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XXXIV Cycle - II year presentation

Electric Ultra-Fast and Wireless Power Transfer charging stations

For the diffusion of electric vehicles, the most important bottleneck regards autonomy and recharge time.
I am studying towards two different and complementary directions:

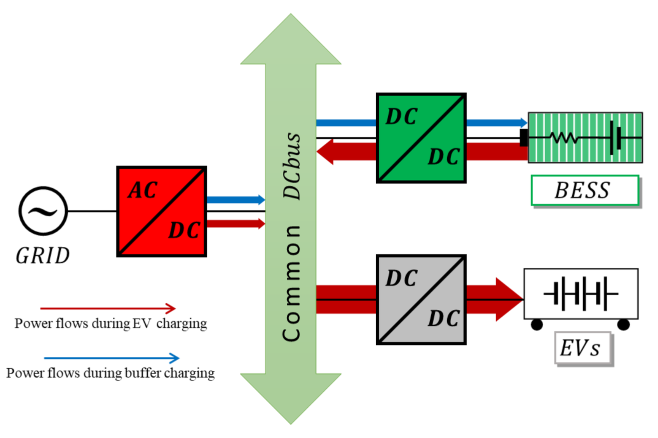
- **Ultra-Fast charge** is intended to maximize the charging capacity of the vehicle's batteries in order to make the time of refueling comparable with that of vehicles with a combustion engine. On the charging stations it is planned to use large amounts of power to push the energy from the network to the vehicle (G2V).
- In **Wireless charge** the tendency is totally different, it intends to provide a widespread branching of recharging points that can exempt drivers from the act of recharging the vehicle. This charging method is much slower than the previous one but has the advantage of being convenient and functional, especially in the city and for vehicles used for car sharing.

ELECTRIC ULTRA FAST CHARGING STATION

My fellowship is associated with a project "ELECTRIC ULTRA FAST CHARGING STATION (E-UFCS)" presented for "POR FESR CAMPANIA 2014/2020- O.S. 1.1", so part of my research deals with charging stations for electrical vehicles. The Mode 4 of electric vehicles charge, also called Ultrafast charge mode, is a defined standard in CEI EN 61851-1:2019-09. This type of charge, is a dc charge, its definition provides an active connection between the vehicle and the charging system including grounding and control systems, the typical value of voltage is 600 V with a maximum current of 400 A.

There are not requirements that set a standard on the charge time, but typically the Ultrafast charge is intended as a charge of a medium size multi-purpose vehicle with the charge time ranging from 10 to 15 min. To provide these charging performances, the energy from the charging station to the vehicle needs to be transferred with a high level of power, as a consequence an Ultrafast charging station with multiple plug-in electric vehicle parking slots needs to have a great amount of installed power.

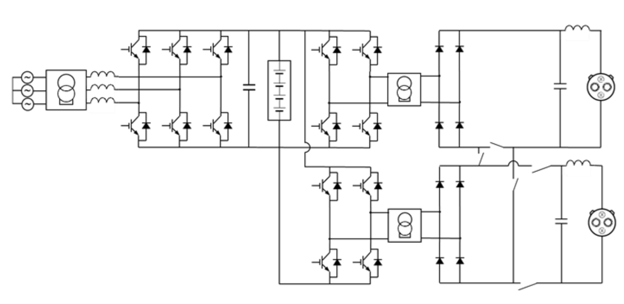
A project constraint requires that the charging station must be connected to the low voltage distribution network, so that the maximum installing power amounts to 100 kW, and it must have two charging slots.



The combination of these two power constraints led to the need of introducing a battery energy storage systems, it charges when no vehicles are requiring to be charged and discharges when the power demanded to the station is higher than that payable by the grid. It should be noted that the charge power of the BESS is the installed power of the grid, the discharge power depends on the charging requests by the vehicles. The power BESS for Ultra-Fast recharge, is determined by the resolution of the power equation equilibrium corresponding to the DC stage:

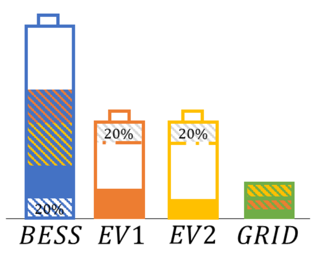
$$\int_{t-(T_{bess}+T_{EV})}^{t} \eta_{gr}\, P_{gr}(\tau)\cdot d\tau + \int_{t-(T_{bess}+T_{EV})}^{t-T_{bess}} \eta_{bess}\, P_{bess}(\tau)\cdot d\tau = \int_{t-(T_{bess}+T_{EV})}^{t-T_{bess}} \frac{1}{\eta_{EV}} \sum_{h=1}^{N_{EV}} \lambda\, P_{EV,h}(\tau)\cdot d\tau + \int_{t-T_{bess}}^{t} \frac{1}{\eta_{bess}} P_{bess}(\tau) d\tau$$

where T_{EV} is the charging period of the electric vehicle, T_{bess} is the charging period of the buffer storage, P_{gr} is the power provided by the grid, P_{bess} is input or output power exchanged between BESS and DC bus, $P_{EV,h}$ is charging power of hth vehicle.



The electrical structure choosen (in the figure on the left) is that which minimize the number of converters required and settle the performances between the charge profile of vehicles and the charge/discharge profile of the BESS in order to preserve its state of health.

This structure has been implemented and installed in the laboratory of engines 'Perez de Vera' of the department and the next step will be the testing phase and the evaluation of charging performance with an electric vehicle or a test-bench simulator.



A strategy to manage a real Ultrafast charging service, taking into account the various operative conditions which the vehicles and the station can found and the chance that a queue occur, has already been developed. The choices on the first vehicle affect the charging profile planning for the second one, but not vice versa. Because the first customer has already accepted the charging profile for his vehicle, and he has paid for it. For this reason, the planning for the second vehicle is more constrained, so the performances of the charge are less than that of the first vehicle.

The charging profile's planning of a vehicle is chosen to minimize its charging time under power and energy constraints. This choice not only guarantee the maximum charging performances to each vehicle, but also tries to leave at least one slot free for a vehicle to come, in order to avoid a queue.

WIRELESS POWER TRANSFER CHARGING STATION

Another topic of my research activity during this academic year is the Wireless Power Charge for the e-bike sharing service implemented at the department as a part of a few years ago project. The goal of this activity has been to renew the custom wireless battery charging system realized for the project and to implement a secondary side sensorless control.

The wireless battery charging system consists of two ferromagnetic coils, that are part of a series-series resonant converter, that exchanges power through electromagnetic induction. On the primary side the system is connected to the grid, on the secondary side the battery of the e-bike is connected to be charged. The sensorless control strategy intends to manage the charge of the battery, identifying the secondary coil current of resonant transformer and the battery voltage without measuring them, but estimating them with a Fourier frequency domain methodology.

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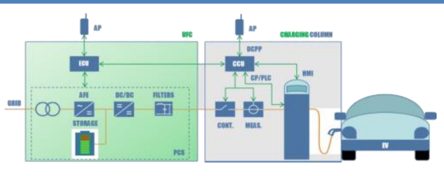
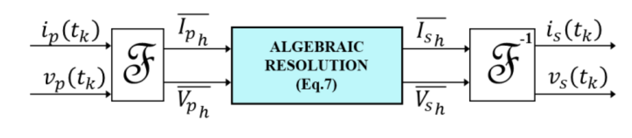
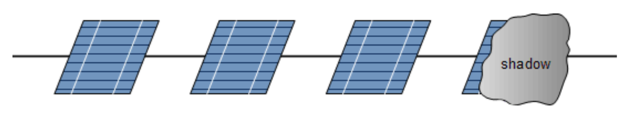


The testing phase and the evaluation of charging performance of the charging station.

Li-ion battery temperature and aging effect modelling, in order to implement condition monitoring algorithms.



Implementation of the sensorless control on the the wireless power transfer system.



Management algorithm for photovoltaic system, integrated with battery modules, in condition of shadowing.

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