



# E-Mobility: Smart Grid and Charging Session of Electric Vehicles

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**Abstract.** This research stresses upon the importance of electric mobility in modern age as sales of Electric Vehicles (EV) have crossed one million cars and current number of charging stations are rapidly growing. In this context, we propose a novel smart connection called DriWe between the EV, the charging point and the environment to improve and consolidate the development of smart grids vs the charging enhancement. In DriWe, performance of the monophasic environment is optimized, providing support to the owner of the EV in order to (i) always achieve maximum power, (ii) easily reach the charging facilities through a special application that can be installed in tablet, smartphone or pc, and identify the various charge points (iii) guarantee the absence of electric blackout, thanks to a combination and an interaction of three elements: smart device, an intelligent framework, namely a DriWe cloud server and charge point. A dynamic load control method based on an Application Programming Interface (API) with a 10 s frame rate update, is applied. The program runs within the end-user smart phone, acquires data from DriWe cloud server, and allows to coordinate the recharge column by allowing the Electric Vehicle (EV) supply equipment's control and variation.

**Keywords:** Electric Vehicles · Smart charging · Dynamic control  
Charging station

## 1 Introduction

Since the beginning of the twenty-first century, the e-mobility market has been aiming for a radical and substantial change of mentality by the community. The fundamental objective of this new vision is the reduction of CO<sub>2</sub> emissions, which are the main cause of global temperature rise. Therefore, the next-generation electric power systems

will integrate these diversified renewable energy resources, storage systems, controllable loads and automated & intelligent management systems [1]. Furthermore, as automated and distributed energy network, the smart grid can be conceived as a two-way flow of electricity and communication, which allows monitoring everything from generation to consumer [2].

Basic support for the evolution of a society based on e-mobility will be given by the support of governments, which, after the Paris agreement on climate change, will have to commit themselves to adopt eco-sustainable solutions to solve environmental problems. The scenario of the planet in which electric cars are moving is gaining more and more attention from the researchers and it is destined to become the indispensable promoter of sustainable mobility in the coming decades. The consumers will not automatically switch to Electric Vehicles (EVs) if the cost trend stays high, if the charging station network is not ready, or if new technologies are not easily usable [3].

The easiest way to recharge EVs is the conductive wired charging, a physical connection between two different parts: car and a domestic plug, or an industrial plug or a charging column. Charging in monophasic environments occurs in alternating current. Nevertheless, according to recent investigations, car and domestic plug are not suitable for recharging vehicles for several hours to a current of 16 A due to frequent over-heating.

In AC conductive charging there are two different charging modes for an EV. Whether one uses the connector supplied with the purchase of the EV, simply connect the two ends of the EVSE [4] (which have two types of electrical sockets) to the vehicle and the domestic plug or to the charging station, respectively. If instead one uses a solution where the cable is permanently connected to the charge point, and then supplied with it, you will have a single free connection terminal that will be inserted in the EV [5].

## 2 Materials and Methods

### 2.1 The Problem

In a first instance the main problem of recharging an EV in a domestic or commercial environment can be summarize as follows: how to avoid the blackout of the building during the EV charging session?

In order to develop the DriWe system, we came across a relatively large and daily problem designed for families or small restaurants, shops and businesses that still want to offer better service to their customers and bring a structural benefit. Families are the strong point of this implementation, as the charging columns will be a strategic element in all homes.

More specifically, a DriWe dynamic control architecture has been developed: the dynamic control of the power loads during the charging session of EVs can be modulated in real time, based on the amount of energy available upstream of the plant (Fig. 1). A smart device is therefore interposed, which assumes the task of evaluating the priorities of the loads and communicating through a specific program to the charge

point whether and how much to deliver. Communication is performed through an Open Charge Point communication Protocol (OCPP).



**Fig. 1.** The main functional blocks of the DriWe framework

The smart device must have some essential characteristics, such as reliability, speed of communication, immediate data transmission, small size but above all a low price.

## 2.2 The Optimization Framework

The proposed framework is based on a block diagrammatic representation, which is quite schematic and easily understandable. The implemented program works by recalling the amount of absorbed loads power in the examined environment: this information is collected through a smart device via an API (Application Programming Interface) which updates every 10 s: (i) a sufficient time to prevent the electric meter from blowing if the contractual power limit is exceeded; (ii) time that avoids a clogging of the communication network. Accordingly, through the initialization of some variables (e.g. the contractual power limit, the monophasic voltage) and a mathematical algorithm checks whether the instantaneous power is higher or lower than the contracted limit power. In case:

- The Current Power is greater than the Contractual Limit Power: we would have an excess power that will be subtracted from the charging power supplied by the charge point, and therefore no electrical blackout.
- The Current Power is less than the Contractual Limit Power: the charge point power supplied can be increased.

Therefore, it is possible to calculate the new current to be supplied by the charge point. This new current must be included within a range of values, a lower limit – namely 6 A, according to the CEI EN 61851-1 - and an upper limit, depending on the specifications and requirements of the charging station. The following configurations may occur:

- The new value of the current is equal to the old one: the configuration parameters are not changed.
- The new value of the current is different from the old one: the algorithm modifies the charging station current through a “Change Configuration” menu, a command given by a special Open Charge Point communication Protocol (OCPP) between the system and charging column. The adopted OCPP protocol, version 1.5, consists of 25 operations: 10 of these operations are initialized by the charging station, whereas the other 15 ones are performed by the central control system [6] (Fig. 2).

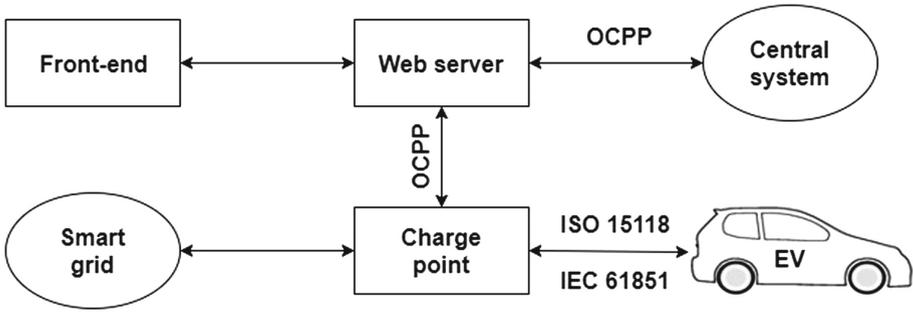


Fig. 2. The DriWe operating scheme [8]

Thanks to these approaches, the configuration parameters of the charging station are changed, maintaining the constant voltage with a variation of the current and therefore of the power delivered to the car. Figure 3 reports an overview of the implementation of the aforementioned process.

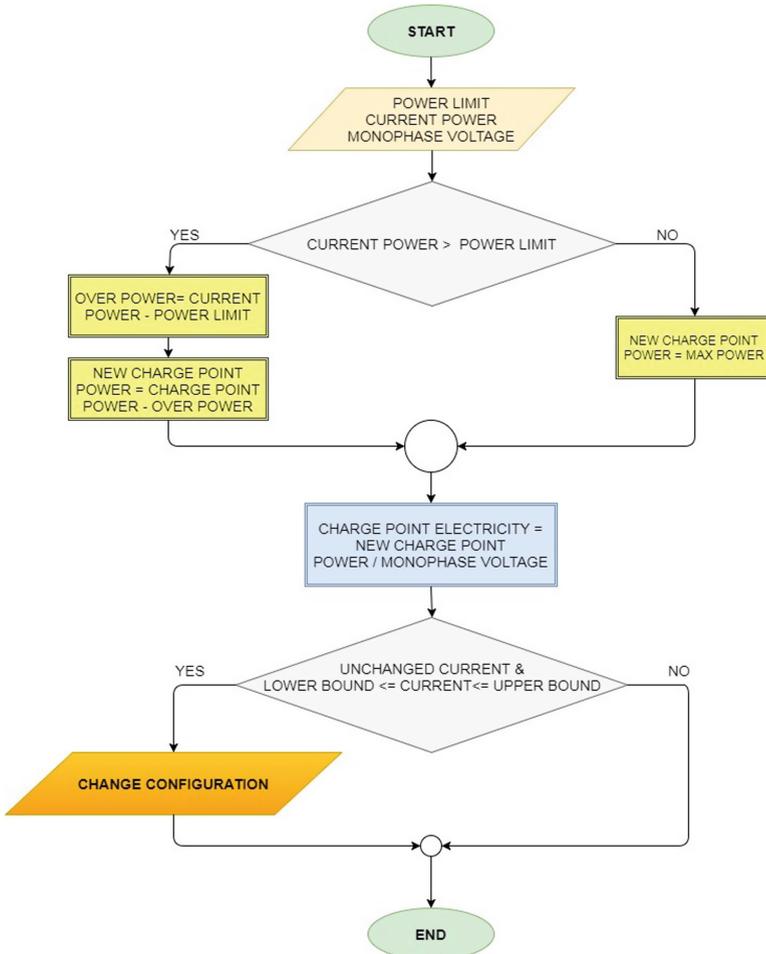
### 3 Experiments and Results

The DriWe has been tested on different commercially available brands and types of EVs. On each test a full charging process has been performed. The tests were carried out at the DriWe laboratories. Each vehicle under examination was monitored for a period of 5 h where it was possible to notice the variation of the current supplied by the charging station vs the changes of the loads occurring in the laboratory. The measurements were performed via the calculation program which has been previously detailed.

We have tested our model on Renault, Twizy and Nissan Leaf to verify the results which are explained below:

**Renault Twizy.** Figure 4 shows the performed output charging power in [W] vs the recharging time in [s]. The red line refers to the threshold power, namely the value of 3 [kW]. The graph shows how the system started with a simple monitoring of the loads in the environment under examination, then with the start of the recharge phase at time [s] an increase in the power absorbed by the network can be noticed; nevertheless, with the consequent introduction of a further electric load, the total instantaneous power exceeds the simulated contractual power limit of 3 [kW]. The calculation program will then be activated with a consequent reduction in the current supplied to the vehicle.

The last part of the graph shows a series of power peaks due to the recharging phase of the vehicle with its consequent detachment. As it can be observed, the recharge session does not result to be successful because changing the current from management there is a communication error given by the absence of the pilot control, “a control conductor in the power cable connecting the control box on the cable or in the fixed part of the EVSE, and the ground of the EV through the control circuit on the vehicle” [7], which does not allow a correct modulation of the signal and therefore a variation of the current.

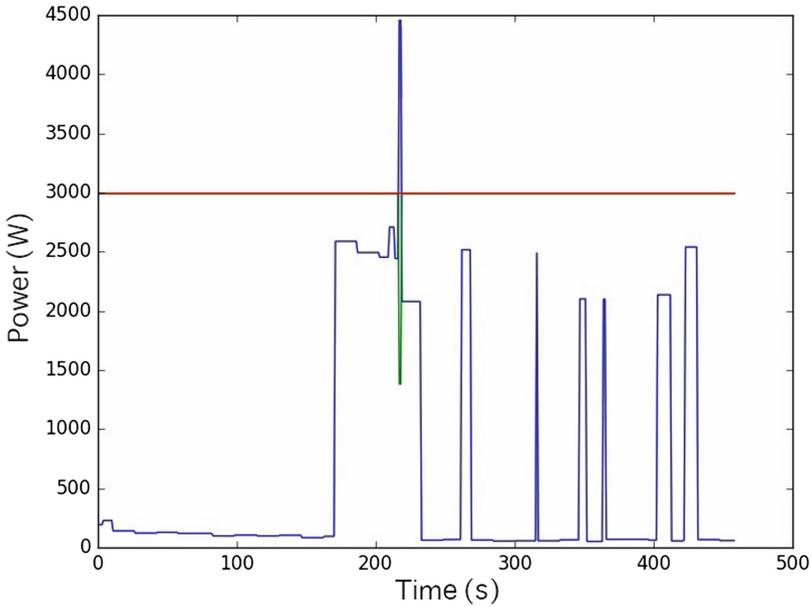


**Fig. 3.** The functional flow chart of the calculation program

**Nissan Leaf.** Figure 5 shows the results of the experiment performed on Nissan Leaf in which the first and third part of the graph shows the line of instantaneous absorbed power.

Figure 5 shows that the instantaneous absorbed power - namely the yellow line within the plot of the figure - follows the red line at 4.5 [kW], meaning that the loads plus the charging station are constantly following the contracted power line.

This pattern shows the correct functioning of the calculation program: in fact, when the loads - blue line in the graph - varies within the examined environment and a correct modulation of the current supplied to the vehicle is obtained, always allowing maximum recharging power, avoids exceeding the contractual limit and the risk of



**Fig. 4.** The Renault Twizy charging pattern (Color figure online)

electric blackout. For instance, when the blue line is overtaken - from 0.75 [kW] to 2.03 [kW] - the current and the maximum power of the charging station decreases from a value of 16 [A] to 10.70 [A] and from 3.68 [kW] to 2.46 [kW], respectively, however the instantaneous absorbed power is constant.

**Table 1.** Phases recharge Nissan Leaf

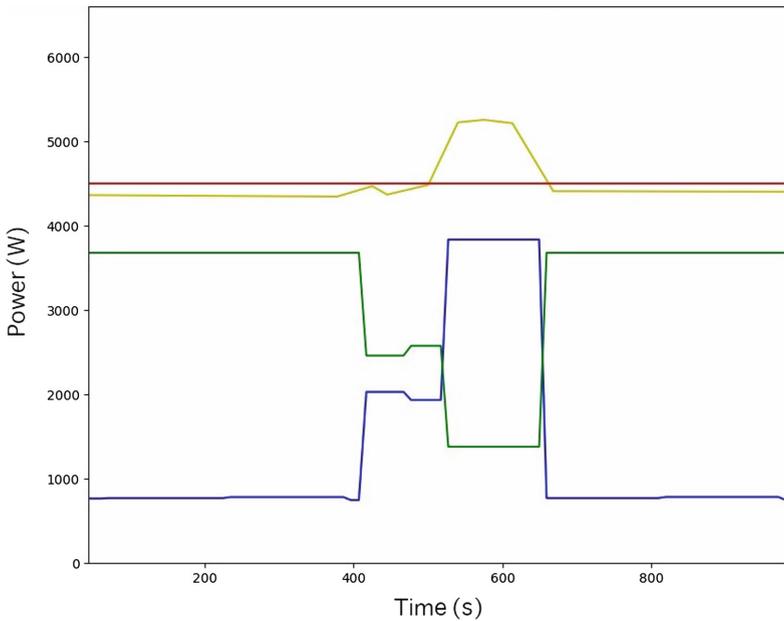
Blue line Power loads [kW]	Charging station Current [A]	Green line Maximum power charge point [kW]	Yellow line Instantaneous absorbed power [kW]
0.80	15.60	3.58	$3.58 + 0.80 \approx 4.40$
0.75	16.00	3.68	$3.68 + 0.75 \approx 4.40$
2.03	10.70	2.46	$2.46 + 2.03 \approx 4.50$
1.95	11.10	2.55	$2.55 + 1.95 = 4.50$
3.90	<b>6.00</b>	1.38	$1.38 + 3.90 \approx \mathbf{5.30}$
0.80	16.00	3.68	$3.68 + 0.80 \approx 4.50$

By analyzing the central part of the graph, greater absorption of the loads present in the examined environment could be witnessed, making it possible to exceed the contractual threshold up to 5.3 [kW]. The dynamic modulation system, to stay below the 4.5 [kW] threshold, would have to supply about 2.5 [A], but the recharge column has a lower supply limit of at least 6 [A] as it was mentioned before.

The above table (Table 1) reports the main values of the power loads, charging station current and the performed instantaneous and maximum power.

Nevertheless, a threshold overrun has occurred but there is no electric blackout. In order to solve this problem, the following strategies maybe adopted with the aim:

- To implement the calculation program in such a way that if the current supplied by the column is less than 6 [A], the recharge terminal is disconnected: following this approach, all the contractual power is used for the power of the loads of the examined environment.
- To send an alert message (i.e. SMS, e-mail or display) to the user to make him aware of the exceeding of contractual power and the risk of electric blackout if the power of the loads is not reduced.
- To integrate the solution with a home automation device or AAL (Ambient Assisted Living) system with a set load priority.



**Fig. 5.** The Nissan Leaf charging pattern (Color figure online)

## 4 Conclusions

We propose a novel architecture to improve and simplify the relationship between the end-user and the Electrical Vehicle, making the recharging process more practical [9]. The proposed DriWe system and calculation program allows the monitoring of the overall process every 10 s in terms of power absorbed by the various loads of a reference environment, avoiding electric blackout by varying, within the time limit, the

power levels delivered by the charge point towards the EV. The results show that our proposed architecture outperforms the existing architectures. Furthermore, it may be integrated and combined with other smart grid application in the Ambient Assisted Living (AAL) context [10].

A future development consists in interfacing the electricity meter with the charging station through the communication on the appropriate Chain 2 channel. It is therefore necessary to carry out a data transmission by means of the PLC (Power Line Carrier) communication channel, using appropriate waves conveyed on the wiring systems that connects the meter directly to the relative user device, in order to be able to modulate the power supplied by the charging station.

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