Future Internet for Electric Mobility in the Smart Grid

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Abstract: With the threat of natural energy resources being significantly depleted and, coupled with the global drive to reduce greenhouse gas emissions, ICT communications can help to provide solutions for increased and more efficient energy usage. If electricity is produced more and more from renewable resources then the CO_2 emissions from energy generation can be significantly reduced. The introduction of electric vehicles can contribute to both to environmentally friendly travel and contribute to valuable energy storage possibility enabling the efficient use of energy from renewable sources.

Fundamental for the deployment of electrical vehicles is the availability of a reliable charging infrastructure. The integration of the charging infrastructure in the evolving smart electrical grid and in the transport infrastructure is an important issue and requires information exchange between the grid infrastructure, the transport infrastructure, the vehicle information systems and the charging points using a sophisticate communication network infrastructure. Furthermore new services and functions like optimized routing of electrical vehicles based on the battery status, the current traffic situation and the availability of charging services and predicting the energy need for charging in a certain region based on the traffic patterns of the electric vehicles in this area have to be considered.

This paper describes the methodology chosen within FINSENY to develop Future Internet technologies as an answer to electric mobility challenges. Several use cases are discussed along with initial requirements that were derived as part of the analysis phase. The paper concludes by giving an outlook on the immediate and long term challenges of e-mobility and a discussion about further work for this project.

Keywords: electric vehicles, Smart Grid, future internet, FINSENY, e-mobility, electric mobility, vehicle-to-grid (v2g)

1. Introduction – The role of electric mobility in addressing a shift to increased use of renewable energy sources of energy generation

The transformation of today's electric grid into a *smart* grid is a monumental undertaking that will bind much of the investment in electricity networks the next years. In the future, the demand for electricity will surge and, concurrently, more and more power will be generated from renewable sources. This presents a challenge since, due to fluctuations in their availability, renewable resources like wind and solar place a heavy strain on existing power grids. The key to mastering this challenge is a flexible, state-of-the-art Smart Grid that can support future energy requirements and that can adapt to changes in consumer needs.

The introduction of large numbers of EVs is expected to bring with it a change in demand patterns for electricity. While the total energy demand for EVs is not seen as critical compared to the overall demand, uncontrolled charging can be critical for certain regions in the distribution grid. If charging is completely uncontrolled then it could lead to significant growth in peak demand during certain times and certain places with significant implications for infrastructure investment. On the other hand, controlling the charging load can lead to better utilization of the existing electricity infrastructure and better integration of renewable generation. Electric mobility could be an essential component of the Smart Grid to absorb and manage some of the increased dynamics in future energy supply. Meeting the new demands requires the introduction of new information and communication technology (ICT) in both the electricity networks and the EVs.

The large scale introduction of EVs will have an impact on the energy infrastructure by providing the necessary charging points, but it also requires interaction between the energy infrastructure, the transport infrastructure, the vehicle information systems and the communication network infrastructure, in order to collect, process and deliver the needed information. It is clear that electric vehicles – which could store electricity and could return it to the grid when needed – will play a major role in the Smart Grid.

2. Methodology used to define use cases and requirements

As a first step, a typical set of scenarios for electric road vehicles were defined with each investigating the interests of a wide range of stakeholders and the likely evolution of their requirements in the coming years as market conditions evolve.

Similarly to other work packages in the “FINSENY” project [1], the method developed in the “IntelliGrid” project [2] was used in order to identify and structure the e-mobility stakeholder, define relevant use cases and determine corresponding functions within these scenarios. The IntelliGrid method specifies an approach to identify and describe requirements in automated electricity systems. Moreover, a step-by-step analysis was conducted for the identified use cases as an initial step towards the requirements analysis.

The content for the scenarios came from the partners’ expertise and knowledge of existing European and international projects on electric mobility [3]–[11]. Research was also carried out into other international e-mobility projects [12], standards [13][14] and technical bodies [15] which helped to substantiate and enhance the scenarios that were being considered. In the end, five general scenarios for EV usage were identified:

1. Short journey
   A car journey is approximately 10km – 30km and does not require an additional charge during the journey e.g., an EV being used to travel between work and home or from home to work.
2. Medium journey
   The journey cannot be completed on one charge, thus requiring the user to refuel.
3. Long journey

The focus is on a journey that is greater than 400km, taking in a number of countries. As such, international issues relating to availability of charge points and payments methods are considered.

4. Grid Operations
   Grid Operations scenarios focus on capacity management issues of the power grid. For example, the handling of the local distribution grid will be critical in the shorter term; while in current operations environments, distribution systems are less automated than transmission systems.
5. Value Added Services
   It is envisaged that EVs will be equipped with new interactive features and services. As with all new technologies, the usability of devices and services will improve and, looking toward 2025+, these scenarios assume better devices and interfaces with constant internet access.

The second step was the derivation of information and communication technology (ICT) requirements from these scenarios. For this task, attributes of requirements were based partly on the Volere [16] structure and partly adapted to the existing needs. Up to now, the focus was on the collection of requirements as many different requirements as possible on the same abstraction level. Due to the multiplicity and diversity of the relevant use cases, the initially collected requirements stretch to cover nearly all kind of requirements known in the ICT domain. The next step will be the classification and hierarchisation of these requirements to increase understanding for implementation. At the same time there is currently a consolidation with other work packages from FINSENY conducted in order to discover common “Smart Grid” requirements.

The third step is to use these requirements to define a functional architecture, with co-operating interfaces between the FINSENY work packages as well as with other projects of the Future Internet programme e.g. FI-WARE [17]. While some functions are realized as specific ICT enablers to support the energy domain, other functions play a role as generic enablers and can be used in other domains as well.

3. Use cases addressed by FINSENY for electric mobility

Projections of the impact of electric mobility on the transport system and on the energy grid have been developed for a range of countries. These projections and the early results of discussions were used to define the parameters of the scenarios.

Consideration has been given to the operation of the network and the significance of the interface(s) between grid operators, intermediaries and EV users. Grid load balancing and optimised scheduling issues illustrate the need for intelligent grid management.

Due to the significance of charging points within each of these scenarios, attempts were made to accommodate the different types of charging mechanisms and practices – for example, domestic charging can take approximately 6–8 hours as a vehicle can fully charge overnight from a residential electricity supply, as can be seen in Figure 1. Domestic charging using a sophisticated charger is also available where an 80% full state-of-charge (SOC) can be achieved in 1–2 hours, as illustrated in Figure 2.

Charging in public requires a network of easily accessible charge points e.g. on-street locations, shopping centres, car parks, etc. Users of public charging facilities will typically only charge their car for 2–6 hours. However, another option is “fast” charging which can be located at service stations and where an 80% full state-of-charge (SOC) can be achieved in up to 30 minutes.

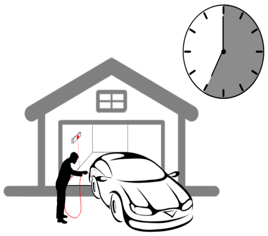

Figure 1 Dumb charging using standard sockets

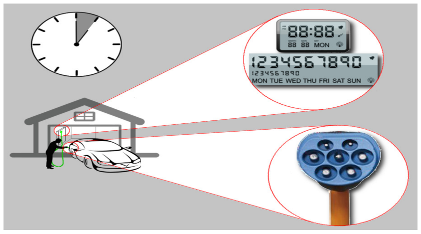

Figure 2 Smart charging using sophisticated home chargers

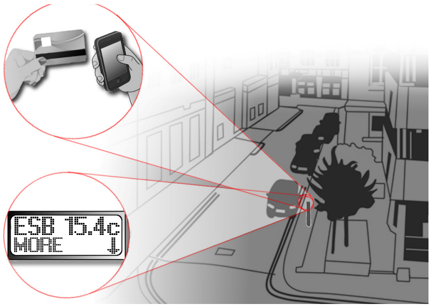

Figure 3 Municipal charging stations

For public charging facilities as portrayed in Figure 3, EV owners can use the authentication token (e.g. RFID card or NFC handy) of his standard E-Mobility Service Provider to access these charging stations. Another means of authentication include phone authentication (dialling a specific number). Since the charge point allows open access to all licensed Electric Power Suppliers, EV owners will also be able to choose the electric power supplier that offers the lowest tariff for energy at the time.

From the Grid operator perspective, there are various ways in which the EV information can assist. For example, a grid operator might cooperate with the operator of a charge spot park. As soon as there is an overload in a certain part of the grid, the grid operator signals this to the charge spot operator who levels down the necessary amount of charge points in this area. Moreover, the charging spot operator can provide real-time data about the energy demand in the grid that is useful for grid operator in order to anticipate critical situations in advance. Additionally, both together could operate a stationary storage such as huge battery blocks. In this way, the costs to include large amounts of renewable power into the grid could be reduced. These mechanisms of interaction between grid and EV are called grid-four-vehicle (G4V) or vehicle-to-grid (V2G), depending on "service-direction".

Building on a core set of key enablers, a number of spin-off applications were identified within the electric mobility domain to provide enhanced services and value-add products, as illustrated in Figure 5. Some key enablers include:

- Future electric vehicles will have a high speed wireless internet connection so that the driver / user can receive information on charging stations
- Future electric vehicles will have a smart device such as iOS, Android, Windows Mobile, QNX, TomTom, Garmin etc. so that the driver / user can visualise maps to closest charging points
- Future electric vehicles will have embedded geo-location & GPS / Galileo technology so that the driver / user can dynamically plot routes to closest free charging points
- Data Roaming and Energy Roaming tariffs will be transparent across Europe and wider countries so that the driver / user can confidently charge in different states / countries

For these services, it was assumed that electric vehicles can (and will) be equipped with these new interactive features and services.

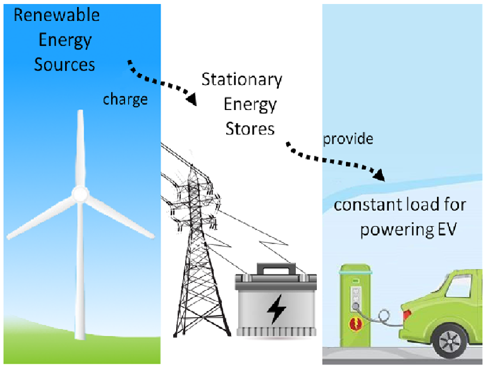

Figure 4 Management of Stationary Energy Stores

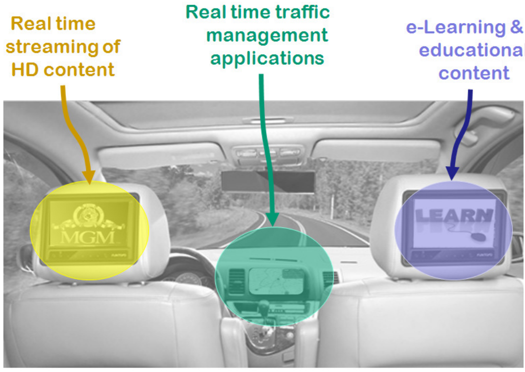

Figure 5 Value Added Services

4. Initial ICT Requirements

4.1 Requirements Engineering

The collected requirements are interpreted as a condition or capability that finally could, should or must be fulfilled [18], in our case by a component of the Future Internet. Descriptions of requirements, amongst others regarding necessity, attribute, measurability and quality, have to be non-redundant and clear. In general functional and non-functional requirements are distinguished: a functional requirement describes qualitatively the function of the system, whereas a non-functional requirement determines with which attributes a function of a system has to be provided [19].

The aim of the performed requirements engineering was to systematically structure and consolidate them and to document them clearly. The investigation in four steps (cf. Figure 6) establishes the fundament for further development and is part of requirements engineering.

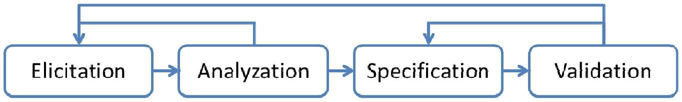

Figure 6: Process of Requirements Investigation

4.2 E-Mobility Requirements in FINSENY

In the following, an excerpt of requirements identified with respect to E-Mobility is described. The requirements were grouped into 15 categories:

1) Interoperability
2) Privacy and confidentiality
3) Reliability
4) Availability
5) Quality of Service
6) Remote accessibility
7) System performance
8) Modularity / Abstraction
9) Security
10) Networking
11) Billing and Payment
12) Information / Data objects
13) Communication
14) HMI / GUI / Apps
15) System Services

For each of these categories, one requirement is listed in more detail. Although the originating use case is mentioned in brackets (as described in FINSENY “Electric Mobility Scenario Building Blocks” [20] deliverable), in most cases many more use cases depend on the fulfilment of that requirement.

1) Interoperability of charge points (derived from “Public Charging”)
ICT: Electric Vehicles (EVs) need to exchange data with charge stations, e.g., the current Battery State of Charge (BSOC) and general technical details such as the maximum charging current. This requires that hardware connections are interoperable and that data exchange protocols and data formats from different EVs can be used at the same charging station.

   Electrically: The charging point supports various models of electric vehicles which mean that plug specifications correspond and protocols for electrical security (e.g. pilot control) harmonize with each other.

2) Privacy of user data (derived from “E-Roaming”)
The information about a user and its EV usage is needed by an E-Mobility provider. In order to be able to fulfil high demands of data privacy, it must be guaranteed by technical and organisational means that no unauthorized user can access this information.

3) Reliability of charging equipment (derived from “Municipal Charging Stations”)
The reliability of ICT components in charging stations has to be significant, despite outdoor usage in hot summers and cold winters. This accounts in particular for ICT functions enabling access, authorisation and accounting of charging EVs.

4) Availability of price information (derived from “E-Roaming”)
Dynamic energy prices need to be distributed automatically (push) or made available (pull) to charging station providers. In order to facilitate charge station technologies to work with different energy providers, the respective exchange protocols and data formats should be standardized.

5) Quality of Service: Low latency of data transmissions (derived from “G4V and V2G”)
The information exchange for grid stabilizing purpose has to be quasi real-time.

6) Remote Updates of public charging stations (derived from “Public charging”)
Software updates in charging stations are very probable. Since in many cases a communication link between a public charging station and a server already exists for authorisation purposes, this link should also be used for remote software updates.

7) System performance: Data throughput (derived from “Enhanced Services”)
In order to provide “Enhanced Services” via ICT to customers data throughput needs to be significant e.g. at charging points.

8) Modularity: Multi-Communication Media (derived from “Enhanced Services”)
For vehicles that are used in different Use Case categories, different communication media may be required (PLC, Wireless, RFID etc)

9) Security: Intrusion detection (derived from “Public charging”)
For authorisation means, each charging station has a kind of ICT front-end to users and/or EVs. Since the charging station itself is connected to the backend, reliable intrusion detection systems must be implemented in order to prevent malicious code in the IT systems of a charging station operator.

10) Networking: Open Web Service APIs of network infrastructure (derived from “Public charging”)
The network infrastructure should feature open web-service API's so that electro mobility cloud services can simultaneously query and reserve both network and cloud services without any human intervention.

11) Billing: Micro transactional services (derived from “Public charging”)

Billing systems at charging stations should support micro transactional services.

12) Information about battery state (derived from "G4V/V2G")
In many use cases, an in particular for V2G-Services, knowledge about the current state of charge of the battery in an EV is necessary. Additionally, detailed information about Volt, Ampere, Cell-balancing-status and temperature is useful.

13) Communication between EV user and charging station (derived from "Home Charging")
EV users need to specify preferences such as the minimum battery state of charge for the next trip. In case of home charging, this could be done by means of a touch screen at the charging station, but also via PC or Smartphone.

14) HMI / GUI: In-Car Unit (derived from "Municipal Charging Stations")
Main information should be accessible and configurable from within an EV. Therefore, EVs should have an additional GUI.

15) System Services: Time Synchronization (derived from "G4V/V2G)
Time synchronization keeps timer elements on different components synchronized. This is particularly important, when control signals are transferred from the grid to the EV and the reaction of the EV depends on the right "time".

This excerpt of requirements shows the multitude and complexity of ICT requirements that currently exist or will appear in the future for E-Mobility usage. FINSENY will consider these requirements and model a functional considering also the future role of EVs in the power system.

5. Conclusions

The FINSENY project has investigated the usage scenarios for electric vehicles and their impact on the energy network from a broad perspective, highlighting the impact of the large scale introduction of electric vehicles and the ICT support required by the energy network.

From the initial investigations of ICT requirements, it is already clear that Future Internet technologies, such as converged heterogeneous network technologies and cloud based computing will form part of the solutions need to meet the requirements of energy networks for security, availability and reliability.

A first definition of the generic ICT enablers required to support electric vehicles, and in particular the charging of the vehicles, has been prepared and work is now on-going to define a functional architecture for the ICT support of future energy networks. The goal of the set of FI-PPP field trials will be to investigate the feasibility of using different instantiations of a single Core Platform for ICT functionality in a wide range of application sectors such as energy, transport, agriculture and urban (city) management.

We conclude that the mass market introduction of electric vehicles will bring both opportunities for smart energy management and for the introduction of a wide range of new services to the energy market. It will also bring challenges in relation to the likely need to upgrade the energy distribution network in many areas as the concentration of electric vehicles grows with a corresponding impact on energy demand in residential locations at night and in relation to the deployment of a density of charging points sufficient to provide drivers with the opportunity to charge their vehicles whenever and wherever they please. The needed upgrading of the energy network will offer energy providers the option of implementing a holistic Smart Grid architecture enabling the dynamic management of demand and supply and resulting in improved efficiency of energy generation and consumption and reduced environmental impact of both travel and energy generation. ICT will be a central element of the Smart Grid enabling dynamic control and secure and reliable communications.

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