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ELECTRIC VEHICLES AND CHARGING CROSSBORDERS INFRASTRUCTURE

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3. Interoperability

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Determination of factors that affect the Interoperability of charging Stations in Europe and which is the situation in Greece.

The electrification of transportation can bring environmental, health, and economic benefits when coupled with a low-carbon electricity generation portfolio. The recently increasing penetration of new electric vehicles may further boost this challenge vitally. The electrified vehicles have become a topic of wider interest in this manner, especially with the increasing environmental awareness against the negative outcomes of the transportation sector; however, ensuring that this transition goes smoothly requires addressing several grid-integration challenges (A. Majoe, 2018).

The energy operators have been facing with a growing level of challenges especially with the increase of the peak demand and the integration of higher amounts of variable renewable generation units, while coping with the challenge of effectively managing the demand and supply balance.

In Greece there are around 10.000 BEV and PHEV vehicles sold from 2018 until the end of 2021. In the same period there are around 1.000 private EV charging stations, 100 of them can also provide DC fast charging solutions that in most cases arrive up to 50 kW power (www.plugshare.com/, n.d.).

The above numbers indicate that e-mobility sector in Greece is still small. Because of that, the legal framework that have to apply to the various energy operators and different EV charging systems is still under development.

With regards to electric vehicle charging infrastructure, interoperability refers to the compatibility of key system components-vehicles, charging stations, charging networks, the grid and the software systems that support them, allowing all components to work seamlessly and effectively. (EPRI, 2019).

It is easy for everyone to understand that the issue of the interoperability is quite complex and has many problems to overcome. In Europe however, it has reached a maturity level which is notable.

There are many ways to apply the interoperability. The most diffused of them are mentioned and explained below:

1. *Interoperability via creation of a new platform*

Many operators choose to create their own application. This solution is not considered very effective because the user hardly is willing to charge his vehicle in only one operator. He prefers to have access to a larger network of EV charging stations, mainly for the regions that are not very well covered yet.

Moreover, some companies use closed-network software that only allows drivers with a specific app to see and access their stations. In this second case the charging issues for the drivers become even harder to solve.

In general, a typical EV user will prefer an application with many integrated platforms in order to cover his needs respect to a closed loop application.

2. Integration in large platform

By joining a large platform, an operator can put and present all its charging points along with some of its competitors. This can be beneficial for the operator itself because it can attract more clients to every charging point that operates and can be also beneficial for the clients since they can charge their vehicles in charging points that discover through the application.

i.e. Car.ge, Hubject

3. Interoperability via direct agreements between the EV charging points operators.

Interoperability between charging stations can be achieved by direct agreements between the operators of the different networks. Afterwards, the operator can use the platform of his partner and vice versa. In this case the drawback can be the different number of separate agreements that each stakeholder brings into the new agreement. In consequences, the management of the different partnerships might not be easy for small operators.

Interoperability study of the individual subsystems of the Electrification System and degree of compatibility and effects of stakeholders

As a general expectation, public EV charging infrastructure should be convenient and reliable for drivers to use. The site hosts should be placed in such positions in order to ensure that every vehicle can go through the distance that wants to cover regardless its autonomy. The electric companies should be capable to resolve any charging problem that could appear during the charging of EVs.

The four key interoperability-related challenge areas are described below:

Charging Network to charging Network

Network interoperability enables customers to use stations across networks. There are two ways to do it so, either by searching a single major network or by having access to a particular platform that includes many different operators.

There are some major individual networks that the EV user can search separately. EVgo, ChargePoint, Volta, and others offer the ability to search for nearby chargers, check the level of charging on offer, and see if plugs are in use. Tesla also has opened its massive Supercharger network to owners of other EVs too.

In the second category, there are the host of dedicated platforms. PlugShare and ChargeHub are two of the most popular that let users search for stations across major charging networks. Both allow users to plan trips and filter search results by connector type, charger power, network, and other features. PlugShare users can also filter for stations with the highest user ratings or for locations with amenities like WiFi.

The above platforms guarantee the interoperability from charging network to charging network for their users.

Charging Station to Network

It has been noticed that in many cases commercial charging equipment providers bundle their charging hardware with software so that the hardware is incompatible with other networks. This create lack of open standards and forces a host that is desiring to change network service providers to purchase and install an entirely new charging hardware.

By installing a networked charging station, site hosts are often tied to the original network provider for the hardware's lifetime, limiting customer mobility and competition.

Open standards-based approaches would mitigate these integration challenges, while improving site hosts' ability to monitor the condition of their charging stations in real time to ensure timely maintenance and the interoperability.

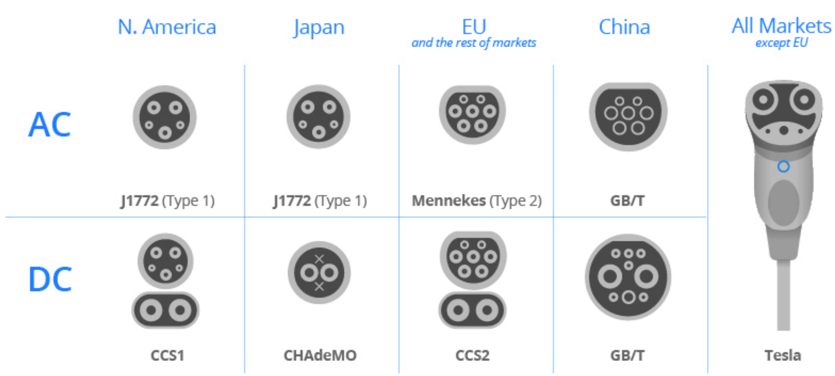
EU directives are trying to solve this kind of problems but there is not any specific law yet to guarantee the interoperability from Charging Station to Network.

The article 32 of the directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 refers:

In 2010, the Commission delivered a mandate (M468) to the European Standardization Organizations (ESOs) to issue new standards or review existing standards with the aim of ensuring interoperability and connectivity between an electricity supply point and a charger of electric vehicles. CEN/CENELEC set up a focus group, which published a report in October 2011. Whereas the report contained a number of recommendations, no consensus on the selection of one standard interface was reached. Therefore, further policy action is needed in order to provide a non-proprietary solution ensuring interoperability across the Union (europa.eu).

Physical Charging Interface

Charging stations should decide which type of DC fast charging and AC charging standards will support. The types are changing also across the continents, Picture 1. Supporting multiple formats adds equipment complexity and cost and may increase the footprint required to serve a given number of vehicles (evexpert.eu, 2021).



Picture 1 Types of EV charging connectors

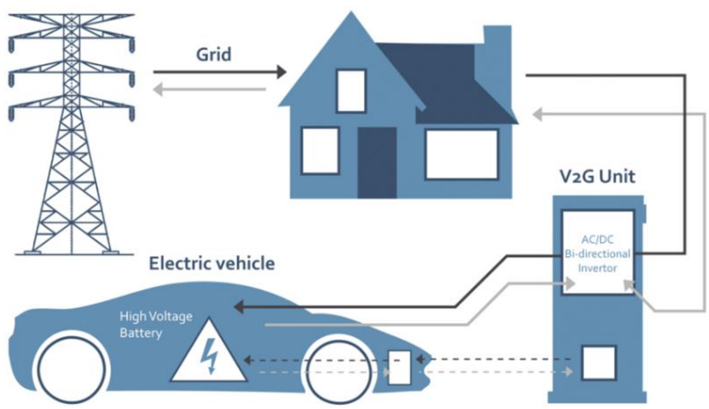
There are four different DC charge ports used today and other four different also for AC charge ports. Tesla vehicles have a different port as well.

Regarding AC charging ports, in Europe the Type 2 "mennekes" became the new European standard. Thanks to the fact that both types of plugs (type 1 and 2) use the same J1772 signaling protocol for communication, car manufacturers can make vehicles in the same way and only at the very end they install the type of plug that corresponds to the market where the car will be sold. Passive adapters also exist among these types. Another important advantage of the Type 2 plug is that it supports a built-in automatic locking system. The Tesla Model S and Model X sold in Europe also have the Type 2 plug (only in a slightly modified version) which they can use for charging at any AC charging station and they also use this connector for the Tesla Supercharger network where they charge using DC.

For the DC charging, in Europe, the most diffused solution is the Type 2 CCS. The European Parliament's efforts to allow only CCS 2 and other plugs to be phased out of Europe have not been successful, but this standard is still winning, mainly because the car has only one socket. When using the CHAdeMO connector, the car must always have two sockets. CCS are not compatible with CHAdeMO and GB/T charging stations because they use different communication protocols, so special adapters are needed and they are not easy to obtain.

Vehicle to Grid (V2G)

Vehicle to Grid is a technology that enables energy to be pushed back to the power grid from the battery of an electric car, Picture 2. With electric vehicle to grid, a car battery can be charged and discharged based on different signals such as energy production or consumption nearby.



Picture 2 Vehicle to Grid operation

The Vehicle to Grid can have a lot of benefits for different stakeholders. For the power grid, when power consumption increases, it can overload the power grid in that area.

The EV's ability to balance its electricity demand with V2G charging stations also helps out the power grid in a small scale. Without control, the EV owner has to accept a higher cost but with V2G the costs and profits can be optimized. In other words, V2G enables energy companies to ask and give back electricity from and to the grid respectively.

In other words, to achieve the maximum optimization, the charging system should be transparent and the electric companies should be able to manage the public charging infrastructure securely, cost-effectively, and reliably, while also planning for future public charging growth. Moreover, the communication should be secured and integrated between the grid and downstream components of EV charging infrastructure is required for optimal EV-grid integration, but it is noticed that currently it is impeded by a lack of open standards, interoperability, and transparency in the current models.

Electric Vehicle Charging Services Platforms and e-roaming

Mass adoption of electric vehicles requires not only an extensive charging network, but also the development of an EV roaming infrastructure. EV roaming refers to opening up EV charging infrastructure for EV drivers, giving them access to thousands of charging locations worldwide.

Roaming agreements between charge point operators and electric mobility service providers are essential in order to accomplish this. The goal for EV roaming is to give EV drivers the ultimate charging experience.

Even if the topic seems simple to the users, delivering electric vehicle roaming services is profoundly complex, requiring negotiated service and clearing agreements among e-mobility providers and charge point operators, comprehensive communications requirements, various protocols, and support of multiple languages, currencies, tax rates, and regulations.

The expectations for the future is to be an easy task to participate in the e-Roaming ecosystem and to be indeed a win-win situation for service providers and their customers. Each player can leverage its competitive advantages to appeal to an even broader client base, while EV charging customers gain the complete elimination of range anxiety, knowing they can charge anywhere they travel in the world.

There are two technical options when it comes to enabling eRoaming. EV charging providers can leverage general a roaming hub, such as Hubject, GIREVE, or e-clearing.net, or use a peer-to-peer Open Charge Point Interface (OCPI) protocol such as OCPI 2.2 that supports both network-to-network/peer-to-peer communications.

Moreover, there are companies worldwide that are working towards the e-roaming optimizations as both consultants and operators as well, such as GreekFlux (GreenFlux). They have connections to all major roaming hubs that are mentioned above.

In Greece, Fortisis is a company which along others, deals also with e-Roaming optimization for EV charging solutions.

Regulatory Framework and Pricing Policy of Electric Car Charger Installations and Impacts on System Interoperability

Law 4233/2014 introduced the possibility of installing charging stations for EVs at Fuel and Energy Stations both indoors and outdoors. Moreover the Joint Ministerial Decision 71287/6443/2015 determined the terms, conditions and technical specifications of the charging devices of electric vehicles for their installation in the above service stations.

Subsequently, Law 4439/2016 incorporated Directive 2014/94 of the European Commission into Greek legislation. Directive 2014/94 establishes a common framework of measures for the development of alternative fuel infrastructure in the European Union and sets out the minimum standards required for the establishment of alternative fuel infrastructure, including charging points for electric vehicles, to be implemented by Member States through national policy frameworks. Moreover, it also sets out the common technical specifications for such recharging as well as information specifications for users.

In other words, it sets the framework for the development and management of electric vehicle charging infrastructure in order to ensure open access to those concerned on market-friendly terms.

About the Electric Car Charger installation cost, there is not yet any common policy across the European Union members. Since the market is quite new the cost for the investment varies from country to country and between the different service suppliers.

Most enterprises look to install level two charging stations, which run on 240-volt power and provide a compromise between power and cost. A level two electric vehicle charging station costs around 6.800 € for a dual-port station, so it can charge two cars simultaneously in 8 to 10 hours. The highest specification for a commercial EV charging station instead, is level three, or direct current fast charge (DCFC). Level three stations can charge a vehicle in an hour with 480-volt direct current. Level three stations cost around 47.000 € for a single port (futureenergy, 2021).

The charging cost in Europe has some differences across the counties too. In Greece the cost is more or less the same within the site hosts and thus within the different electric companies.
However, the invoice policy to charge an electric vehicle, up to now has not any kind of common agreements between the European Union members.

There are some surveys have been conducted among the EV owners that have given some useful results in the users' level as well, (LeBlanc, 2022). The main result reveals unawareness among EV owners regarding the cost to charge their EV. In the question whether they are paying more, the same, or less for charging their EV respect to traditional fuel, the reply as following:

- 37% same as fuel
- 33% less than fuel
- 28% more than fuel

From the interview we had with the Carge CEO, Mr. Eleutherios Karabatsakis, when he was asked about the problems that his clients mention while they are trying to find a charging station, he gave us the data below:

- An EV is parked in the location and it is not charging anymore (52%)
- A car with traditional engine is parked in the location (32%)
- The charge point is not working (9%)
- The charge point is located at a private commercial property (4%)
- The charge point is only accessible during certain times of the day (3%)

All the above arrhythmias can provoke interoperability problems in every level of the procedure. Common laws can moderate the impact that different policies have on the e-mobility operational chain.

Business Models

In Greek market there are different business models applied for the implementation of the various software govern the operation of the charging stations.

In details, Greek law 4643/2019 adopted the recommendation of Opinion No. 7/2019 issued by the Greek Regulatory Authority for Energy (RAE) according to which the development of publicly accessible EV charging infrastructure should be deployed on competitive market terms (e-nomothesia.gr, 2022).

The main e-mobility market players are the electric vehicle charging infrastructure providers (EVCIP, in Greek ΦΕΥΦΗΟ), the e-mobility service providers (EMSP, in Greek ΠΥΗ), the processor of e-mobility transactions (PEMT, in Greek ΦΔΣ) and the aggregator of electricity for electric vehicles (the Aggregator, in Greek ΦΟΣΕΦΗΟ).

A) An EVCIP may be either a single-member partnership or legal entity registered with the Greek General Commercial Registry and is responsible for the overall administration (both technical and commercial) of one or more EV charging points. It may provide its services to:

i) users on an ad hoc basis
ii) users having previously entered into a bilateral agreement with the EVCIP
iii) users who have entered into a contract with an EMSP.

An EVCIP may own or lease the relevant plot on which the charging station is installed (where no EVCIP is involved in a publicly available charging spot, its role shall be undertaken by the owner of the relevant infrastructure). An EVCIP may also enter into a connection agreement with the Hellenic Distribution Network Operator (HEDNO) and conclude a contract with one or more electricity suppliers under its capacity as an end consumer, while it is exempted from the obligation to get a license for the supply or trading of electricity.

B) An EMSP can be either a single-member partnership or legal entity registered with the Greek General Commercial Registry, which provides e-mobility services to subscribed users by setting pricing policies, charging fees and methods of verification.

C) A PEMT may be either a single-member partnership or legal entity registered with the Greek General Commercial Registry. The PEMT ensures interconnection between contractually-unrelated charging infrastructure, by processing and settling transactions between EVCIPs and EMSPs.

D) The Aggregator is a legal entity which represents the parties connected to the EV network in the electricity market. It also provides data to Distribution Network Operators.

- In an ad hoc payment model, a PEMT is not required. Moreover, an EVCIP, a EMSP and a PEMT (where applicable) may be the same legal entity. However, in no case may an EVCIP also be an electricity's provider.

- This public network charging infrastructure model makes it possible for any user to charge an electric vehicle regardless of the Electric Vehicle Charging Infrastructure Provider (EVCIP) they have a contract with.

Law 4643/2019 also stipulates that Distribution Network Operators may not own, develop, administer or operate charging points for electric vehicles, other than private charging points exclusively for their own use. According to its provisions, eligible potential stakeholders may act simultaneously as an EVCIP, EMSP and PEMT.

Information System Implementation Study (Software Implementation Plan)

There are some important studies in literature that describe the necessary framework for all the actions and indicate that to cover all the scenarios, the implementation needs a high grade of flexibility (Wellisch, Kunze, & Pöschl, 2015).

For the development of a modular software for charging stations with smart charging capability, the software shall be able to run on a broad range of different types of charging stations. To this direction, the hardware should be separated from software in order to achieve platform independence. The implementation shall be able to run on various operating systems such as Windows, Linux and Mac OS.

To do it, there are many connections needed and high effort from the software is required. Due to this fact, it is important that the software is processed with high speed, so that no requestor response from a connection is missed. In this kind of cases, the traditional programming languages like C and C++ cannot be applied. The study proposes the development and coordination of all threads with inter process communication. Instead of a C and C++ implementation a programming language with suitable connection handling is preferred. In this specific study the Node.js has been promoted as a good choice in terms of connection handling and processing speed.

To feed this modular software and make it even stronger to process every kind of demand, the charging data is absolutely necessary. By monitoring and post processing of charging sessions, every charge point operator is able to predict user's behavior. The software itself can be ameliorated by the taken post processed information.

In literature there is also a different approach regarding the Implementation Plan which is not only software oriented. Specific study proposes a developed electric charging station using microcontroller ATMEGA8535 as controller and RFID (radio frequency identification) as identifier of the EV users (Panatarani, Murtaddo, Maulana, Irawan, & Joni, 2016). In this kind of configuration the desired features of charging system were the input EV voltage of AC220V/40A, the visual information on the state of charging and the users' identification. In other words, in this development, RFID technology was applied to allow automatic identification of users, solving the specific interoperability issue.

Carge CEO, Mr. Karabatsakis, says that in Greece the communication protocols are the same among the charging stations' operators. The whole system is developed correctly from the beginning and his clients rarely refer interoperability problems related to SW issues. He continues saying that of course the market in Greece is still small and every stakeholder should be careful in order to be maintained the regularity in this interoperability aspect.

Mr. Karabatsakis are also referred in the interoperability problems that deals with in Italy, where he found out in several cases that municipalities installed charging stations without using any specific software or even hardware. In this case the software is not subject to Open Charge Point Protocol (OCPP) leading to major interoperability problems.

The conclusion from the literature and from the interview is that the Software Implementation Plan should be common among the operators in order to have at least a common core operation. This is going to facilitate the monitoring of the interoperability problems since the range of the possible problems is going to be reduced.

Bibliography

A. Majoe. (2018). Global EV Outlook 2017: Two million and counting. *International Energy Agency*.

e-nomothesia.gr. (2022). *Law 4643/2019.*

EPRI. (2019). *Interoperability of Public Electric.* Electric Power Reasearch Institute.

europa.eu. (n.d.). *Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure Text with EEA relevance.*

evexpert.eu. (2021). *Connector types for EV charging around the world.*

futureenergy. (2021). *HOW MUCH DO EV CHARGING STATIONS COST?*

GreenFlux. (n.d.). *EV Roaming.*

LeBlanc, B. (2022). *EV charging and pricing: What are consumers willing to pay?* esource.com.

Panatarani, C., Murtaddo, D., Maulana, D. W., Irawan, S., & Joni, M. (2016). Design and development of electric vehicle charging station equipped with RFID. *AIP*.

Wellisch, D., Kunze, S., & Pöschl, R. (2015). A Modular Software Implementation for Smart Charging Stations. *International Symposium on Smart Electric Distribution Systems and Technologies.*

www.plugshare.com/. (n.d.).