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A whole approach for the Electric Vehicle infrastructure in the Basque Country

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Abstract

This paper introduces MUGIELEC's approach and objectives and presents its last results for a proposal for the exploitation of the infrastructure for charging Electric Vehicles. One main goal is the management of information and knowledge, in order to provide adequate added value services and pave the way for a Business Models analysis.

During MUGIELEC development, the communication and protocols among the different players and systems, mainly Electric Vehicle, Supply Equipment, Services Provider and System Operator, have been implemented. For these three years the manufacturers and Companies involved are designing and developing different products according to an integrated and spreadable concept.

At the end of 2012 a full demonstration will be realized. Some Supply Equipment by different manufacturers, corresponding to residential, car-park and fast charging stations, are to be controlled from an Operation Dispatch corresponding to the Service Provider, which communicates with the infrastructure and carries out the whole management.

All this approach is intended, and so will be the outcomes from the demonstration, to come up with an open platform that should help assess the economic feasibility of valuable technical solutions for integrated intelligent charging infrastructure for Electric Vehicles, also providing advice for Standardization.

Keywords: Infrastructure, Service Provider, Charging, Smart grid, Market

1 Introduction

The MUGIELEC initiative [1] is a publicly funded R&D project in the Basque Country, in the north of Spain, contributed by many important players in the energy sector in order to collaborate on EV (Electric Vehicle) related technology and applications, with a strong focus in the infrastructure side. The project comprises a complete system-level approach, covering from grid operation, to the infrastructure-to-vehicle communication, including critical subsystems such as recharge infrastructure scenarios, impact on the grid, V2G technical feasibility, or customer behaviour analysis.

MUGIELEC is led by ZIV, and TECNALIA is its technical coordinator. AEG, CEMENTOS LEMONA, FAGOR, GAMESA, IBERDROLA, INCOESA, INDRA, INGETEAM, ORMAZABAL and SEMANTIC SYSTEMS are the rest of the partners. It will be running from September 2010 until the end of 2012. Its budget is around 10M€.

MUGIELEC aims at enabling a seamless integration of EVs and charging infrastructure. In this sense, a current or future EVSE (***EV Supply Equipment***, which is a Charging Point or a group of Charging Points) manufacturer should be able to deliver its products without any extra development required. Likewise, an EVSP (***EV Service Provider***, or ***eMobility Operator***) using the MUGIELEC approach is able not just to communicate with all defined actors and companies, but it can also find a simple interface connection to its existing ERP (Enterprise resource planning).

To sum up, this system covers existing and innovative EV concepts. In addition, due to its modularity, future implementations will be easily added to MUGIELEC. As a result of the openness of the system and approach, the previously deployed components will be able to coexist with those implementing new features in the future.

2 Charging infrastructure

In every country, policy makers are deciding how to structure this new EV charging activity within the classic electricity-related activities (electricity distribution and retail of electricity), and probably a lot of different models will be implemented depending on the specific market conditions, economies of scale, government decisions and/or incentives, and technical know-how of each individual country. In 2010, the Spanish Government decided that EV charging is a non-regulated activity (in opposition to electric distribution), and the charging infrastructure must be managed separately from the regulated electricity networks. [2]

So, in practice, we are talking about three main players now: DSOs, who manage the electricity networks, and their objective is ensuring the electricity supply for all the purposes in everywhere; EV users, who have to buy (or sell) energy; and the charging infrastructure managers, who are new players to manage the needed electric infrastructure for retailing the electricity to the users.

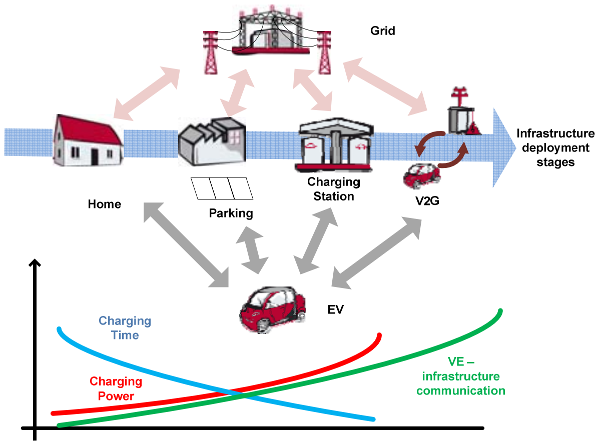

Figure 1. VE charging according to MUGIELEC approach

MUGIELEC, focused mainly on the charging infrastructure, has a global and complete vision, considering not only the technological attributes, but also the relationship, integration, and communication needs with both electricity networks (and its Operators) and EVs (and their Users). As a result of this, MUGIELEC performs a deep analysis of the different recharge scenarios proposed for the short to long term, carefully tackled from the point of view of the electricity grid. The interaction between all these stakeholders will be explained in the paper.

2.1 Charging station

One of the goals of MUGIELEC demonstration is focused on the fast DC charging. The whole charging facilities, for the purpose of this demonstration, will consist of a 50 kW DC and four 22 kW three-phase AC CPs (***Charging Points***), developed in MUGIELEC according to specifications coherent with the rest of the concepts. Taking into account the relevant power that is needed when several fast charging CPs are present, the secondary substation is a main component to develop this concept. So, in this case, the secondary substation will have to deal with 138 kW, regarding EV loads. Charging modes 3 and 4 are implemented. [3]

Figure 2. Charging Station

In order to optimize the possibilities of demand response techniques and minimize the impact of the power demand from the fast CPs when installed in weak networks, the secondary substation integrates a battery based storage and an intelligent management system. CHAdeMO protocol is being implemented for communications between EV and the DC charging point. In this demonstration, the EVSE controller will be part of the secondary substation's intelligent management system.

2.2 EVSEs for residential purposes

MUGIELEC has also analysed different approaches for residential EVSE. The new Low Voltage Regulation for Infrastructure for EV charging in Spain, which is under development at the moment, will impact the requirements to be fulfilled by the residential charging devices. MUGIELEC supports the spirit of this Regulation to be fully open, in order to facilitate the growth of any business models that could arise for the exploitation of this new still undefined market. In this way four different schemes are considered, opening different approaches for the EVSE. [4]
The MUGIELEC prototype for residential application includes a module for legal smart metering. It responds to a master-slave concept, in which PRIME, Home Plug or other PLC-based communications are used. The master charging device could also be able to communicate with the DSO through the secondary substation using also PLC (Power Line Communication), such as PRIME. These devices implement charging mode 2. They include an RFID module for authentication purposes, which can be verified by communicating with the EVSP. The main objective is to achieve a low price charger with high performance, able to be monitorized and controlled from the EVSP.
Communication between residential EVSE and the EVSP is carried out via Ethernet or M2M 3G, where the used protocol and information is transparent.

2.3 The car-park approach

Multiple car parks are another key usage scenario for electric vehicles in the early adoption phase. Different parking topologies are considered, from small parks outside to complex several storey parking lots with different charging managing companies. In most cases the impact on the secondary substation is not deemed relevant, and a mean 150 kW peak power has been considered, as a reference, depending on the grade of penetration of EVs (number of car parks devoted to EVs) and the supported charging power.
Charging modes 3 and 4 are considered in the car-park approach. Eleven AC charge points will be set up in this demonstration (all of them for mode 3 charging), eight of them one phase, 230 V 16A (3,7kW). The remaining three CPs will be 32A, 400V 3 phase (22kW). Additionally, one 50 kW DC fast CP will implement mode 4 and will serve two park places.
For those scenarios where several CPs must be deployed in a small area, master-slave architectures are a cost-effective solution. Local intelligence is concentrated in a single master CP that will centralize all reporting activities and will communicate with the slave CPs. Power Line Communication technologies have been chosen as a default due to their obvious advantages (no additional communication infrastructure is required), but wireless technologies may also satisfy the requirements of such systems.

3 The MUGIELEC concept

In principle, looking at the grid and the consumers, the EV is like any other load. However, their geographic and temporal uncertainty for connection, the fact that they include storage instead of mere loads, and the specific load profiles according to customs, EV types, etc., bring specific challenges and opportunities.
This need for an intelligent management and communication obliges to set up at least a minimum level of intelligence at every relevant stakeholder and device.

Currently, due to the lack of standards and the still minimal penetration of the EV in the mobility business, each EVSP is implementing its own solution, according to its vision of the EV scenario. The resulting platform is not open, with usually an ad-hoc communication system (protocols and technologies) to access to the EVSE, with a set of interfaces with the different actors required in their business logic.

The following figure depicts the standardization framework where the different actors move. "Agreement" stands for some kind of rule or specification accepted by different players but without legal obligation or approval within a Standardization Body.

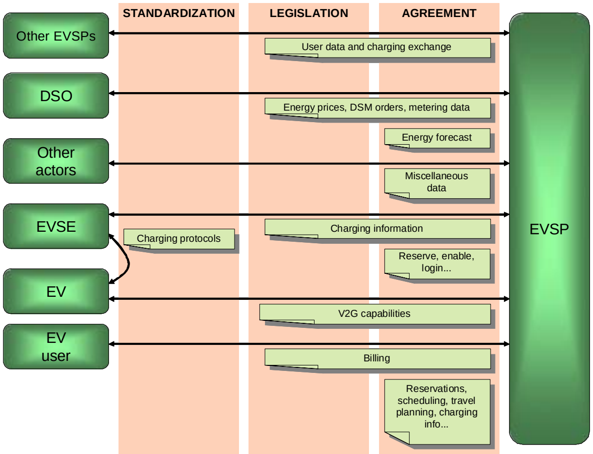

Figure 3. Messages and Frameworks

The MUGIELEC approach has taken into account the present outcome of Standardization Groups and other on-going relevant initiatives, trying to cover present and future functionalities and services. The key feature of this project is that the EVSP always deals with well known data in its own language by means of this normalized information (data model and messages).

Thus, defining an information architecture that manages any possible charging scenario in a system-wide coherent way is one of the main challenges of MUGIELEC. These information architecture will not only have to be useful for different market players with different needs (energy management, grid automation, billing, user identification etc.) but it must also address the communication between these market players (EVSPs, DSOs, etc.).

MUGIELEC also assumes different degrees of harmonization in communication between potential devices. If both receiver and sender comply with normalized communication, the message is sent directly. However, if one of them does not use the normalized message scheme, the message has to be translated in advance. This way, MUGIELEC manages information internally as normalized messages. For example, if the EVSP has to send a message to an EVSE that does not comply with this agreement, it is translated into another message that is understood by the EVSE. Likewise, when a message is received from a non-normalized component, it must be translated into a normalized message. Both the normalization as well as the interfaces for the components that do not comply have been defined.

3.1 System architecture

The main systems and stakeholders are the EVSP, the EVSE, the EV user, the EV itself, and the secondary electricity network and the DSO. MUGIELEC also considers other actors, such as Traffic Control Managers, to implement other added value services (maintenance service location, points of interest, on-route information, etc).

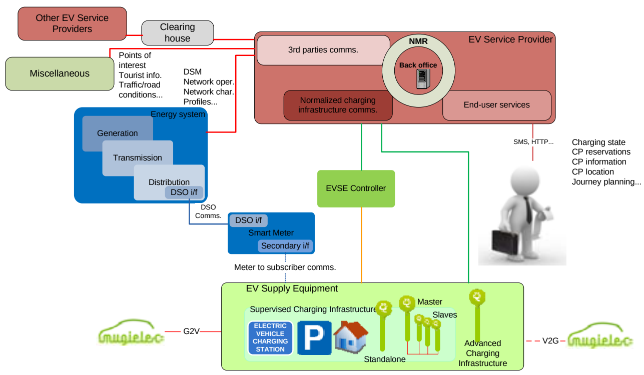

Figure 4. The MUGIELEC concept

The MUGIELEC approach to EV charging systems tries to stay business-model independent, by depicting the functionalities that are required for the successful deployment of an EV charging infrastructure and the associated services: Energy supply, EVSE and end user services. These functionalities have been wrapped up in three generic boxes corresponding to the main systems that are necessary to provide advanced charging services to an EV-driver: Energy, eMobility and Charging [1].

3.1.1 Energy System

The **Energy System** is depicted in blue, with the functions carried out by the traditional stakeholders of the electricity system. Advanced equipment, such as metering devices with bidirectional communication capabilities and an additional interface with electricity subscribers, can be used to exchange metering information, price signals, etc. enabling active local electricity management. Global demand management can be carried out by means of the direct interconnection between the energy system and the eMobility system.

3.1.2 eMobility System

The systems related with **eMobility** management are depicted in maroon, where the contractual relationship with EV-users, EV-charging related information and services, etc., are carried out.

eMobility systems relay on MUGIELEC's Information and Knowledge management system. Three external interfaces are considered:

- End user services: This interface is in charge of the communication between the eMobility system and the EV user. This interface may not be standardized since each e-Mobility operator may want to offer different services to its customers. Generally this communication is HTTP based and SMS messages are used for some notifications.
- Normalized charging infrastructure communications: This is an open interface (web-service based) used to manage the information exchange between the charging infrastructure and the eMobility systems. Charging infrastructures status, user identification and validation, etc. is managed through this interface.
- Communications with 3rd parties: This interface takes care of the interconnection with different EVSPs through a Clearing House, as well as with other stakeholders related to the provision of different ancillary information and services.

The different modules constituting the EVSP Management System are explained in section 4.

3.1.3 EV Charging System

The **EV Supply Equipment** is depicted in green. Integration into the charging infrastructure can be intended by a variety of CPs with quite different capabilities. Two possibilities are considered:

- Advanced charging system: Any EVSE able to directly communicate with the EVSP through its web-service based normalized communication interface.
- Supervised charging system: Any EVSE that cannot communicate directly with the eMobility system.

The CP controller is a device that allows interconnecting the EVSP and the EVSE, offering a normalized interface (web-service based) on the side of the eMobility system, thus letting it independent from the particular features of the supervised charging infrastructure below. This system eases the integration of multivendor CPs into a common e-Mobility system while allowing the independent development of both systems.

4 Information and Knowledge management

4.1 EVSP Management System

The EVSP Management System must perform whatever activity in relation with EVSE remote control, monitoring and communication within a certain infrastructure. It manages the logical base of the business model.

The core of the Management System is built around a set of Functional Modules containing the necessary functions to operate all the EVSE:

- **EVSE Inventory**: for inserting, modifying and deleting the specific information which is directly or indirectly referred to EVSE.
- **CP Monitoring**: to allow users to visualize EVSE location as well as their real-time status on a geographical application through a code of colours. Also, it will be possible to navigate from this module to the EVSE Operations Module.
- **Operation on EVSEs**: to carry out the EVSE remote operation by means of certain operations that will depend on their own capabilities, such as start/stop the charging process, lock/unlock the Access, reboot the EVSE, etc.
- **Configuration management**: for remotely looking up and updating one or several EVSE configuration.
- **Reception of events**: to collect and manage every event sent by EVSE, including those not needing an immediate intervention, as well as the incidences on the Management System itself as a result of any problem on the application modules.
- **Management of the historical records**: for storing a historical record of user data and EVSE charges. Also, it manages deleting criteria of those historical records based on the parameters that had been configured.
- **Access management**: to perform on-line user authorization process for recharging.

- **Reporting management**: to provide, according to some reports templates defined previously, the needed information of EVSE infrastructure to be managed and operated by EVSP.
- **Security management**: to manage different system access profiles and levels of permissions.

The **Communication Interface** is the connection of the Management System with the different EVSE. It includes the APIs for information acquisition and control, and takes charge of the EVSE interoperability. It also incorporates communication protocols and interfaces for different EVSE suppliers. It takes care of tasks such as: monitoring the status and functioning; remote control; sending incidences; information about events and alarms; sending charging information; sending authentication requests; receiving operational authorizations, etc.

4.2 Semantic technologies

When facing the problems of interoperability between heterogeneous systems, Semantic Technologies [5] and the linked data approaches are envisioned to be the most suitable in very different functional areas going from Public Administration, Health, Science, to Industry and also to the electric network. Semantic Technologies allow for an effective exchange of information, knowledge and data between systems involved abstracting from the heterogeneity of the underlying systems and agents (distribution systems, the operator, end user, etc.).

Combined with the SOA (***Service Oriented Architecture***) approach adopted for the overall architectural design for the MUGIELEC knowledge system, the semantic layer will serve as interoperability- interlanguage that will allow the access to the information of the whole system, regardless of proprietary formats and protocols. All the concepts to be managed in the data access and algorithms will be described in standard formats of Semantic Web and Semantic Grid (specifically RDF and OWL). The format of these descriptions is also XML based, according to the W3C standards.

That way, the layer serves as common understanding glue for all the actors involved in the EV context.

Below it the physical integration layer has been built up, which allows accessing to the real time data standing on devices or IT systems, translating data and signals/orders into concrete packets and protocols that fit with the interfacing needs of the integrated devices and systems. This layer is transparent for the knowledge management tools, hiding the complexity of the underlying heterogeneity of formats and technologies.

This approach allows designing and executing services and algorithms on different layers of abstraction and in different degrees of integration of information and, together with the SOA approach, it will make possible to implement algorithms and global improvements to the system in an open approach.

4.3 Information exchange: communications and protocols

This section describes the information flow among the different systems involved with EV charging, according to Figure 4.

All the information to be acquired and exchanged has been defined according to the Open Charge Point Protocol [6]. Some additional messages according to information considered as relevant to be managed in MUGIELEC have been developed, coherent with OCPP.

4.3.1 Communications between EV and EVSE

Although there are different protocols and standards for information exchange between the EVSE and the EV, MUGIELEC only considers those that are widely accepted nowadays. In some cases there are still issues under discussion or pending for agreement, but they have reached anyway to a certain maturity.

Two protocols have been implemented:

- ISO-IEC 15118: This International Standard is composed of three document parts, which are in a draft status.

  Under MUGIELEC initiative, a Gateway is being developed, using an embedded Linux platform, which communicates CAN networks in the Electric Vehicle and the EVSE. It allows also a direct communication by using a programmatic interface in form of a library of functions. The library implements all the messages defined in the standard.

  This protocol is meant as the basic one when AC charging is used.
- CHAdeMO: is the trade name of a quick charging method for battery electric delivering up to 62.5 kW of high-voltage DC via a special electrical connector.

  A Finite State Machine to manage different internal and external events, evolving through the charging process from the initial to the final state, has also been implemented. They are classified in different groups: digital input/output, CAN frames reception, button press, time-out events, or voltage and current measurements.

In the last months the new Combo Charging System has been agreed among major car manufacturers in Europe and US, as well as relevant EV Associations [7]. Although this option should be relevant for MUGIELEC in the future, CHAdeMO has been implemented because its advanced degree of definition and early adoption by several available EV models.

Much information can be potentially exchanged between EV and CP. In the MUGIELEC approach there is no vital compulsory information to be considered for a minimally intelligent infrastructure management. However, the following high added value services can be provided if the EV is able to supply it:

- Charging power limitation
- State of Charge
- Estimated load-profile of the charging process
- Readiness of V2G (yes/no, how much).

4.3.2 Communications between EVSE and EVSP

The relevant information related to the EV charge must be available to the EVSP, in order to ensure the adequate management of the electric infrastructure and the optimal offer of added value services to the users. This is really difficult, due to the aforementioned lack of harmonization and a non-existing presumably complex marketplace.

So, all the information acquired and stored by the EVSE must be made available to the EVSP.

However, these messages and signals have to arrive to the target whatever the protocol the EVSE implement. Thus, two approaches are considered:

- A standard CP, which implements the normalized messages by means of the defined protocol and data model (Web Services using XML documents as payload). The services are synchronous, holding the channel open until the response is received.
- A proprietary solution, whose protocol is unknown or private. An EVSP controller is installed between EVSE and EVSP, in order this one to be able to access to the EVSE according to the standard approach.

For instance, if the EVSP wants to read the last charge at a particular CP, it configures the message (timestamp, charging point and message identifier), and passes it to the communications module, which maps the CP identifier, with the proper protocol and sends it. An example of this is depicted in the following figure, where the same message is sent to two different EVSE.

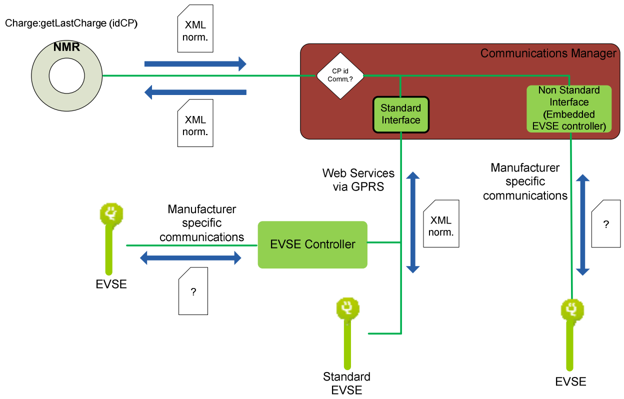

Figure 5. Accessing to different charging points

In the figure above, the Standard EVSE (in the middle) uses Web Services containing the normalized XML documents accessed by its own cellular (GPRS) communication. However, in the rest of the cases the EVSEs cannot be accessed directly, so the communications module access to the intermediate EVSE Controller. Likewise, the response (the last EV charging) is sent back accordingly. The Web Service installed in the EVSE controller holds the connection until the charging point provides the information, sending the data by the same opened channel back. Therefore, the response must be translated into a message that can be understood by the EVSP.

The information to be exchanged is scheduled according to different potential levels of intelligence of the CP.

RANK1 is the MUGIELEC reference for minimal information. If an EVSE is not able to provide all those items, it is considered RANK0.

RANK2 would correspond to advisable information to produce in order to offer high value services. The management algorithm considers which information is really available by an EVSE and, if so, will take it into account.

RANK1 information:

- Authentication, when the user is going to charge the EV
- Authentication, when the user leaves the CP
- Total Energy supplied by a CP to an EV.

RANK2 information:

- Load profile (Wh) during each charge, with a 15 minutes resolution.
  A query for all the charges performed within a period should be possible.
- CP current state
- Order to CP to start charging the EV
- Order to CP to Stop/Pause the EV charging
- Order to CP to Lock plug/socket
- Order to CP to Unlock plug/socket
- Charging power limitation
- State of Charge from the EV
- Estimation of EV State of Charge
- Alarms within the CP which have to be notified to the EVSP.
  The EVSP can request a list of alarms.
- The EVSP assigns a CP to an EV
- Order to CP to Set LEDs colours.

4.3.3 Communications between EV User and EVSP

The EVSP Management System contains a web platform which will allow Users accessing to certain functions of CP management. This platform has the following functions:

- **Users Management**: This module offers system users the function to create and change their user profile as well as their assignation to specific physical devices for accessing to the EVSE (e.g. through RFID).
- **Charging management**: This module allows User parametrizing charging management regarding to their specific conditions or requirements. Different functions, such as managing a group of CPs with power constraints, or programming the charging time based on vehicle availability requirements or economical consumption, are considered.
- **Accessing to the information**: This module allows authorised Users visualizing and managing the information related to charging.
- **Visualizing EVSE and booking**: This module provides authorised Users with information on the EVSE real-time status, and on whether they are public and available. It also allows booking/unbooking a CP for scheduling recharge, including information about existing CP in a particular route or zone.
- **Smartphone App**: Nowadays, Smartphone potential for communication and remote access asks for developing new applications which allow replicating basic functions of the web platform, so that Users are able to manage their VE charging from anywhere they are.

MUGIELEC considers the following potential information flow between EV user and EVSP for added value service provision:

- User sends charging preferences:
  - Maximum energy (kWh) the User wants for his EV charging
  - Maximum time allowed the User wants for his EV charging
  - Time to start charging
  - Requirement for Charging Power limitation
- User removes the charging preferences
- Request of charging at some CP at some lapse of time, including energy
- Get CP locations
  - EVSE location
  - Different EVSE along a journey
- Get information about CP availability
- CP reservations
- Energy price that EMO apply for a User
- EVSP assigns a CP to an EV User.

According to the intelligence RANK of the different available Charging Points, some of those services could be provided or not.

4.3.4 Smartgrids and eMobility

The DSO and EV infrastructure

The DSO requires communication capability to access to the Secondary Substation level information, such as grid automation and metering information, in a SCADA-like approach. The Metering Operator is in charge of reading the smart meter, though in many Countries, such as in Spain, the DSO is responsible for it.

This information can be used for demand response, billing purposes, or any activities that can improve the grid quality through the DSO.

The DSO may deal with EVSE in 2 ways: Centralized (the DSO sends requests/offers to the EVSP, responsible for deciding which actions are to be taken at each CP) or Distributed (where the DSO accesses to the EVSE´s smart meter as to any other manageable load).

GPRS and Ethernet based communications are the most common choice, but there are many other valid options that may fit the requirements of this communication. Remote control messages will usually be based on IEC 60870-5-104 telecontrol protocol, while DLMS protocol will be used to carry metering information. The secondary substation level local communication will be IEC61850 based.

The DSO and the EV Services Provider

From the point of view of the DSO communications, the EVSPs are just the same as other retailers. Therefore, the kinds of messages are not different than those already defined for them.

On the other hand, EVSPs are special actors according to their user's consumption patterns, so they need different algorithms and procedures to configure the messages that eventually are sent to them. This difference is based on the way the DSO encourages the EV charging.

In principle, the communication between the Electricity System Operator and the EVSP is expected to be carried out through the DSO.

There are two different methods to modify the demand: by means of **Tariffs** or by applying different **Prices** along the day. Usually, tariffs are fixed for the same period of the day and can take into account the season, the workdays and the holidays. This is a static strategy because this method establishes the prices for the tariffs in advance. As a result, the user knows in advance the cheaper periods to charge his EV. This solution covers the energy supply as well as the energy demand in normal situations. Therefore, the DSO can offer cheaper tariffs when the demand is usually low, and expensive ones at peaks because the DSO can predict its demand.

Tariffs are a good tool to normal situations, but when a contingency arises or, for instance, when the wind farms are producing an excess of energy that could be used for charging EV, this method cannot seize the opportunity. In order to cover these situations in the model, a more dynamic method has to be applied, such as sending prices which can vary from day to day. This way, if a huge energy generation is predicted for the wind farms, the DSO can send a message to the e-Mobility Operators decreasing prices for that period.

Obviously Price Signals method is more dynamic, but some prerequisites must be considered when configuring the price signals, such as ensuring that EV users are properly informed in order to react to the query.

Again, storage systems in the EVSE can be used to match the offer and the demand of energy and increase the whole system efficiency, although, in this case, the management of the storage system is more complex.

4.3.5 Communications with other EVSPs

The way how to carry out this activity is under analysis in global projects such as Green eMotion [8].

Anyway, taking into account that roaming and the clearing house are concepts that will have to be developed when EVs reach to a sufficient deployment, MUGIELEC considers all the available information about different EVSE managed by other EVSPs, for its adequate management.

Thus, one of the services that an EVSP could provide to its customers is the information about available EVSE, such as their reservation state and prices, even if they belong to another operator.

5 Conclusions

MUGIELEC, as an industry R&D initiative gathering many relevant actors in the field of energy and electricity, is carrying out some achievements in order to provide a comprehensive, full-perspective approach to the challenge of electric vehicle charging infrastructure.

Within these three years different innovative products for the EV charging infrastructure have been developed, in the fields of EVSE and added-value services provision.

A special focus is placed in communications technologies and protocols, systems architecture and information and knowledge management, taking into account the perspective from the EVSP and the electricity DSO. The EVSP implements its own language and optimizes the use of information based on semantic technologies, though it is able to integrate and communicate with non-standard equipment.

As a result, MUGIELEC's outcomes, mostly looking at the vision of an intelligent open management infrastructure, are aimed to be considered as good practices experience for EV stakeholders and, mainly, Standardization Bodies.

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