TECHNICAL SOLUTIONS FOR ELECTRIC VEHICLES INTEGRATION

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ABSTRACT

This paper aims to identify technical solutions for different charging environments, offering not only technical solutions but also a systemic analysis of integration. The charging solutions found for electric vehicles and plug-in hybrids (EV) are divided in five categories:1)Single or three-phase connection; 2)Direct current connection; 3)Controlled charge in direct current; 4) Controlled charge in alternating current; 5) Exchange batteries. An Universal Charging Station is proposed, introducing a Smart Protection concept.

INTRODUCTION

The current prospects for the development of the electric vehicle market and the plan to build up a platform to enable the national vehicle fleet integration, requires actions at infrastructure level, charging solutions and other related services. Therefore, it is necessary to create a set of infrastructures to provide battery charging. Many companies are still working to provide technical solutions to this need.

UNIVERSAL CHARGING STATION

In order to build up an infrastructure of charging stations, it´s important to take into account a variety of factors, such like the batteries characteristics and the users needs. A schematic of an universal charging station is presented in figure 1.

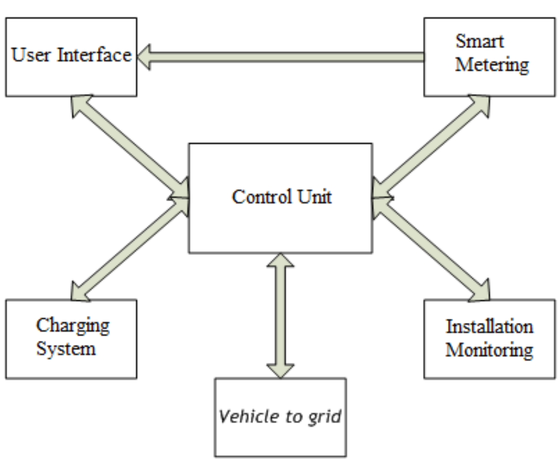

Figure 1 – Schematic of a Charging Station.

Each module of the scheme has a specific role in the process and is related with others. A brief explanation is presented following.

Control Unit

The control unit module is the "brain" of the entire system, being responsible for the coordination between all the modules and to process all the tasks and operations. This module must implement the appropriated algorithm, dependable on the EV charging technology and the user needs.

User Interface

This unit is responsible for all communication processes between user and charging station. The module must have the ability to identify the user, payment mode and other useful information.
Charging process will not start until all conditions were met. As represented in figure 1, this module requires a two-way communication with the Control Unit and receives also data from the Smart Metering module in order to exhibit information like the metering results on the screen.

Smart Metering

This module is constituted by hardware capable of bi-directional energy metering and two-way communication between the meter and the Central Unit, enabling the communication with the grid operator, accordingly to the smart-grid concept. Some of the benefits are: immediate price actualization; more effective and easier power management; energy consumption optimization, according to energy tariff rates; evaluation of availability of power.
The vehicle-to-grid and charging system abilities, requires independent and bi-directional meters, in order to obtain the different metering results. Charging stations with multiple terminals must have an independent meter per terminal.

Vehicle-to-Grid

Vehicle-to-Grid is a thematic introduced with the popularization of electric vehicles. It means that EV can not only be supplied by the grid, but also, deliver energy to the grid when needed, in order to load-balance the electricity grid. This is a new concept of energy reservation.
However, there is still a lack of regulation contemplating

the EV-Grid connection. In Portugal there is a clear regulation for micro-producers. Technically, EV-Grid connection could respect the same method, changing standard circuit-breaker for Smart Protections.

Installation Monitoring

The charge of the batteries of an electric vehicle is a process that requires high electrical power. Common electrical installations have **limited peak power**, so a monitoring system can give an important advantage.
In order to optimize the available electric power, it is necessary to define a charging strategy. In figure 2 is presented a schematic of an hardware capable of supporting the main idea of this topic.

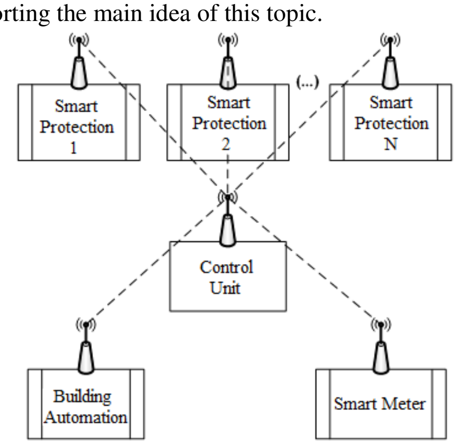

Figure 2 - Installation Monitoring System.

In the scheme we could see some smart protections, smart meters and the building automation communicating with the control unit (see figure 1). To facilitate the process, the communication must be wireless. The building automation, responsible to control the building charges, must communicate with the control unit, responsible to evaluate the electrical power required for the charging process of the EV.
Another existing possibility is to adapt an existing building, without any kind of automation, into a more efficiency building. The peak current of a charging station is limited by the local electrical installation where the EV is connected. The smart protection concept can assume an important role on the availability of electric power. A schematic of the smart protection concept is presented in the figure 3.
As could be seen in the figure 3, the power circuit is made by a series circuit between the circuit breaker and controlled circuit. The remaining modules belong to logic and programming control.

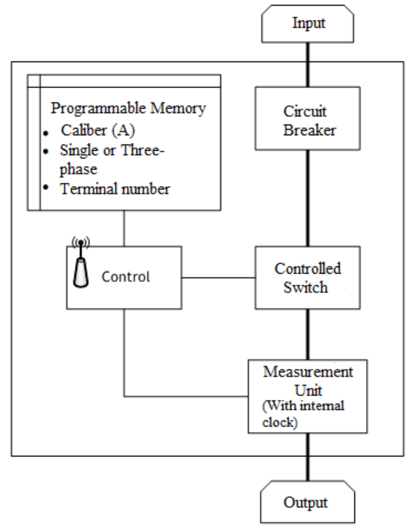

Figure 3 - Smart Protection scheme**.**

A Smart Protection allows automatic connection/ disconnection of certain charges, to provide electrical power to charging process, if necessary and possible. It is constituted by:

- Programmable memory: all electric and network characteristics must be programmed in this module;
- Circuit Breaker: overload and short-circuit protection;
- Controlled Switch: switch commanded by the Control module, to connect or disconnect the linked load;
- Control: central processing unit, responsible for all command operations and information transmission;
- Measurement Unit: this unit is made by a current intensity transformer device for measuring a variable electric current; All measures must be associated to a time variable to compare them between different Smart Protections.

With these Smart Protections, Control Unit can calculate, in time, the needed peak power for the electric installation, thanks to measuring capacity.
By changing some regular circuit-breakers to Smart Protections, in high-power loads like air-conditioners, is then possible to connect or disconnect them.
After Control unit calculates how much peak power is needed to charge the EV batteries, automatically becomes possible to disconnect specific charges, during a specific period, ensuring that EV gets fully charged or gets the maximum possible charge.

Charging System

This module represents all types of battery charging.
Most electric vehicles include a Battery Management

System (BMS), which is very important in the charging or discharging optimization process and also to determine the state of the battery [1].

A charging station must have a BMS to control and monitor all required parameters. The most common parameters are:

- State of charge (SOC) determination;
- State of "health" (SOH) determination;
- Memorization of charging current rate, voltage, temperature and capacity of charging acceptance, during charging process. These measures can be compared to battery designer data, to use in a battery diagnostic system [1];
- Processing and control a charging algorithm, managing voltage, electric current, internal temperature, density or internal pressure (depending on battery type). Some developed charging algorithms may use BMS as a charging optimizer, according to battery diagnostic [1];
- Temperature control. Battery charging requires an optimal temperature range. Sometimes it may be necessary heating or cooling the battery [1];
- Short Circuit protection;
- Electric and/or thermal isolation detection;
- State of charge equalization between battery cells.

Charging solutions are commonly divided in five categories:

1- Single or Three-phase Connection

This is the most common charging method. This kind of charge is the typical slow charge solution, because is usually applied in electrical installation with a very restricted peak power. A common EV can take several hours to complete full charge.

Attending to most people´s timetable, the residence or a parking area will be the applicable places, because more than five hours may be need, to obtain the full charge.

In this situation the EV BMS controls the charging process. BMS can be internal or external of the vehicle, however it is dedicated at the specific battery model.

For the previous reason, this Charging Station structure does not allow user to achieve any information about battery (SOH, SOC, ...) or even an estimation of total price.

In this type of charge, the Charging Station just has the function of supplying the same electrical peak power during a certain time, then it begins to decrease until battery reaches the full state.

2-Direct Current connection

Another method to charge batteries is connect them directly, supplying in direct current. This solution implies to "know" the battery characteristics, BMS is inside the Charging Station. The charge is only possible if all the batteries has the same electrical characteristics, otherwise the Charging Station will be dedicated just to one kind of battery.

Typically charge will consist in a constant voltage application until battery nominal voltage reaches a standard value.

This kind of Charging Station is more applicable to industrial services, because is possible to have all EVs with the same battery characteristics.

3-Controlled charge in Direct Current

Controlled charge in direct current is an evolution of the type 2. In this situation, the charge consists in a variation of the voltage applied, according to a fast charging algorithm, specifically planned to the battery model.

While on the type 2 charging method the complete charge can take several hours, in type 3 it could take just less than an hour.

4-Controlled charge in Alternating Current

Like the first case, in this type of charge, the Charging Station has the function of supply a certain electric power in alternating current. The main difference is that in this case the external BMS implements a fast charging algorithm. The peak power will be much higher and be required for less time. In this situation is more important the evaluation of the capacity of the electric installation or there could be inopportune circuit breakers actuations.

5-Exchange batteries

Exchange batteries could be a very useful solution for those who need their batteries charged in just few minutes.

Attending to the celerity of this process, it would be a interesting application for "service stations" and other places of ease access, where people conveniently spend a couple of minutes.

Due to the multiplicity of batteries designs, it is very difficult to have an automatic system to exchange them. Each brand as a specific method to assembly and access the battery so, to implement this technique it would be necessary to specify the battery design and format.

The method of exchanging batteries can begin a new issue, because some users could question what happens if they change their battery, for another in worse condition. Each battery type has a specific kind of result, when subjected to specific tests like: internal resistance determination, energy storage determination, temperature variation when subject into a specific electric current peak, stabilized open circuit voltage metering; [2] can be good SOH battery indicators. To be reliable, all the collected data should be compared with reference values, provided by the constructors.

To be possible, the charging station must have a database with all the referred battery data, from all types of batteries, which could be very difficult, because of the constant evolution of the battery and EV.

A possible solution to this issue can be the introduction of a policy like "people own their vehicle, but not the battery". So, the quality of the batteries (SOH) have to be guaranteed by the government.

REAL APPLICATIONS

EDP has sent to the market a Request for Information, specifying the general requirements for the charging posts, with the purpose to buy 100 charging posts, 97 of them with standard charging and 3 of them with what is called coordinated charging.
The standard charging process (accordingly to IEC/EN 61851 is considered Mode 1) will not have any communication or auxiliary electric interaction between the charging post and the vehicle. Once the client process allows the user to charge, the plug is well inserted and the plate is locked, the socket is energized and the vehicle will pull power as needed.
The coordinated charging (accordingly to IEC/EN 61851 is considered Mode 3) will be implemented using PLC system, where an induction ring inserts a communications signal on the ground cable that is used for data exchange as well as control pilot functionality. The plc communications will cover all the sockets, including the slave mini posts, in the posts versions in which that applies.

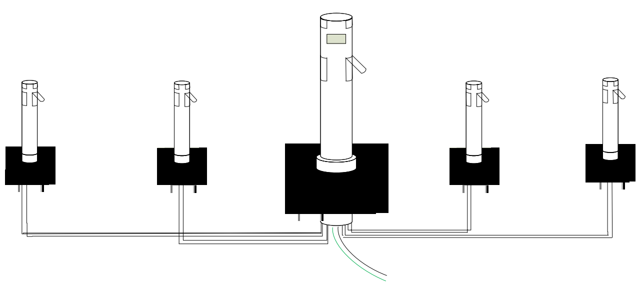

Figure 4 - Charging posts.

The charging system is designed so that in the future it is possible to upgrade the Charging post to a flexible charging with minimal changes. For that purpose there will be room left inside all the charging posts to insert a plc modem with corresponding induction rings for every socket and data communication cables going into every socket for a possible new connector.
With the purpose of develop, design and construct a charging network, a consortium of Portuguese companies working together in a project named MOBI.E. The MOBI.E project intends to construct a network of charging posts, compatible with all makes of electric vehicles and accessible to all users, with the purpose to be a first step to the introduction of electric vehicles in Portugal.

CONCLUSION

To face the integration of electric vehicles is presented some important conditions and possible solutions to implement a network of charging stations.
The presentation of an Universal Charging Station has the objective to represent all aspects that may be needed to build up a infrastructure of charging stations. To make the electric vehicle a competitive mean of transportation, it´s necessary to take in count a variety of factors that were referred on this paper. Users will prefer the electric vehicle if it offers at least the same convenience as the combustion vehicles, at a low price.
To optimize the charging of the electric vehicle batteries in a non-automated building, the smart protection concept brings the advantage to prevent non desirable circuit breakers actuation and the integration of a semi-automatic charge management system.
The multiplicity of brands and models with different battery designs and characteristics is the biggest barrier to the simple implementation of all kinds of charging solutions. In a first generation, only "slow charging" concepts will be possible, implying that a full charge lasts longer than 5 hours. Faster charging solutions are dedicated to a battery design and, on that case, a battery could be fully charged in minutes, depending on its capacity. While we don't have a standardized design, construction and electric charge of electric vehicles, only some of them, with dedicated chargers could offer fast charging solutions.

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