POLITECNICO
MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE
E DELL'INFORMAZIONE

eMall – e-Mobility for all

Requirement Analysis and Specification Document - RASD

Author(s): **Fabio Lusha - 10882532**

Bianca C. Savoiu Marinas - 10684465

Academic Year: 2022-2023

Contents

1 | Introduction

1.1. Purpose

Widespread electrification of transport is the most efficient way to reach Europe's climate objectives for the sector and electric charging is the main asset to overcome the obstacles of the take-up of electric vehicles (EVs). EVs can reduce CO2 by an estimated annual 600,000 tons by 2030, going towards a carbon neutral Europe and the importance of this aim raises the problem of having efficient systems that manage the charging services. The e-Mall is thought as an all-encompassing application that oversees the entire process from the user interaction to the effective recharge of the EV's battery.

The main goal we want to achieve with the e-Mall software is to help The EVDs (electric vehicle drivers) to have a better access to recharge and to be able to book a charging point in order to avoid interference with his daily plans. Another important purpose of the system is to safeguard not only the users but also the providers of the service and this is made thought privacy agreements and the actual interaction that guarantees to supervise the both interested parts, in order to get the best possible service and pay for it accordingly, having also a technical and economic exploitation of the charging infrastructures.

In this context there is an increase in the requested electric energy, but large amounts of power in short periods would require investments in the reinforcement of the distribution networks, which have not been designed to accommodate such load. It becomes necessary to introduce new systems and solutions to optimize the operation of distribution networks and we can identify the DSOs as important actors that have to monitor the networks in order to have a safe and controlled supply of the energy and manage faults in the assets. The DSOs communicate with the e-Mall, and in particular with the CPMS modules that decide from where to acquire energy in order to satisfy as well as possible the CPOs economical interests.

Goal	Description
G1	The EVD is able to identify the charging stations nearby
G2	The EVD is able to visualize the tariffs of the charging stations
G3	The EVD is able to visualize any special offer available at the charging station
G4	The EVD is able to book a charge in a specific charging station for a certain time-frame
G5	The EVD is able to start the charging process at a certain station
G6	The EVD is able to pay for the obtained service
G7	The CPO can decide from which DSO to acquire energy
G8	The CPO can decide the cost of charging
G9	The CPO can set special offers
G10	The CPO can decide whether to store or not energy in batteries
G11	The CPO can decide whether to use the energy available in the batteries

Table 1.1: Goals

1.2. Scope

World phenomena	Description
WP1	The EVD wants to charge the EV's battery
WP2	The EVD wants to plan where and when to charge the EV's battery
WP3	The prices for energy often vary in real world economy
WP4	The providers of energy, as marketing strategy, have special offers during certain time periods.
WP5	The providers of the charging service make special offers during certain time periods.
WP6	EVs may have an integrated rectifier that converts AC electricity to DC
WP7	Some type of chargers have an integrated rectifier that converts AC electricity to DC. They supply the EV directly with DC current
WP8	A charging of type X, provides electricity in mode C and is given through Z connectors

Table 1.2: World Phenomena

World phenomena CPO	Description
WP9	A charging station is owned and managed by one CPO
WP10	A CPO owns and manages one or more charging stations
WP11	A charging station may be equipped with batteries
WP12	*Charging stations equipped with batteries grant more flexibility to CPOs on how to choose between the energy stored in the batteries and the one offered by DSOs*
WP13	Low voltage (3.7 - 11 kW) chargers need more time to charge the battery
WP14	Medium voltage (22-90 kW) chargers need less time to recharge a battery of capacity C than a low voltage charger
WP15	High voltage ($>$ 90 kW) chargers need less time to recharge a battery of capacity C than a medium voltage charger
WP16	Batteries can only be charged with direct current (DC) electric power
WP17	Given a continuous supply of power W, and a battery with finite capacity C, than the charging time T is finite.
WP18	A battery can store a finite amount of energy, given by its capacity C.
WP19	The charger of a specific charging station may be unusable because of maintenance or faults

Table 1.3: World Phenomena

World phenomena DSO	Description
WP20	The DSOs distribute and manage energy from the generation sources
WP21	The DSOs provide energy to a charging station
WP22	Most electricity is delivered from the power grid as alternating current (AC)
WP23	During the day the electric power supplied to the station can vary
WP24	During the day a short-duration reduction in the voltage supplied to the electrical power systems may occur due to high current demand or faults in the system.
WP25	During the day a momentary increase in voltage may occur. This may happen when a heavy load turns off in a power system.
WP26	The DSOs operate and manage the electricity distribution networks
WP27	The DSOs solve grid problems, such as faults and network breaks

Table 1.4: World Phenomena

Shared phenomena	Description	Controller	Observer
SP1	The eMall notifies the EVD when the charging process is finished	eMall	EVD
SP2	The EVD creates an account	EVD	eMall
SP3	The EVD in order to register inserts in the mobile app of the eMall the personal data (name, surname, payment details)	EVD	eMall
SP4	The EVD logs in	EVD	eMall
SP5	The EVD accepts the terms of service in order to use the eMall	EVD	eMall
SP6	The EVD shares its location with the eMall	EVD	eMall
SP7	The EVD confirms the payment from the mobile application of the eMall	EVD	eMall
SP8	The EVD deletes previously inserted EVs from its account	EVD	eMall
SP9	The EVD updates the specifications of the EVs on its account	EVD	eMall
SP10	The EVD adds a new EV to its account	EVD	eMall
SP11	The EVD inserts the maximum and minimum current supported by the EV	EVD	eMall
SP12	The EVD inserts the maximum power supported by the EV	EVD	eMall
SP13	The EVD inserts the inlet type of the EV	EVD	eMall
SP14	The EVD inserts whether the EV is equipped with a built-in rectifier	EVD	eMall
SP15	The EVD inserts the capacity of the battery in kWh	EVD	eMall

SP16	The eMall shows to the EVD the map of the charging stations nearby his location	eMall	EVD
SP17	The EVD chooses a charging station from the map	EVD	eMall
SP18	The eMall shows the user the rating of the charging station	eMall	EVD
SP19	The EVD inserts the expected time when he plans to start the charging process	EVD	eMall
SP20	The EVD inserts the expected time when he plans to end the charging process	EVD	eMall
SP21	The eMall shows to the EVD the list of available chargers of the charging station	eMall	EVD
SP22	The eMall shows the charger type and its connectors	eMci / eMma	EVD
SP23	The EVD chooses the charger he wants to use from the list of available ones	EVD	eMall
SP24	The eMall shows to the EVD the charger costs (per kWh, per minute, additional costs)	eMma/eMci	EVD
SP25	The eMall shows to the EVD the status of the charger	eMci	EVD
SP26	The eMall shows to the EVD the battery level of the connected EV	eMci	EVD
SP27	During the charging session the eMall shows to the EVD the power output of the charger	eMci	EVD
SP28	During the charging session the eMall shows to the EVD the remaining time to complete the charging process	eMci	EVD

SP29	The EVD starts the charging session from the charger	EVD	eMSP
SP30	*The CPMS asks the DSO about the current available energy sources, their prices, and special offers*	CPMS	DSO
SP31	The DSO dynamically changes the price of electricity	DSO	CPMS
SP32	The DSO changes dynamically the *energy sources* from which acquires energy	DSO	CPMS
SP33	The DSO makes special offers	DSO	CPMS
SP34	The CPO logs in	CPO	CPMS
SP35	The CPO selects the charging station for which to set the parameters (price, energy) of the charging service	CPO	CPMS
SP36	The CPO selects the DSO from which to acquire energy	CPO	CPMS
SP37	The CPMS shows to the CPO the *energy sources* and the relative current prices and special offers of the DSO	CPMS	DSO
SP38	The CPO sets the cost of charging	CPO	CPMS
SP39	The CPO can set a special offer	CPO	CPMS
SP40	The CPO selects the energy sources from which to acquire energy	CPO	CPMS
SP41	The CPMS shows if there are available batteries in the charging station	CPMS	CPO
SP42	The CPO selects the battery in which to store energy	CPO	CPMS
SP43	The CPO sets the amount of energy to store in the battery	CPO	CPMS
SP44	The CPMS dynamically shows to the CPO the number of EVs charging	CPMS	CPO

SP45	The CPMS dynamically shows to the CPO the charging stations consumption of energy	CPMS	CPO

Table 1.5: Shared Phenomena

1.3. Definitions, Acronyms, Abbreviations

1.3.1. Abbreviations

- **eMall**: e-Mobility for all
- **eMma**: e-Mall mobile application
- **eMci**: e-Mall charger interface
- **CPMS**: Charging Point Management System
- **CPO**: Charge Point Entity
- **eMSP**: Electric Mobility Service Providers
- **DMS**: Distribution Management System
- **DSO**: Distribution System Operator
- **EV**: Electric Vehicle
- **EVD**: Electric Vehicle Driver
- **EVSE**: Electric Vehicle Supply Equipment
- **HV**: High Voltage
- **LV**: Low Voltage
- **MV**: Medium Voltage
- **SCADA**: Supervisory Control and Data Acquisition
- **SCM**: Smart Charging Management
- **OMS**: Outage Management System

- **AC**: Alternating current
- **DC**: Direct current

1.3.2. Definitions

- **DSO**: typically the entity responsible for the operation and management of distribution networks – High, Medium and Low Voltage networks. For this purpose, the DSO typically owns systems such as Supervisory and Control Data Acquisition (SCADA)/ Distribution Management System (DMS) for the monitoring and general overview of the state of the network. It also owns other systems such as the Outage Management System (OMS) and Work Force Management System (WFMS) for addressing the network operation problems related with the continuity and quality of service.
- **CPO**: entity that technically manages all the EV infrastructure assets, depending of existing country regulation – this role can be assured by the DSO or other entity.
- **eMSP**: is the entity that can explore the economic side of the EV charging infrastructure, namely by selling energy for charging purposes.
- **CPMS**: is a software system that manages the charge point infrastructure – can manage the technical and economic aspects of the charging infrastructures.
- **EV Driver**: person or entity who owns an EV car and can use the public or private facilities for charging purposes.
- **EVSE**: Electric Vehicle Supply Equipment. It is an equipment that is able to charge EV batteries with AC or DC loads and with different rated powers depending on the type of equipment.
- **Private parking**: can be a condominium, industry or other entity who has private owned EV
- **Voltage sag**: a short-duration reduction in voltage of an electric power distribution system. It can be caused by high current demand or fault current elsewhere in the system.
- **Voltage swell**: the opposite of voltage sag. Voltage swell, which is a momentary increase in voltage, happens when a heavy load turns off in a power system.
- **Socket outlet**: the port on the electric vehicle supply equipment (EVSE) that supplies charging power to the vehicle

- **Plug**: the end of the flexible cable that interfaces with the socket outlet on the EVSE.
- **Cable**: a flexible bundle of conductors that connects the EVSE with the electric vehicle
- **Connector**: the end of the flexible cable that interfaces with the vehicle inlet
- **Vehicle inlet**: the port on the electric vehicle that receives charging power
- *Inverter*: It is a power electronic device or circuitry that changes direct current (DC) to alternating current (AC).
- **Rectifier**: an electrical device that converts alternating current (AC) to direct current (DC).
- **eMma**: the eMSP subsystem responsible for the EVD interaction from the mobile app
- **eMci**: the eMSP subsystem responsible for the EVD interaction at the charger
- ***additional costs****: overtime penalty, deposit for unregistered users*
- **Status of the charger**: can be free, occupied, booked and in maintenance
- **Smart meter**: is an electronic device that records information such as consumption of electric energy, voltage levels, current, and power factor; allow the reading of energy flow and real-time usage, and consequently permit the identification of interruptions in energy flow

1.4. Reference Documents

- `IEEE 29148-2018 International Standard - Requirements engineering`: defines the construct of a good requirement and provides attributes and characteristics of requirements; provides also additional guidelines for applying the requirements and requirements-related processes
- `RDD` assignment document
- `Electric Vehicle CPMS and Secondary Substation Management by F. Campos, Efacec, Portugal; L. Marques, Efacec, Portugal and K. Kotsalos, Efacec, Portugal (15 October 2018)`: used to define the interactions between the different parts of the system and the actors; models the EV public infrastructures, the

eMSP, the DSO and the CPMS together with the APIs and protocols that allow their communication

- `EV CHARGING: HOW TO TAP IN THE GRID SMARTLY? by Platform for Electromobility (May 2022)`: used to understand the environment of the problem and contextualize the analysis

1.5. Document Structure

This document mainly follows the guidelines of the `IEEE 29148-2018 - International Standard - Requirements engineering`, with some changes in the order of the contents. Also in the final part of the document is present an `Alloy` formal analysis of the described model, an additional section with respect to the standard. The document is composed by the following parts:

- An introduction to the domain in which the system will operate (world phenomena) and an initial description of the software to be, the eMall, specifying the goals to achieve
- The overall description of the functions that the eMall has to implement specifying the requirements and a domain model, its interaction with the different users describing with diagrams the most important shared phenomena, and the domain assumptions necessary to the system to be
- A thorough list of requirements both functional and non functional: giving a detailed description of the functional requirements using use cases, use cases diagrams and UML sequence diagrams to better specify the interactions; and characterizing the non functional requirements through software system attributes
- A formal analysis using alloy in order to show the soundness and correctness of the model described in the document, considering only a part the most important requirements of the system
- A section that contains the effort spent by the members of the group working towards the completion of this document

2 | Overall description

2.1. Product perspective

2.2. Product functions

2.3. User characteristics

2.4. Assumptions, dependencies and constraints

Assumptions	**Description**
A1	The end user has internet connection
A2	The end user has a mobile phone with an integrated GPS module
A3	The end user has the mobile application of the eMSP installed on his mobile phone
A4	The CPMS shares the location of the charging station to the eMSP through APIs
A5	The end user payment from the mobile app is handled by external APIs.
A6	The EVD that creates an account inserts the personal data and the EVs specifications during registration
A7	The non registered EVD inserts the EVs specifications and payment details during the booking phase
A8	The DSOs use smart meters to detect interruptions and restore the supply of energy
A9	The CPO uses company credentials to access the CPMS

Table 2.1: Assumptions

3 | Specific requirements

3.1. External Interface Requirements

3.1.1. User Interfaces

3.1.2. Hardware Interfaces

3.1.3. Software Interfaces

3.1.4. Communication Interfaces

3.2. Functional Requirements

3.3. Performance Requirements

3.4. Design Constraints

3.4.1. Standards compliance

3.4.2. Hardware limitations

3.4.3. Any other constraint

3.5. Software System Attributes

3.5.1. Reliability

3.5.2. Availability

3.5.3. Security

3.5.4. Maintainability

3.5.5. Portability

4 | Formal analysis using Alloy

5 | Effort spent

6 References

List of Figures

List of Tables