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CHARACTERISTICS OF CHARGING STATIONS FOR ELECTRIC VEHICLES

BY

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Abstract. Green energy represents an important element for the future technology of electric vehicles. Also another important element when it comes of electric vehicles it is represented by the infrastructure and the number of charging stations which are available “on the road”. In the last two years at least in Europe a lot of countries decided to focus on infrastructure, electric vehicles and charging stations to offer a good alternative to vehicles with internal combustion engines. It is not enough to have as many charging stations as possible but also it is necessary like a charging station to have some characteristics: charging capacity which will influence charging time, multi brand compatibility and cost of charging. According to studies and some European programs it is the intention like up to 2020 to be implemented up to 400 fast charging stations (HPC – High power charging) with a capacity of 350kW which will enable to reduce charging time significantly if it is compared with existing systems which are already installed. In the last period of time some researches has been done for inductive charging but for the moment the efficiency is not the desired one. This paper has the purpose to focus on describing charging stations, principles and efficiency of different types.

Keywords: electric vehicles; high power charging stations; distance range; energy management; charging mode.

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1. Introduction

Electric vehicles can be found on the market in different configurations with different types of energy storage systems (Electric, 2011). All the aspects are important starting with the motor, and depending on size and performances the total power ranges are between 15 and 200 kW. At this moment on the market one of the electric vehicles is BMW i3, small 4 seats sedan and it has 125 kW electric motor with 170HP.

The battery set provides the energy necessary for the motor to operate. Charging can take place either during vehicle deceleration, motor in generator mode or upon connection to a charging station. Battery capacity can be approximately 5,...,90 kWh at a voltage of 300,...,500 V (A123, 2016). Any person who is willing to buy an electric vehicle it is interested about aspects like comfort, safety, maintenance costs but also autonomy of such vehicles. The vehicles distance range depends on battery capacity, driving style, road configuration, use of accessories (multimedia systems, headlights, heating etc).

The charger has the purpose to convert ac to dc current from the charging station into direct current and limits the current to the maximum acceptable by the cable and charging station combination (Li *et al.*, 2002).

The vehicle is equipped by the manufacturer with one or two sockets inlets, depending by the type of charging required, normal or accelerated charging on the AC network and a second inlet for charging at a fast charging station.

2. Charging Stations for Electric Vehicles

Battery technology has made a significant progress in the last years and at this moments researches continues with a view to improve capacity and reduce weight and heating during power charging (Tesla, 2017). The most efficient battery at this moment is lithium-ion because don’t have memory effect and can be charged without having to be completely empty. This kind of battery can found not only on electric vehicles but also in laptops, aircrafts and different other machine which are using lithium-ion battery.

There are several types of charging stations which can be installed either at home or in public places like at work, in parking areas, on the street, on the highways or service stations (Cassidy, 2015). Of course the ideal case is to have as many charging station as possible and in any moment to have possibility to charge in fast mode batteries. In this situation has been a developed charging station which gives the possibility to charge in 4 modes:

a) Mode 1 – direct connection of the vehicle to 220V grid with non dedicated power socket, with simple cable but with the risk of overheating. This type of charging it is used mostly in U.S.A protection level – high.

b) Mode 2 – direct connection with non-dedicated power socket but with possibility for communicating charge monitoring device - protection level is considered acceptable.

c) Mode 3 – direct connection to the grid with dedicated power socket and cable incorporating charge monitoring - protection level is high.

d) Mode 4 – indirect connection of the vehicle to the grid with fast charging using direct current external charger with charging monitoring system and dedicated attached cable.

In Fig. 1 are represented all the charging systems described above and the types of cables used to connect the electric vehicle to charging stations.

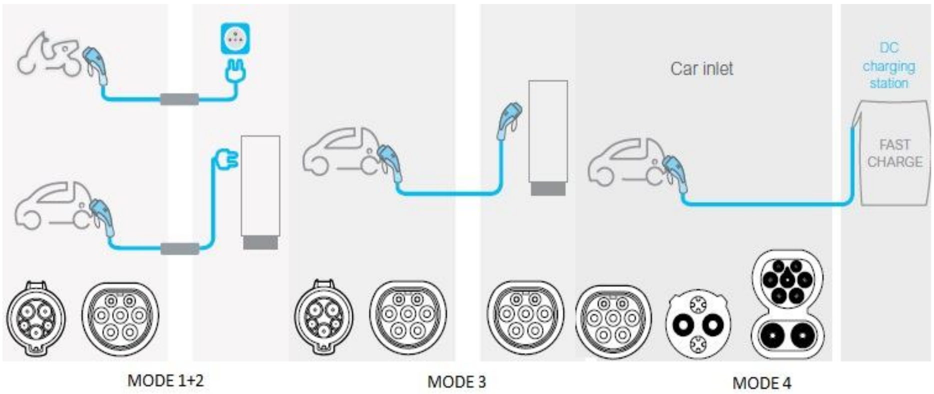

Fig. 1 – Charging system for electric vehicles (Schneider Electric Industries SAS, EVlink - Electric vehicle charging solutions, 2017).

From safety point of view charging cables has been designed to protect the vehicle and also the station. The internal construction of cable has 4 wires, neutral, minimum one phase depending on the grid, three phases or monophasic and pilot wire which allow the communication between charging station and vehicle. Charging of the vehicle will start only if there are fulfill the following conditions: indication of the maximum power allowed by the charger, vehicle connection and vehicle earthing.

Charging capacity it depends on the power source and battery capacity and in table 1 are represented data's to determine the charging speed. According to data's in Table 1 using the right cable for charging it is mandatory and also according to the type of grid the time of charging can longer or shorter. It can be observed that using a three phase source with dc power socket the charging time can be 24 times less than using domestic power socket, single phase. It is obviously which type of charging stations are recommended but it is a problem of infrastructure. For installing charging stations it is necessary to design electrically distribution panels and depending on the architecture can be connected one or several charging stations to the same panel and work in the same time independently. This type of charging stations could be mounted in parking stations.

Table 1
Time vs Power of charging station

Vehicle with 24kWh battery				
Type of source	Domestic plug	Dedicated AC power plug		Dedicated DC power plug
Power	Single phase 2.3 kW	Single-phase 7.4 kW	Three-phase 22 kW	Three-phase 43kW
Time to charge	12h	5h	1h 30’’	30’’
% of charge reached in 30 min	4%	10%	34%	100%

3. Power Supply of Charging Stations

There are many types of charging stations which are compatible only with installations type TT, TN-S or TNC earthing mode. In some conditions it is necessary an isolations transformer for charging certain vehicles. It is well known the fact that some vehicles don’t start charging if the ground resistance if it exceeds a threshold. Normally the ground resistance must not exceed 100 Ω. Each charging station must be compatible with electrical vehicles and that’s why an under voltage release must be combined with charging station circuit breaker. If the grid where the charging station is connected cannot charge the vehicle at nominal power then it is necessary to install an energy management system and also the connection to be made with flexible cables.

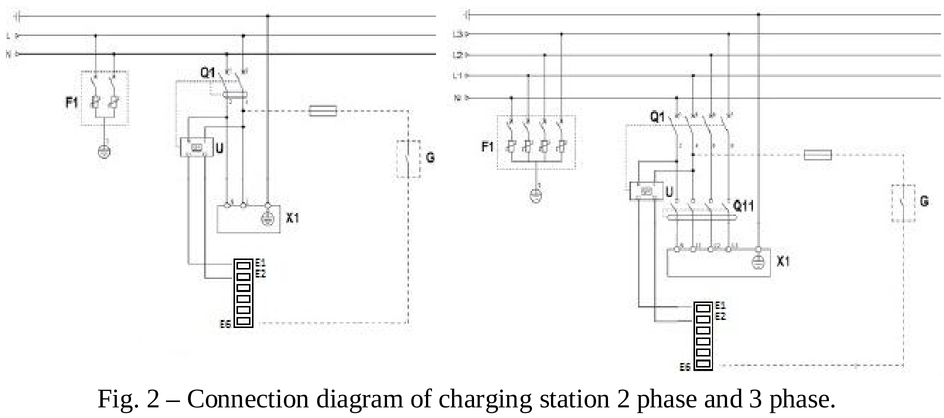

Fig. 2 – Connection diagram of charging station 2 phase and 3 phase.

In Fig. 2 it is represented a connection diagram where Q1 for single phase power supply represents an overload and a short protection circuit breaker and a residual current circuit breaker and in case of three phase power supply exist an separate residual current Q11 (Onar *et al.*, 2016). Basically the electrically cabinet for power a charging station has an overvoltage protection

F1, an under voltage release, terminal block for under voltage release E1, E2 a contact for power limitation and a power terminal X1.

Charging stations have also a conditional input E6 which is configured as a delayed condition to start charging or as a power limitation. The conditional input can be connected to any device, relay for an example, capable to close a contact and to be active when is connected to main phase and will be inactive when not connected. Delayed start of charging can be obtained by connecting the conditional input to a clock or an off peak contactor. This kind of condition can be usefully when for example it is needed to charge the car only during the night when the necessary demand of electricity is not so big. Charging station can work in two modes: charge delayed start (Fig. 3) and charge power limitation (Fig. 4).

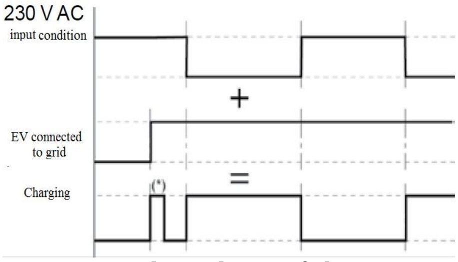

Fig. 3 – Conditional start of charging EV.

Charging EV in power limitation to a station with three phase connection and 16 A nominal current it is mandatory to check the compatibility with charging current 10 A corresponding to the power limitation.

In case this condition is not full filled the charging will not be carried out in power limitation mode. The conditional input will be connected to a loader and the maximum charging power will be limited as long as the input will be active. In Fig. 4 it is represented the power limitation cycle for a charging station.

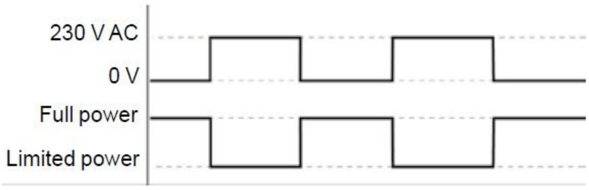

Fig. 4 – Charging in power limitation.

In this paper it has been defined that charging stations for electrically vehicles can be used in 3 main contexts:

a) home charging using normal connectors;

b) charging while vehicle it is parked in public places supermarket etc.;

c) fast charging in public charging stations which have > 40 kW and can deliver enough energy for 100km in almost 30 minutes.

Another possibility for a fast charging is swapping the battery with a charged one eliminating the delay involved in waiting for the battery to charge but this aspect must be taken in consideration in the moment of designing the car.

4. Calculation of Power Consumption for Charging Stations

Depending on the architecture of charging station and also the place where it is located can be charged several vehicles in the same time but it depends on the installed power of cabinet, number of charging stations connected to the cabinet the sections of the cables, circuit breakers. During charging cycle must exist an algorithm to calculate the total power demanded of each charging point and the controller will perform data acquisition to control the total demand and power allocation to the vehicle.

If we discuss about a charging station with dual socket outlet it is necessary to limit the maximum power and to balance the load between two sockets, to charge the vehicle as quickly as possible while remaining with the maximum power limit set for the charging station.

Also it is necessary to implement an energy management system to avoid disruption which can cause losses, to reduce energy and electrical infrastructure costs and to make operation more efficient.

For a system with several charging stations an automatic control system is necessary to supervise total consumption and make power consumption optimization. Which means when a value is approached to the limit the management program will send to charging stations a command to limit charging.

It is possible then to charge simultaneously several vehicles but depending of the type of charging fast or slow it is necessary to implement a charging priority privileges. If a energy management system it is implemented the system will require to make the acquisition of data's like location information, starting and ending moment of charging and charging time. All these information's are necessary to have the possibility to make an estimation of power consumption needed and for this it is used:

$$P_{\text{consumption}} = \int_{t_0}^{t_0+T} P(t)\mathrm{d}t = \left(1 - \mathrm{SOC}_{\text{initial}}\right)Q_r, \tag{1}$$

where: $P_{\text{consumption}}$ represents the electric power consumption during time T, $\mathrm{SOC}_{\text{initial}}$ – the initial state of charge of electric vehicle battery, Q_r – the rated capacity of the electric vehicle battery, t_0 – the starting time of charging, T – the charging duration and $P(t)$ – the charging power at time t. Based on eq. 1 charging time represents an important factor for calculating the electric power consumption of vehicle charging stations. Also it is important to know the battery SOC of the battery at the beginning of charging for estimating the power consumption and in some cases even if the charging duration is the same the electric power consumption can be different according to SOC. In Fig. 5 can be observed the charging curve of a lithium ion battery.

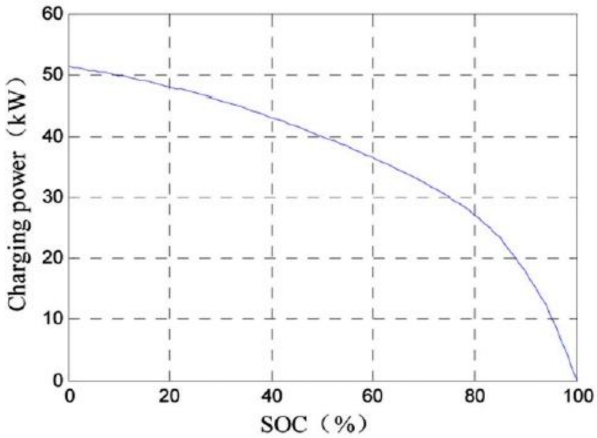

Fig. 5 – state of charge of a lithium-ion battery according to charging power.

Because of different levels of SOC power consumption cannot as a real value and in this case can be used the number of charging that is performed for a specific period of time. Mathematically this problem can be solved by integrated the number of charging performed in a specific period of time so the influence of the battery SOC to be significantly reduced (Skypump, 2015).

In order to calculate a real power consumption for an electric vehicle can be used an analytically regression model using the relation between charging time and the number of charging. The regression model it is described by:

$$P(X_{ct}, Y_{nct}) = w + w_{ct} X_{ct} + w_{nct} X_{ntc} + e, \qquad (2)$$

where: $P(X_{ct}, Y_{nct})$ is the charging power, *ct* – the charging time, *nct* – the number of charging, X_{ct}, Y_{nct} represents predictor variable and w_{ct}, X_{ntc} are the weights for the predictor variables and e is the error which is calculated as differences between real and predicted power and can be obtained based on eq. (2).

5. Conclusions

At this moment increasing the number of electrically vehicles it is hard because the price of such vehicle comparing with a conventional one is much higher, but this is not the only reason. It can be observed that installing charging stations depends of many factors, grid, infrastructure, type of electrically vehicles, charging time, time when it is necessary to charge the vehicles, safety measures must be taken also in consideration.

To stimulate people to buy electrically vehicles some terms must be established between car manufactures, charging stations providers and government of the countries to provide the necessary support. It is very important the location of a charging station because even if a few people had the financial possibility to achieve this kind of electrically vehicle have complained about the possibility to charge even in city not necessary to drive long distances.

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CARACTERISTICILE STAȚIILOR DE ÎNCĂRCARE PENTRU VEHICULE ELECTRICE

(Rezumat)

Energia verde reprezintă un element important pentru tehnologia viitoare a vehiculelor electrice. De asemenea, un alt element important atunci când se vorbeşte de vehiculele electrice este reprezentat de infrastructura şi numărul de stații de încărcare care sunt disponibile "pe şosea". În ultimii doi ani cel puțin în Europa o mulțime de țări au decis să se concentreze pe infrastructură, vehicule electrice şi stații de încărcare pentru a oferi o bună alternativă vehiculelor cu motoare cu combustie internă. Nu este suficient să existe cât mai multe stații de încărcare posibile, dar este necesar şi ca o stație de încărcare să aibă anumite caracteristici: capacitatea de încărcare care va influența timpul de încărcare, compatibilitatea cu mărci multiple de vehicule şi costul încărcării. Potrivit studiilor şi a altor programe europene este intenția ca până în 2020 să fie puse în aplicare până la 400 de stații de încărcare rapidă (HPC – încărcare de mare putere) cu o capacitate de 350 kW, ceea ce va permite reducerea semnificativă a timpului de încărcare dacă este comparat cu sistemele existente deja instalate. În ultima perioadă de timp unele cercetări au fost făcute pentru încărcarea prin inducție, dar pentru moment eficiența nu este cea dorită. Această lucrare are scopul de a se concentra pe descrierea stațiilor de încărcare, prezentarea principiilor şi eficiența diferitelor tipuri.