Communication Infrastructure for E-Mobility Charging Stations V2G Applications

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***Abstract*—This paper main goal is to analyze the ISO 15118 standard used for E-Mobility charging applications, identifying advantages and disadvantages from the infrastructure used in the market and to propose a new strategy aiming to adapt metering infrastructures for vehicle-to-grid energy trading platforms. The idea of exchanging energy with the grid is raising awareness among end-users. While consumers start to produce their own energy and decentralized generation is emerging as a new paradigm for the electricity market, flexible-loads such as e-mobility charging platforms are also on the rise, which may cause a negative impact in the long term, considering the big increase in the demanded amount of energy. Therefore, not only new algorithms and strategies need to be taken into account in order to mitigate the drawbacks e-mobility may have in the near future, but also fast and reliable communication protocols need to be addressed, since they form the key infrastructure for real-time data to be transported, stored and analyzed. The unfolding considers a pure-theoretical approach on charging stations infrastructure, with a clear emphasis on communication protocols used nowadays. Followed by a innovative proposal of using sub-1 (GHz) radio signals building a distributed mesh-network for data acquisition in noisy environments, aiming to propose a bi-directional communication framework between vehicles, users and the grid. Conclusions are drawn, emphasising in the advantages and disadvantages of both proposals, as well as analyzing the main requirements for ensuring a feasible communication infrastructure for vehicle-to-grid integration.**

***Keywords*—ISO 15118, IETF 6LoWPAN, V2G, E-Mobility**

I. Introduction

E-mobility has been proposed as an ideal solution for reducing not CO2 emissions, but also suppressing tailpipe harmful pollutants. Considering also the relatively quietness and smoothness, another advantage for electric vehicles lies in the reduction (almost suppression) of noise pollution, which has become together with pollution the main drawbacks of living in urban nuclei. Although the emergence of electrical vehicles seems to be one of the most suitable solution for achieving sustainability goals, the truth is that promoting the use of e-mobility uncontrollably could lead to more several problems in the near future. It is normally forgotten that, despite being an enormous and synchronized system, energy generated and injected into the grid is, unfortunately, limited. Even worse, there is still a big percentage of energy sources that are not based in renewables, thus contribution to pollution. Simply, if the demand of energy grows without support, distributed generation alone will not be sufficient for keeping energy resources under control.

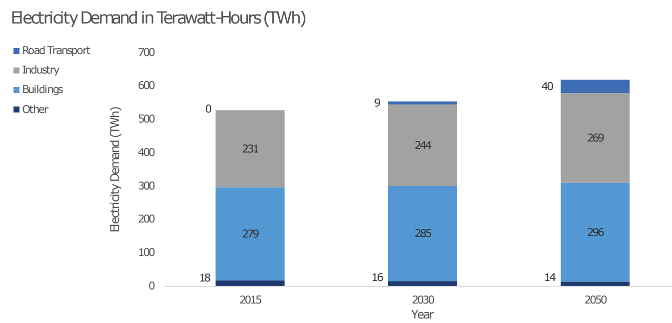

Fig. 1. Compound annual growth rate in electricity demand in Terawatt-Hours (TWh) for the period 2015-2050 [1].

Moreover, considering the relatively flexibility that characterizes the distributed generation sources, it is not difficult to guess that an increase in electric vehicles could lead to such an increase in the demand that renewables cannot cope with, and thus causing a negative effect where non-renewable energy sources, being more predictable, could take the lead again.

A. Increased Electricity Demand

As it can be depicted from Fig. 1, road transport and e-mobility are one of the fastest growing sectors in electricity demand share, with a global compound annual growth rate (abbreviated as CAGR) of approximately 40% for the period 2015-2030 [1]. Not only promoting investment towards renewables, but also with the risk of overloading the system, truth is that the impact of e-mobility in the traditional electricity market could be potentially dangerous, if not catastrophic, if adequate strategies are not proposed. Lines overloading and load shedding schemes could just be the first consequences of a much larger issue. Reshaping the electricity load curve emerges as a top-level solution, whether an equilibrium point between end-users and the electricity market requirements can be achieved. Avoid to connect electrical vehicles during peak-demand hours, or simply reducing the charging current could be beneficial strategies not only for the grid, but also could be translated as incentives for consumers. Moreover, having the ability to reschedule charging schemes and reallocating or delay them to valley-demand hours could be the perfect strategy for using surplus generated energy.

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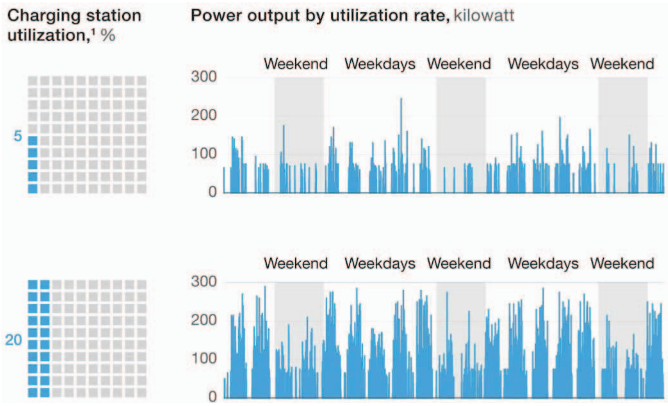

Fig. 2. Load profile for fast-charging stations, emphasising in the percentage of utilization [1].

B. Impact of Charging Stations

Logically, the impact of charging stations in the electricity market is related with the percentage of use. For fast-charging stations, classified according to power output from 150 (kW) up to 300 (kw), increasing four times the share of time an electric vehicle is using the charging station could easily surpass the peak-load capacity of a feeder-circuit transformer [1]. Moreover, the peaks in current demand imposed by the charging stations implies that dedicated balancing systems are required, given the erratic and inconstant load profile depicted in Fig. 2. As charging schemes and strategies can be easily molded according to the requirements of the electrical system, this are often referred as flexible-loads.

C. Proposed Strategies

Fortunately, the boom of electrical vehicles has not reached a point of no return yet. Several strategies can be proposed, even converting the previously mentioned disadvantages into potential benefits for end-users and the electricity market itself, enumerated as follows:

- **Flexible Loads Reallocation:** Delaying charging schedules may come at a cost, since the end-user also has to perceive a benefit from its willingness to sacrifice time and resources. Therefore, proposing a differentiated tariff-scheme or a reward system could be attractive points for consumers. Moreover, peer-to-peer energy exchange algorithms may be also analyzed, having a platform that supervises the actual situation of the market and proposes the best offers for users.
- **Vehicle-to-Grid (V2G):** One of the most interesting and beneficial solution relies in considering a cluster of electrical vehicles as a huge controlled-battery. Considering the amount of vehicles parked during working hours, truth is that this massive infrastructure could be useful to provide the grid with the necessary amount of energy to cope with peak demands.

Although algorithms and strategies can be proposed, the main factor that will determine the effectiveness of a real-time infrastructure will be communications. The way that data is processed and stored will be the milestone for achieving a solid framework relating end-users with the grid system and the electricity market.

II. ISO 15118 Standard

There are many aspects that need to be addressed by the infrastructure in charge of data transfer. One of the most important parameters is to guarantee a secure channel for both parties, before starting to exchange useful data. As pointed out in [2], charging stations in the public sphere need to be connected online, enabling integration with smart grids and offering remote operations together with IoT and the use of distributed energy resources, often known as DER.

A. Plug&Charge: V2G Applications

Efficient and safe integration of the emerging boom of electric vehicles into the already developed grid is the main pursued target when designing a suitable communication protocol. Founded in 2010, the ISO/IEC Working Group developed the first standard towards integration of E-Mobility with distributed generation and decentralized smart grids. The detailed analysis on the ISO 15118 standard is extracted from [3], aiming to obtain the guidelines on how the standard was designed by the joint working group and thus, how to implement a new strategy towards low-power communications implementations in the scope of lossy communication infrastructures.

B. The Physical Layer Composition

Considering the relatively simple endpoints that take part in the communication, on one side the electric vehicle is represented as the electric vehicle communication controller, also abbreviated as EVCC. On the other side, the charging station is represented by the supply equipment communication controller, or SECC. OSI Model Layer 1, or physical layer, describes how the communication between the electric vehicle and the charging point is established, which could be implemented using wired methods or wireless strategies. While the last one is fully addressed in ISO 15118-8 part, the first one is described in ISO 15118-3 part. The former one describes the use of the power line communication protocol, abbreviated as PLC. This protocol being used for V2G applications is fully depicted in the HomePlug Green physical specification [4]. The use of PLC communication protocol for energy data measurements has been proven effective, but nevertheless presents some drawbacks, such as latency and reduced bandwidth, which may have a large impact in real-time focused applications. Therefore, using the wireless physical implementation addressed previously, a new communication protocol is proposed, aiming for low-power consumption and proper bandwidth for real-time applications in V2G energy transactions.

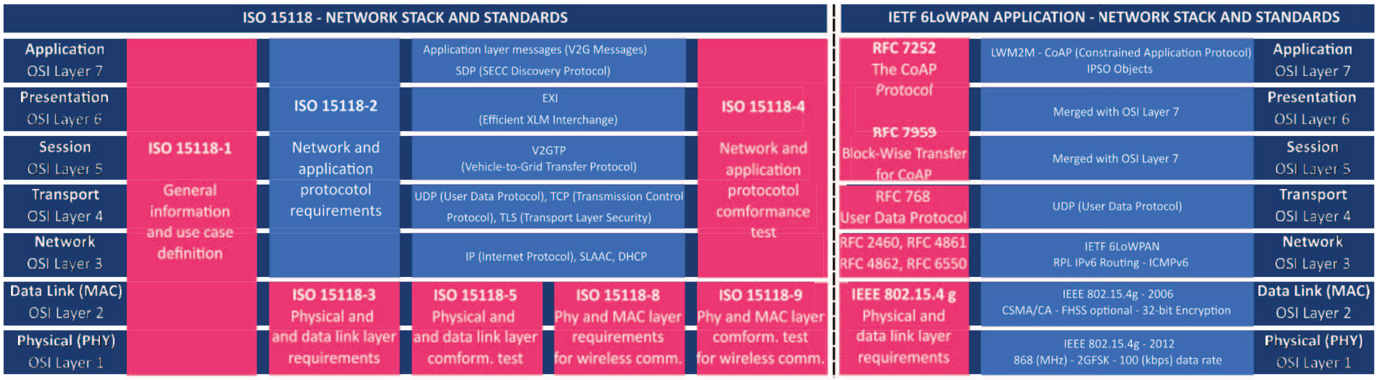

Fig. 3. Comparison between ISO 15118 and IETF 6LoWPAN network stacks for E-Mobility charging station communication. Adapted from [3].

III. Low-Power and Lossy Networks Protocol for V2G Implementation

Wireless strategies addressed in ISO 15118-8 part opens a new paradigm for protocols implementation. Radio links described in the former standard are based in frequencies above 1 (GHz), which are suitable for short-range communication, but lack of a proper penetration constant for noisy environments. Moreover, for V2G applications a mesh-device network, which interrelates not only electric vehicles between them, but also monitoring devices, energy meters and a multitude of charging stations all together may be proposed. The interconnection of many devices into an extended mesh-network allows the exchange of information among devices of different nature, enhancing reliability and ensuring proper data acquisition.

A. IETF 6LoWPAN

The protocol proposed in this paper is based in the IETF for Low Power and Lossy Networks, also known as 6LoWPAN. Both network stacks for ISO 15118 standard and 6LoWPAN implementation are compared in Fig. 3. 6LoWPAN is based in sub-1 (GHz) radio links, often in the 868 (MHz) radio band for implementation in the European sphere. This kind of signals not only have an improved penetration constant value, which makes them ideal for communication in noisy environments, but also combine adequate bandwidth for real-time data acquisition and are designed for low power consumption applications.

B. Adapting layers

As depicted in Fig. 3, both protocols share some parameters in common. The proposal of using 6LoWPAN for V2G energy transactions, as well as proper electric vehicle charging sessions is based in replacing OSI Model layer 1 (physical layer), layer 2 (data link layer or MAC layer) and layer 3 (network layer). First one refers to the use of sub-1 (GHz) radio links, as well as low energy consumption modulations schemes, such as 2-GFSK. The use of simpler modulation techniques implies a reduction in bandwidth, but with the aim of keeping energy consumption as low as possible. Second one also considers the use of CSMA/CA and data encryption.

The third one is based in IPv6 addresses rather than IP Protocol version 4, given the emergence of IoT devices flooding the market. For building a proper mesh-network, RPL protocol is used, defined in RFC 6550. On the other hand, OSI Model layer 4 (transport layer) may be implemented with User Data Protocol (UDP), rather than Transmission Control Protocol (TCP), thus reducing the required bandwidth.

IV. Conclusions

Although it has been proven that ISO 15118 is a reliable standard for V2G implementations, some limitations regarding reduced bandwidth might arise from the use of PLC communication infrastructures. Moreover, the use of wired infrastructures for communication purposes implies that vehicles are only sharing data as they are being charged, which prevents from having an overall control of charge status or forecasting daily-energy consumption. Using wireless mesh-network infrastructures based on IETF 6LoWPAN allows not only acquiring data in real-time for flexible-loads management, but also shows an improved behaviour in noisy environments with an adequate bandwidth for energy transaction applications, as well as greatly reducing power consumption. This solution could become potentially a solution for real-time energy transactions between E-mobility and smart grids.

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