for EV up to approximately 20÷30 kWh, the fast charging option is gaining interest since it may provide a 80% charge in up to 30 minutes. In the following, fast charging (FC) will be referred as to charging stations with rated power equal or higher than 50 kW.
The present paper proposes to install FC stations in already existing fossil fuel station, creating then 'hybrid stations' where car drivers can refuel quickly their vehicle, no matter if they are Internal Combustion Engine (ICE) or an EV. In the metropolitan area of Milan there are about 1100 gas stations, and because of their position all these stations could be considered as future hybrid stations. The following Table I summarizes the main hypotheses adopted into the analysis.

Table I – Estimation of the average energy per day provided by a FC station

Milan fleet at 2030 - Daily mileage	~80.000.000 km/day
Milan EV fleet at 2030- Daily mileage	~36.000.000 km/day
Average EV at 2030 (including losses)	140-150Wh/km
Daily Energy demand of the EV fleet at 2030	5GWh/day
• Fleet with private parking place	3,8GWh/day (Slow Charge)
• Fleet without private parking place	1,2GWh/day (Fast Charge)
N° of refuelling stations at 2030	~ 1100
Energy per day provided by the average FC station	~ 1200 kWh/day

IMPACTS OF FAST CHARGING STATIONS ON THE DISTRIBUTION NETWORK

The current fuel stations are very likely to become "hybrid" stations, providing FC for about 300.000 vehicles (that is between 120 and 150 vehicles fast charged everyday by each "hybrid" refueling station). Hence the energy that should be provided by the average urban "hybrid" refueling station of the city of Milan should be about 1.2 MWh per day (see Table 1).

Unlike the slow charge at home, 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.

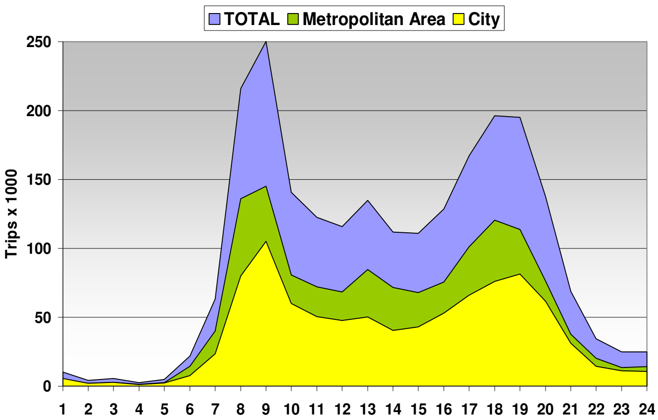

Fig. 1 - Mobility diagram of the metropolitan area of Milan.

To evaluate possible impacts of FC stations on the distribution network, the position of all present gas stations was identified and then each of them was "connected" to the nearest (less than 150meters) node of the MV grid.

The following Figure 2 summarizes the superposition of the existing gas stations and the distribution grid in a portion of the city. For each station, three buffers (50-100-150 m radius) were created and the nearest MV feeders identified; the MV line closest to the station is then chosen. In this urban area, it is rather simple to find a MV lines quite close to the possible FC station, as the following map clearly shows. The availability of a quite high number of FC station will allow EV drivers to recharge their vehicle within a time that is comparable to the traditional ICE refuelling time. This option is considered, in combination with the slow recharge in private parking lots or garages, as a key driver to support the diffusion of this technology.

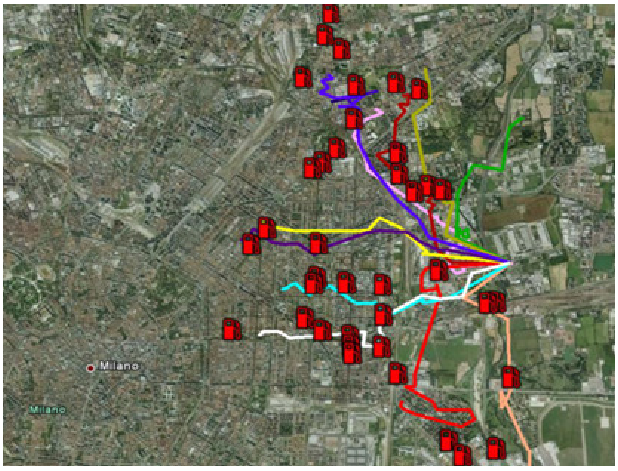

Fig. 2 - Milan MV distribution grid portion (lines), with possible FC stations (squares).

Direct connection of FC stations to an already congested grid may result in inconveniences like feeders overloading and voltage drops.

Load flow analysis was used for evaluating voltage drops along MV and LV lines: results show that the direct connection of fast charging stations to MV line may not represent, generally, a problem for MV lines. In particular, calculations show:

- maximum power peak increase : ~+5%
- increase of energy from HV/MV transformer : ~ +1%
- operating conditions for the transformer: well under the limits.

Voltage drops during a whole day are evaluated along already overloaded MV lines as shown in Figure 3. Calculations show that a 'robust' urban distribution network, such as the Milan grid, with nearly constant cable section and oversized to support reverse feeding, is able to face this additional demand respecting voltage limits set by the standard EN50160 (voltage drops within ±10%).

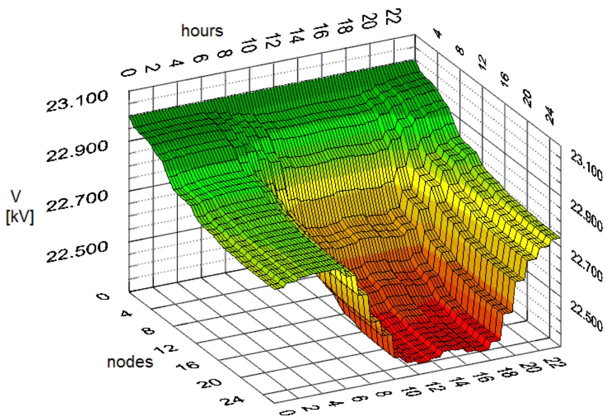

Figure 3 - Voltage drop along a MV line during one day

Simulations with FC load profiles higher than the average (up to +300%), representing larger fuel stations, show that even in that cases the additional voltage drop caused by the FC station remains below 1% of the rated power, largely within the admissible range.

POSSIBLE SUPPORT FROM STORAGE UNITS

FC station may pose problems to distribution network; as detailed in the previous section, for the specific case of the metropolitan area of Milan, the average hybrid station can be directly connected to the MV network without causing significant voltage drops but this doesn't apply generally to all urban distribution networks.
In this paper the possibility to adopt storage units in the FC stations is considered, both for optimizing the power request from the grid, and for storing energy when tariffs are lower (e.g. during the night or to store excess of 'green energy').

FC stations connected directly to the LV network may be equipped with an own storage (about 210 kWh) and a 60 kW direct connection to the LV busbar of the nearest MV/LV substation.

Figure 4 shows the state of charge of the average hybrid refueling station of the Metropolitan area of Milan:
- 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.

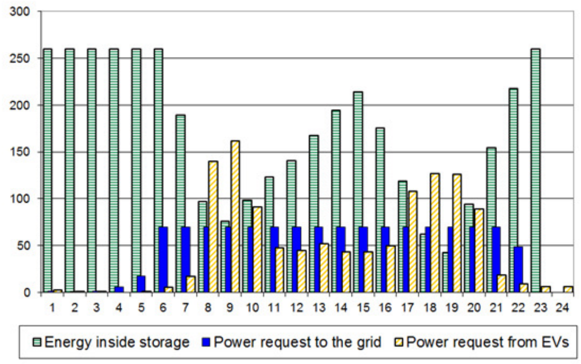

Figure 4 - State of charge of the average hybrid refueling station of the Metropolitan area of Milan

It becomes clear that, given a flat load in the central part of the day (insufficient to recharge all EVs), the storage unit is able to store the excess energy in the 'off peak' hours and provide the requested energy in the peak hours.
With the proposed approach, the size of the FC station could remain limited (nearly 70 KW in this example) and the storage unit could have a limited size, too.

FINAL CONSIDERATIONS

This paper summarizes the analysis of the impact of FC stations on the MV grid, focusing on the hypothesis of having fast charging stations in the existing fuel stations. The analysis shows that the addition 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.
A deep analysis of the real MV network in Milan, using realistic data about the EV recharge, was carried out: results show that in robust urban networks the additional load deriving from FC stations doesn't represent a real challenge.
The paper evaluated the adoption of storage devices in the FC station to maintain the peak power under limited values and facing overloading problem or voltage drops on the feeders.
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, to shape correctly the requested load profile according to real time conditions.

Acknowledgments

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